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Birds, barks, and boats in Burrard Inlet:

A spatial analysis of winter marine bird communities and recreational disturbances along the Kitsilano shoreline

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A community and student partnership.

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1. Executive Summary

1.1 Introduction

British Columbia's Burrard Inlet is recognized internationally as an Important Bird Area (IBA) (IBA Canada, 2017). IBAs are crucial for preserving biodiversity because they include globally important bird populations, and they are internationally accepted as effective conservation tools. The Burrard Inlet was established as an IBA due to the potential threats that residential urbanization, commercial and industrial development, as well as recreational activities pose to the integrity of marine bird communities (IBA Canada, 2017).

The Kitsilano shoreline, a component of Burrard Inlet, attracts both people and birds alike. With beaches such as Spanish Banks Beach Park, Jericho Beach Park, and Kitsilano Beach Park, the Kitsilano shoreline is a popular destination for beach use among locals and visitors. Additionally, the region is a critical habitat for numerous species of marine birds, many of which are species of interest (IBA Canada, 2017). Burrard Inlet currently supports 1.5% of the global population of Barrow's Goldeneye, though it has historically supported 4% of the estimated global population (IBA Canada, 2017). Additionally, Burrard Inlet supports over 7,000 Surf Scoters, 100 Great Blue Herons, and 100 to 500 Western Grebes (IBA Canada, 2017).

The City of Vancouver is striving to be the greenest city in the world by 2020. The preservation of the city's bird biodiversity will be instrumental in achieving this, as it will contribute to meeting *Goal 6: Access to Nature* (Greenest City: 2020 Action Plan, 2012). To accomplish this, efforts to mitigate the impacts of urbanization on native bird species are critical. Increasing human activity pose threats to bird communities along our coasts and beaches, since recreational activities can disrupt the foraging, courting, and resting behaviours of birds. Therefore, it should be of utmost priority to adopt strategies that encourage beach users to engage in recreational activity in a manner that minimizes the disturbance impacts to marine birds (Vancouver Bird Strategy, 2015).

The primary goal of this project is to assess the status of marine bird communities along the Kitsilano shoreline. We completed a series of spatial analyses based on field data collection from November 2017 to February 2018. Additionally, we addressed the observed trends between bird distributions and anthropogenic activities using a combination of quantitative analysis and anecdotal observations.

The **research questions** driving this project:

1) **What marine bird species are present along the Kitsilano shoreline between November and February?**
2) **What are the abundances and spatial distributions of the observed marine bird communities?**
3) **What human recreational activities are present along the shoreline and is there a trend between human disturbances and marine bird distributions?**

1.2 Methods

From November 2017 to February 2018, point count data was collected on marine bird communities and recreational disturbances along the 7.8 km Kitsilano shoreline. Data was collected during nine survey sessions, capturing 17 unique datasets at 68 point count sites that were distributed between Spanish Banks West and the Burrard Bridge (Figure 4). The study area was characterized by shoreline substrate types, and the point count sites were randomly generated by ArcGIS within the substrate categories (sandy off-leash, sandy on-leash, mixed on-leash, and engineered on-leash). A spatial analysis on the collected data was then completed on ArcGIS.

1.3 Findings

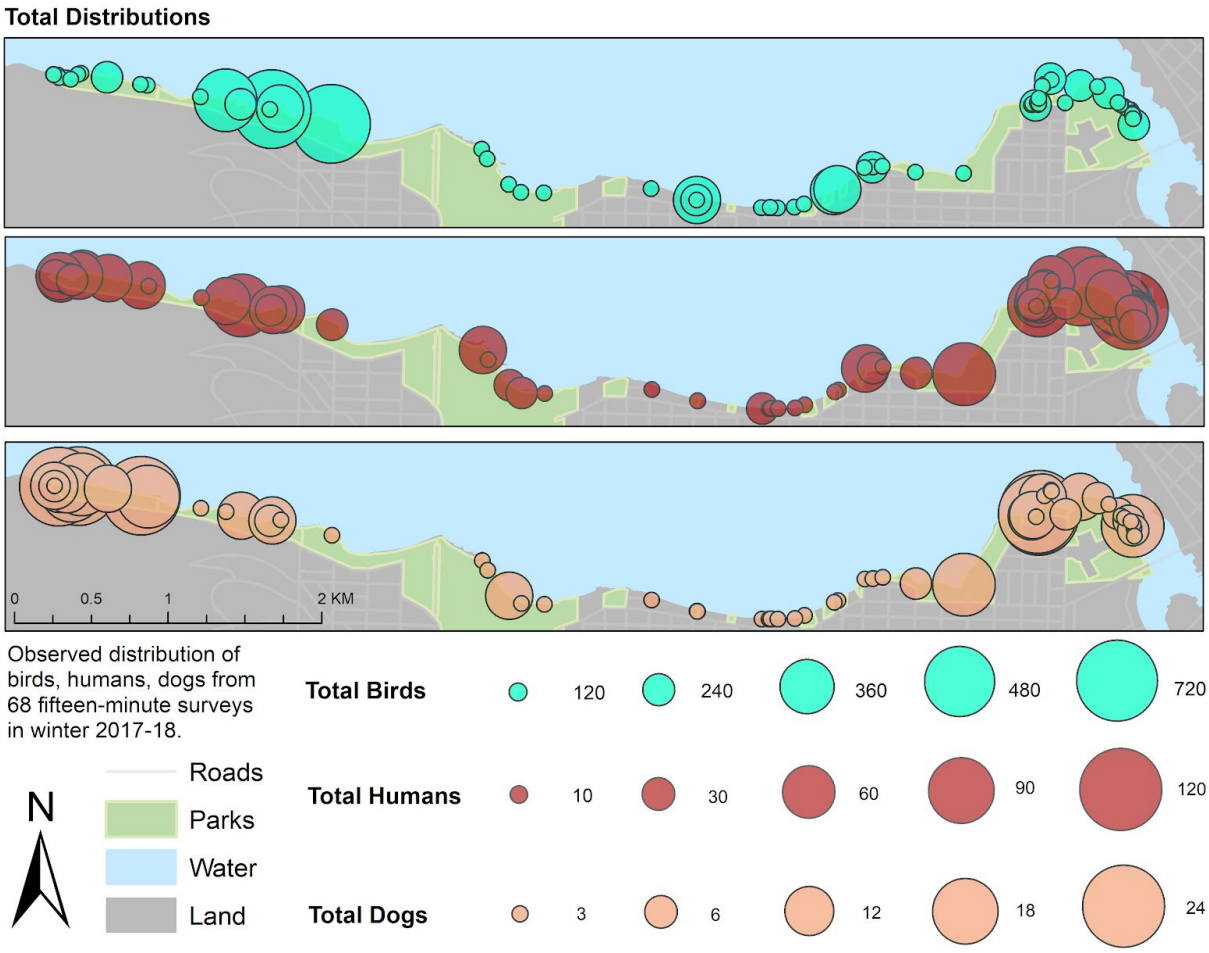

Figure 1. The total observed abundances of marine birds (teal), humans (red), and dogs (peach) during the 68 field surveys over nine survey dates. The highest abundance of marine birds can be seen around Spanish Banks; large clusters of humans can be seen around Hadden and Vanier Parks, whereas large clusters of dogs were observed around the Spanish Banks and Hadden Park dog beaches.

From 17 survey datasets, a total of 5919 individual birds from the nine subfamilies were observed: dabbling ducks, diving birds, geese, loons, grebes, cormorants, gulls, predatory birds, and kingfishers (Figure 1). Predatory birds include eagles and hawks. The three most commonly observed bird subfamilies were: diving birds, gulls, and dabbling ducks.

The recreational activities observed along the shoreline included on-leash and off-leash dogs, motorized and non-motorized boating activities, and human activities near and in the water, such as walking, running, biking, fishing, and swimming. More than half of the dogs observed in on-leash areas were in violation with the city bylaw rule, as they were off-leash. Comparison of total marine bird abundance at each survey point to the abundance of humans and dogs can be seen in Figure 1. The large clusters of birds near Spanish Banks are associated with smaller cluster of humans and dog abundances. Similarly, the larger clusters of dogs and humans in the engineered and sandy off-leash substrate areas are associated with fewer and smaller clusters of birds.

1.4 Conclusions and Recommendations

The 5919 bird individuals from 24 species were observed during nine field visits from November to February demonstrate that the Kitsilano shoreline is an important habitat for local marine bird communities. However, the Kitsilano shoreline is also an attractive destination for recreational activity, as 2533 recreational beach users (humans, boats, & dogs) were observed in the region during the same time period. Mapped data, quantitative analysis, and anecdotal observations show that recreational activities do interact with marine bird communities.

Based on our data and observations, we suggest the following recommendations:

1. Update the signage of dog-leash bylaws within the city, particularly near beaches and biodiversity hotspots, so that signs are standardized, informative, novel, visible, and understandable.
2. Encourage rental companies (that provide equipment for water-based recreational activities) to issue warnings that instruct customers to avoid steering directly into or near bird flocks in order to minimize disturbances to native biodiversity.
3. Conduct further research on the status of marine bird communities in the region to minimize uncertainties and contribute to long-term monitoring.
4. Support participation in citizen science initiatives that promote educational awareness of native bird species within the City of Vancouver.

2. Author Bios

Nicole Yeung
Nicole is soon to be a 2018 UBC graduate of Environmental Sciences, with a specialization in Ecological Conservation. Nicole worked as a Geomatics Analyst under Parks Canada, building ecological databases and creating distribution maps using ArcGIS. She also has extensive experience in field surveys, as well as database management.

Braela Kwan
Braela is in her final year of the Environmental Sciences program at UBC within the Land, Air, & Water specialization. She has experience conducting outdoor field work, undertaking large-scale research projects, employing the scientific method, performing data analyses, and applying science communication strategies.

Ada Li
Ada specializes in Land, Air, and Water under UBC Environmental Sciences. She is currently volunteering as the mapping coordinator for the invasive plants mapping team at Pacific Spirit Park. She has gained extensive experience on mapping plant species from her volunteer work. She has also worked as a GIS technician at Mineral Titles and a geological assistant at BC Geological Survey.

Jamie Gauk
Jamie is majoring in Geographical Sciences with a focus in Geographic Information Science (GIS) and Biogeography while minoring in Environmental Sciences. Growing up in Bermuda, she has participated in two marine science internships where she learned surveying techniques for data collection involving quadrats, transects and species identification.

Figure 2. Our team in the field at Locarno Beach.

3. Introduction

3.1 Research Objectives

This project aims to spatially assess the ecological status of marine birds along the Kitsilano shoreline of Vancouver, British Columbia, and identify the recreational activities that may disturb marine birds. To examine species distributions and identify the trends between recreational disturbances and marine birds, our strategy is to establish a baseline survey of bird species abundance and community composition among different habitat-substrate types along the coastline, and concurrently record various types of anthropogenic disturbances at survey sites. The information collected will answer the following questions:

1. What marine bird species are present along the Kitsilano shoreline between November and February?
2. What are the abundances and spatial distributions of the marine birds?
3. What human recreational activities are present along the shoreline and is there a trend between human disturbances and marine bird distributions?

As a collaboration with City of Vancouver and Vancouver Park Board through CityStudio Vancouver, our project contributes to the long-term monitoring of the avian community in Burrard Inlet, using a standardized methodology that is consistent with the existing regional-scale BC Coastal Waterbird Survey. Our goals align with the City's target to foster the conservation and restoration of avian habitats as identified in Vancouver Bird Strategy (2015). Furthermore, with limited research on the impact of recreational disturbances on avian communities, our findings will illuminate the extent to which human activities could influence local bird populations. In light of the International Ornithological Congress taking place in Vancouver in 2018, we hope to provide preliminary information for establishing a long-term citizen science monitoring program, and for developing educational materials to support the rise in public interest.

3.2 Motivation and Relevance

3.2.1 Ecological Values and Ecosystem Services of Marine Birds in Burrard Inlet

The coasts of British Columbia support a wide range of avian biodiversity (Bird Studies Canada, 2011). Over 250 species of resident, migratory, and overwintering birds are frequently observed in Vancouver (Vancouver Bird Strategy, 2015). In particular, Burrard Inlet supports significant populations of diving ducks, dabbling ducks, mergansers, cormorants, gulls, aerial divers, and shorebirds (Butler, Couturier, & Dickson, 2015). In 1999, Burrard Inlet was established as an Important Bird Area (IBA) of Canada -- *English Bay & Burrard Inlet, BC020* (IBA Canada, 2017), due to the high volume of wintering marine birds that utilize the region (Worcester, 2011). IBAs are elected based on standardized criteria and are significant since they are internationally recognized as distinctive habitats that support specific bird communities, where practical conservation actions could take place (IBA, 2017). Due to their sensitivity to changes in food supplies, marine birds are key indicators of marine ecosystem health (Furness & Camphuysen, 1997). They are commonly adopted as a proxy for the status of fish stocks, as well as

monitoring markers for pollution levels and mercury contamination in marine food webs (Furness & Camphuysen, 1997). In addition, Vancouver is recognized as a common destination for birding, where bird watching serves as a popular outdoor recreational activity along the shoreline (Vancouver Bird Strategy, 2015). Birds along the Kitsilano shoreline thus serve crucial ecological and social roles to residents and visitors alike.

3.2.2 Marine Birds at Risk

Research indicates that there has been a 35% decrease in bird species along the Pacific Coast of Canada due to urbanization (North American Bird Conservation Initiative Canada, 2012). Several marine bird species in Burrard Inlet are of concern. Based on provincial conservation status ranks, flora and fauna in B.C. are classified as red listed if the species is at risk of being extirpated, blue listed if it is a species of special concern, and yellow listed if the species is at the least risk of being lost (B.C. Conservation Data Centre, 2018). Currently, red listed species in Burrard Inlet include: Western Grebe, Brandt's Cormorant, and Pelagic Cormorant subspecies (B.C. Conservation Data Centre, 2013). Furthermore, blue-listed species that could be found in the area include: Surf Scoter, Black Scoter, Marbled Murrelet, Double-crested Cormorant, Great Blue Heron, and Short-billed Dowitcher. Western Grebe and Great Blue Heron are also classified in the federal Species at Risk Public Registry as species of Special Concern (Species at Risk Public Registry, 2018). Moreover, Burrard Inlet was established as an IBA in part due to conservation concerns for three specific species: the Western Grebe, Surf Scoter, and Barrow's Goldeneye (IBA Canada, 2017). To conserve local avian populations, more studies are required to elucidate the anthropogenic factors that may be affecting bird survival and distribution.

3.2.3 Observed Distributions of Marine Birds and Anthropogenic Disturbances

A number of biotic and abiotic factors contribute to habitat use by marine birds. Food availability generally determines the feeding success of waterfowl and shorebirds (Holm, K. J., & Burger, A. E., 2002). For instance, tidal upwellings bring prey to surface waters and increase the accessibility of prey to waterfowl; thus, tidal mixing generally increases forage success for waterfowl (Holm, K. J., & Burger, A. E., 2002). Changes in food availability may induce physical stress to waterbirds as they may be required to adjust their foraging behaviours (Lewis T. L. *et al,* 2008). When food availability is low, dabbling ducks have been observed to increase their surface feeding rates and/or swim faster to maintain adequate levels of food intake (Lewis T. L. *et al,* 2008). Similarly, diving ducks may endure longer dives when prey availability is low due to the lessened likelihood of encountering sufficient prey intake (Lewis T. L. *et al,* 2008). Ultimately, the largest numbers of marine birds are found where food availability is highest, which is dictated by various factors, including seasonality, oceanic conditions, and predation (Hay, R. B., 1992). When food availability is low, waterfowl may be forced to alter their physical behaviours. Research is required on the potential impact of food availability on marine bird populations in the Burrard Inlet.

Although marine bird distributions are generally determined by food availability, anthropogenic activities may alter these distributions. When wildlife detect human presence, they may delay or interrupt their natural activity in order to focus their energy on the anthropogenic stimulus (Tablado, Z., & Jenni, L.,

2017). In the presence of humans, marine birds may reduce their foraging behaviour, since they perceive humans as threats (Yasué, M., 2005). Reduced foraging may lessen the survival odds of marine birds due to the insufficient intake of nutrients and hence energy.

Studies indicate that the presence of a dog poses a larger threat to marine birds in comparison to the presence of a human, which could be attributed to the higher likelihood of dogs to discover bird nests through their enhanced sense of smell, as well as the bird's perceived danger of dogs as active predators (Lord, A. *et al.*, 2001). In an Australian woodlands avian community, dog walking was associated with a 35% reduction in bird diversity and a 41% reduction in abundance (Banks, P. B., & Bryant, J. V., 2007). More studies on the impact of dog-walking on marine birds are required to shed light on whether similar trends are present in these bird communities. Boat disturbances have also been shown to have an impact on nesting and roosting seabirds (Chatwin, Joy, & Burger, 2013). Many seabirds, especially Harlequin Ducks, Brandt's and Pelagic Cormorants, have displayed agitation in response to boating disturbances (Chatwin, Joy, & Burger, 2013).

4. Methodology

4.1 Bird Species of Focus

Metro Vancouver is home to over 250 species of birds (Vancouver Bird Strategy, 2015). To identify the species we would likely encounter during the field surveys, multiple sources were consulted. A 2015 report on the spatial distributions of 48 marine bird species in Burrard Inlet highlights local marine bird diversity (Butler, Couturier, & Dickson, 2015). These maps were compared with our study area to establish a baseline guide of species that have been documented in our region of interest. Further, we attended meetings in the field with ornithology experts Mark Drever (Environment and Climate Change Canada) and Karen Devitt (Bird Studies Canada). Drever and Devitt were able to review and provide feedback on the baseline list of potential important species. Additionally, eBird (http://ebird.org) of Cornell Lab of Ornithology was consulted as a supplementary resource. A list of bird species of focus was then finalized and the data collection sheet was constructed (Appendix B).

4.2 Study Area and Survey Points

The study area for this project includes the 7.8 km shoreline that extends between Spanish Banks West and the Burrard Bridge. The Kitsilano shoreline consists of residential neighbourhoods, shops and businesses, and park land including Jericho Beach Park, Hadden Park and Vanier Park. Two off-leash dog parks are included in our study region: Spanish Banks and Hadden Park.

The area of interest (Burrard Bridge to Spanish Banks West) (Figure 4) was delineated and segmented using ArcGIS (ArcMap 10.4.1., ESRI 2017). Substrate types along the shoreline were delineated from the 2009 Burrard Inlet Environmental Action Plan (BIEAP) Habitat Inventory data. They were categorized into the following: sandy, mixed, and engineered (Figure 3).

Figure 3. *Left*: Sandy substrate type at Locarno Beach. *Middle*: Mixed substrate type at Volunteer Park. *Right*: Engineered substrate type at Vanier Park.

Using ArcGIS, the data for dog leash law areas along the shoreline was intersected with the substrate data layer, generating four categories of segment-polygons (shoreline segments): (1) sandy off-leash, (2) sandy on-leash, (3) mixed, (4) and engineered. The 68 point count sites were randomly generated in ArcGIS, where each point count is located in one of four shoreline segments (Heywood *et al*., 2011). Two discrete data sets are collected on every survey day, each with four point-count sites distributed randomly within the four segment types. Randomization of the observation points captures general trends across the shoreline as well as both spatial and temporal variances during the winter survey period.

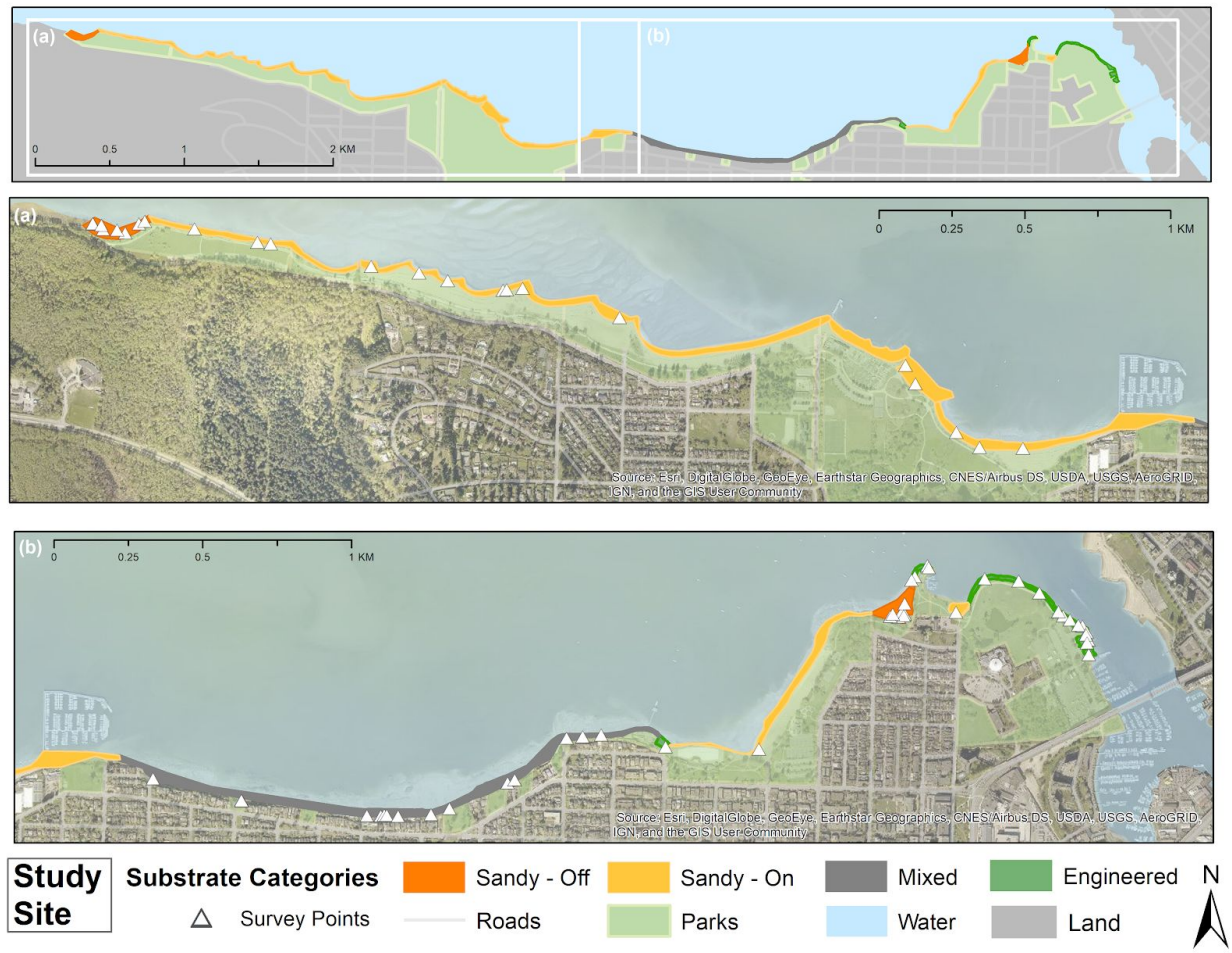

Figure 4. Map of the study area, with 68 randomized survey points, categorized by substrates and dog leash laws.

The 68 survey sites were divided by the four substrate and leash law categories: (1) sandy off-leash, (2) sandy on-leash, (3) mixed, (4) and engineered. This allowed for 17 surveys to be conducted in each of the substrate zones (Figure 4). The 68 survey sites were generated using ArcGIS to create a random distribution along the Kitsilano shoreline. As the substrate zones varied in size with sandy on-leash being the largest and sandy off-leash the smallest, the density of survey sites differed between the categories. The 68 surveys were completed over nine days between November 2017 and February 2018.

4.3 Field Survey Methodology

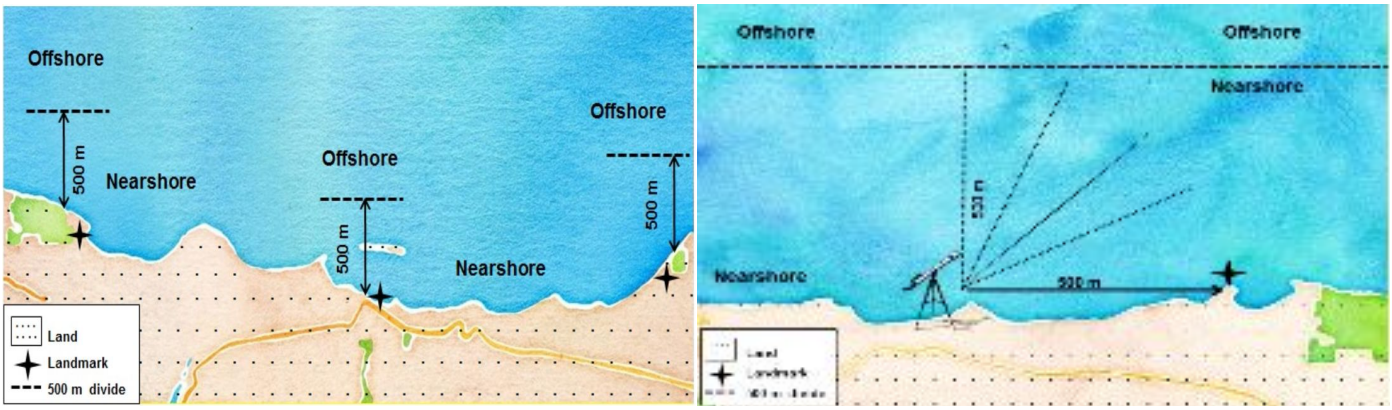

Figure 5. Distance estimation method for point count survey along the shoreline. Retrieved from BC Coastal Waterbird Survey Protocol (Bird Studies Canada, 2017).

A point count method was adopted for data collection, as standardized to BC Coastal Waterbird Survey (BCCWS). Each point count was conducted by a group of two team members to minimize the potential of errors in bird identification. Each group member was equipped with their own set of binoculars and each pair was equipped with a spotting scope.

A total of nine surveys were conducted during the winter season, starting in November and ending in February. Two surveys were conducted per month, with one on a weekday and another on a weekend. Eight point counts were completed per survey, with each pair completing four points. A minimum time period of five days between each survey was imposed in order to minimize the influence of variation from potential multi-day weather events. In order to acquire more data, we chose to complete an additional survey of four point counts on one day in February. The timing of data collection was standardized to high tide, so that all data was gathered within two hours of high tide, as per BCCWS protocol. Each fixed point count was completed in exactly 15 minutes.

For bird counts, both onshore birds (within the terrestrial substrate of the marine habitat) and nearshore birds (in the water) were recorded. For nearshore birds, birds were recorded up to 500 m from the shoreline, due to the potential of bird identification errors for distance more than 500 m from the shore (Figure 5). Bird flyovers were omitted from counts, due to the increased probability of making an error in bird identification for birds in motion and because these birds were not directly utilizing the substrate. Due to the potential human error in distinguishing between individual species of scaups, gulls, and cormorants, these birds were grouped together and not identified at the species-level. However, we are confident that all the observed cormorants were one of either double-crested cormorants or pelagic cormorants.

In addition to recording data on birds, we observed and recorded point count data on recreational activities along the shoreline and in the water, such as runners, walkers, bikers, dog walkers, and boats. Boats that were anchored (not mobile) were excluded from our analysis, because they were stationary,

which we assumed would not have an impact on birds. A detailed look at how data was collected can be gathered from the field data collection sheet (Appendix B).

4.3.1 Sampling Error

Point count surveys are observation-based. As a result, the data collected for marine bird detection and identification was subject to human error. Count difficulty increased with larger flock size and greater distance from shore, resulting in a greater potential for error, both in terms of identification and estimates of abundance. Another source of human error was visibility. High amounts of precipitation increased the difficulty of accurately detecting and identifying birds. When observing birds nearshore, higher waves decreased the visibility of birds in the water, adding to potential human error.

Observations may vary between surveyors when they are recording the number of human and dog disturbances and their initial activity level. At the start of each survey, the initial activity of multiple humans and dogs often needed to be recorded. The initial activity type may change for several individuals while counting was in progress. The lag time that occured between seeing the initial activity in action to recording that activity is a source of error.

When counting the number of human and dog disturbances, the initial activity was recorded for each individual e.g. - at rest, walking, running, etc. This means that changes in activity were not recorded during the 15-minute point count interval. e.g. - a dog at rest may start to run, or an on-leash dog may become an off-leash dog.

When conducting the 68 surveys, our mode of transport between survey sites changed from travelling in two cars from opposite directions along the Kitsilano shoreline to travelling in one car in the one direction. On days where one car was used, a greater number of surveys were completed in proximity to one another during the same time period. This increases the likelihood of double-counting humans, dogs and birds. The location of survey sites and the routes between them were designed to minimize spatial overlap within each survey period but, due to the mobility of birds, humans and dogs within and between sites, double-counting may still occur.

The time of day in which we completed the 68 surveys was standardized by tide level i.e. - within a 2-hour window of the daytime high tide. As high tide time varies from day to day, the time period in which we completed the surveys differed over the nine survey dates. The decision to standardize by high tide time accounted for variations in marine bird activities that are tide-dependent. However, bird activities that are time-dependent were not standardized. Human and dog activities are more time-dependent and the number of individuals differ between early morning and late afternoon. These activities are, therefore, not standardized.

4.4 Data Analysis

4.4.1 Quantitative Analysis

To effectively answer our objectives, figures were generated based on total number of birds, birds by subfamilies, birds by species, onshore and nearshore birds, humans, off-leash dogs, on-leash dogs, motorized boats, non-motorized boats, and a matrix of all observed disturbances.

***Table* 1.** Matrix values in order of increasing impact: human, on-leash dog, motorized boat, non-motorized boat, off-leash dog. The values range from humans with a value of 1 to off-leash dogs with a value of 12.

	Humans	**On-Leash**	**Motor Boats**	**Non-motor Boats**	**Off-leash**
Impact Value	1	2	4	8	12

The matrix was created in order to find any relationship between the total number of birds and what might be disturbing them during the surveys. The observed counts for the above factors was multiplied by the impact value. For example, during survey ID 9, we observed five non-motorized boats. The disturbance value for non-motorized boats in survey 9 would therefore be:

Equation 1. $disturbance\ value\ = 5\ boats\ \cdot\ impact\ value\ 8\ =\ 40$

All of the disturbance values would be added together for each factor in a survey to produce a matrix value for each of the 68 surveys. We decided on the order and the values seen in Table 1 based on the following assumptions of impact.

We assumed that human and on-leash dogs would only have an onshore impact as all observed individuals were found on land. In contrast, motorized and non-motorized boats would only have a nearshore impact as these disturbances would be traveling in the water within 500m of the shoreline. Off-leash dogs were found both onshore and nearshore as they would often swim in the water up to 10 meters off the shoreline. We also assumed impact value based on flushing observations and the near shore regulations. It was observed that on-leash dogs flushed more birds compared to humans. According to Banks & Bryant (2007), birds may perceive dogs as predators resulting in their flushing or other forms of distress. However, an on-leash dog confined by a leash will have decreased mobility. Humans were therefore given the lowest impact value of 1 and on-leash dogs were given a value of 2.

Motorized boats have speed and distance restrictions in nearshore waters. Motorized boats must stay at least 300 meters away from swimming beaches. In other nearshore areas, they must reduce their speed to 10 km/h (5 knots) in order to minimize wake. These restrictions would reduce their impact as motorized boats would only be able to travel at greater speeds on the outer 200 meter of our observed nearshore

study area. We assumed that motorized boats would also have a set trajectory and destination meaning they would be less likely to approach a flock of birds in the water. Non-motorized boats which include sailboats, stand up paddle (SUP) boards, kayaks, canoes and any other boat that is paddled or propelled by wind are assumed to have a larger impact value. These non-motorized boats were observed to travel closer to the shoreline where many bird species were found feeding. We assumed these boats were travelling for leisure and are more likely to come in close proximity to nearshore birds. We observed SUP boarders, kayaks and sailboats flushing large flocks of birds on multiple occasions. For these reasons we assigned motorized boats an impact value of 4 and non-motorized boats an impact value of 8. Off-leash dogs were observed to have the highest impact on onshore and nearshore birds. They would often travel at higher speeds, produce more noise (barking) and move between nearshore waters and onshore land. Off-leash dogs were observed chasing onshore birds and flushing both onshore and nearshore birds. They were therefore, given an impact value of 12.

4.4.1.1 Data Limitations

The objectives of this report were to identify what species were present along the Kitsilano shoreline, what the abundance of those species was, and if there were any relationships found between marine birds and anthropogenic effects. Our objectives were affected by a number of confounding factors. First, data was collected between November 2017 and February 2018. Four months is a very short time to identify any significant trends. Only collecting data in the winter months also means that we are not observing different species that may be present along the Kitsilano shoreline in the other eight months of the year. During the four months of data collection, a total of 68 surveys were completed over a nine day period. Although this was a large amount of work for the four of us to complete, compared to other bird surveys in the scientific literature, these numbers are low. As students, we could only commit a certain amount of time to this project. Trying to find times when all four group members could complete a two to three hour survey during the weekday was challenging, and this resulted in all weekday surveys being completed on Fridays. With all surveys collected on either a Friday, Saturday or Sunday, this may have affected the observed human and dog activities.

The final objective was to identify any relationship between marine birds and anthropogenic effects. This objective was difficult to isolate from other variables that may be affecting marine birds. For example, the location where many nearshore birds are located is largely dependent on food availability in the area. Large flocks of Surf Scoter or Barrow's Goldeneye are constantly moving to where there is more available food. As we were not able to quantify food availability along the Kitsilano shoreline, this factor could not be accounted for. Another factor that may have affected abundance of different bird species was the weather on survey dates. Sunny days with light wind and small waves may have affected the presence of birds along the shoreline compared to overcast, rainy days with strong wind and large waves. The survey dates were not chosen based on weather and the amount of sunny to rainy days were not proportional.

4.4.2 Spatial Analysis

All spatial statistical analyses were conducted on ArcGIS. Hot Spot Analysis (Getis-Ord Gi*) was conducted to investigate local spatial pattern in comparison to regional patterns. A significant hotspot indicates that the feature has a high value and be surrounded by other high-value features, forming a cluster of features with high values. In terms of density, a hotspot signifies that the site has a significantly high concentration of dense populations. Multiple testing and spatial dependence were corrected through adopting the False Discovery Rate (FDR) correction method. The same test was applied to check for a clustering pattern of density of total number of humans and dogs.

4.4.2.1 Analysis Limitations

Patterns of distribution are subject to the scale of analysis, because our spatial relationships of interest are distance-relative. This is particularly true for proximity, which is the focus of our study question in terms of the density of birds, humans and dogs across the shoreline. Hence, the significance of spatial correlation results and observed clustering patterns could be subjected to variations from chosen frames of analysis. Hotspot analysis results are more than 95% significant, which presents a maximum 5% likelihood that the clustering of dense populations is actually by chance.

5. Results

5.1 Observed Bird Species

During the nine field visits from November to February, a total of 5919 birds were observed, with a total of 24 unique species (excluding crows and starlings, but including kingfishers and predatory birds such as eagles and hawks) (Table 2). We observed birds from nine subfamilies: dabbling ducks, diving birds, geese, loons, grebes, cormorants, gulls, eagles, and kingfishers. Some characteristic niche requirements (particularly foraging behaviours and feeding requirements) of these subfamilies are described in Table 2. Under the conservation framework established by the provincial government, of the species observed, the Surf Scoter, Black Scoter, and Double-crested Cormorant are considered species of special concern (blue-listed), and the Western Grebe and Pelagic Cormorant subspecies are at risk of being lost (red-listed) (B.C. Conservation Data Centre, 2018). Figure 6 shows the distributions of the total observed birds.

Table 2. List of observed bird species, organized by subfamily. Includes descriptions of subfamily niche requirements.

Subfamily	Species Common Name	Species Scientific Name	Niche Requirements
Dabbling Ducks	American Green-Winged Teal	*Anas carolinensis*	Forage in the intertidal zone on algae and eelgrasses (Baldwin & Lovvorn, 1992).
	American Wigeon	*Anas americana*	
	Gadwall	*Anas strepera*	
	Mallard	*Anas platyrhynchos*	
Diving Birds	Harlequin Duck	*Histrionicus histrionicus*	Dive below the surface of the water to acquire food sources, such as mussels, barnacles, small fish, and algae (Butler *et al*., 2015).
	Bufflehead	*Bucephala albeola*	
	Common Goldeneye	*Bucephala clangula*	
	Barrow's Goldeneye	*Bucephala islandica*	
	Red-breasted Merganser	*Mergus serrator*	
	Greater Scaup	*Aythya marila*	
	Lesser Scaup	*Aythya affinis*	
	Black Scoter (**blue-listed**)	*Melanitta americana*	
	Surf Scoter (**blue-listed**)	*Melanitta perspicillata*	
	White-winged Scoter	*Melanitta deglandi*	
Geese	Canada Goose	*Branta canadensis*	Feed mainly on vegetation (Martin *et al*., 1961).
Loons	Common Loon	*Gavia immer*	Facultative predators that eat fishes, crustaceans, and other aquatic animals (Barr, 1996).
Grebes	Horned Grebe	*Podiceps auritus*	Consume small fish, aquatic insects, mollusks, and crustaceans from sea (Martin *et al*., 1961).
	Western Grebe (**red-listed**)	*Aechmophorus occidentalis*	
Cormorants	Double-crested Cormorant (**blue-listed**)	*Phalacrocorax auritus*	Feed primarily on small, forage fish (Butler *et al*., 2015).
	Pelagic Cormorant (subspecies is **red-listed**)	*Phalacrocorax pelagicus*	
Gulls	Gull, Seagull	*Laridae*	Skilled scavengers, and feed on small fish, crustaceans, and mollusks (Martin *et al*., 1961).
Eagles	Bald Eagle	*Haliaeetus leucocephalus*	Predatory birds that feed on fish and other birds (Martin *et al*., 1961).
Kingfishers	Belted Kingfisher	*Megaceryle alcyon*	Dive from land to sea to predate on fish (Butler *et al*., 2015).
Hawks	Cooper's Hawk	*Accipiter cooperii*	Preys on small birds and mammals (Davidson, 2015).

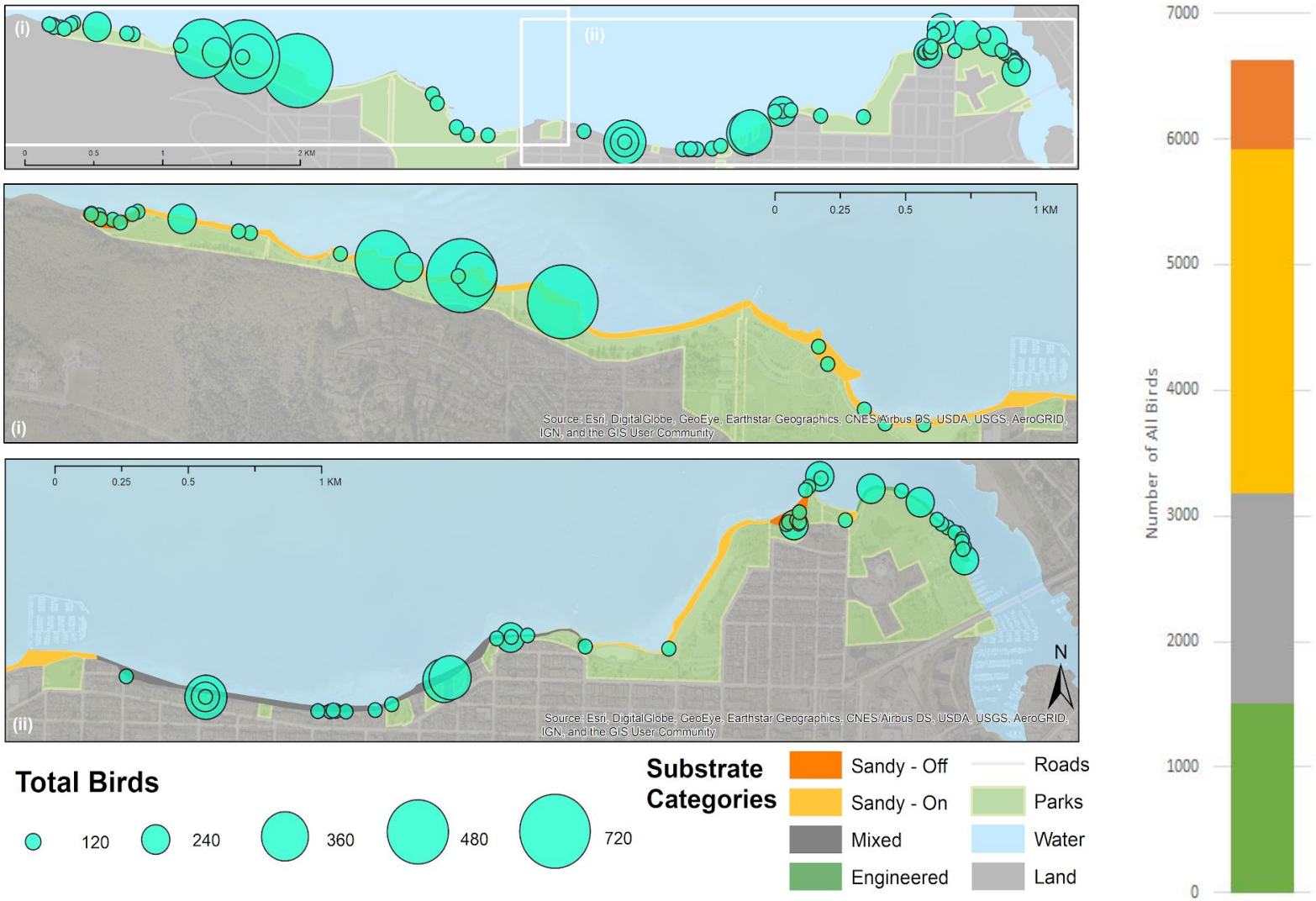

Figure 6. Distribution map showing the total number of birds observed at each of the 68 survey sites (bottom) and the observed distribution of all birds with relation to substrate categories (top).

The highest density of birds was found in the sandy on-leash areas followed by mixed substrate on-leash areas (Figure 6). The lowest density of birds was observed in sandy off-leash areas, particularly near the Spanish Banks and Hadden Park dog beaches. 11% of all birds were observed near sandy off-leash areas; 41% near sandy on-leash areas; 25% near mixed areas; and 23% near engineered areas.

5.1.1 Proportion of Each Subfamily Observation

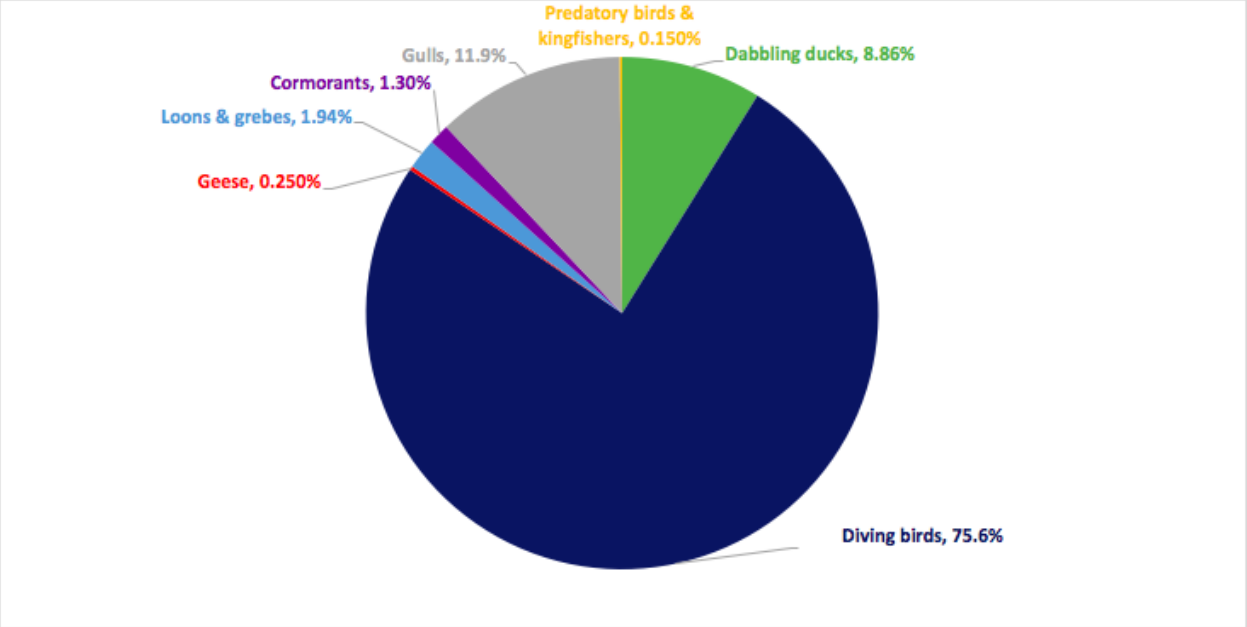

Figure 7. Proportion of each subfamily of birds over the nine field surveys (total number of birds, n = 5919). This data excludes counts of crows. The 'predatory birds and kingfishers' category includes kingfishers, hawks, and eagles.

Though we observed a diverse variety of bird species, some were more common than others. As indicated by Figure 7, the three most commonly observed bird subfamilies were: diving birds (76%), gulls (12%), and dabbling ducks (9%). The remaining subfamilies were relatively less abundant: 115 loons & grebes, 77 cormorants, 15 geese, 9 predatory birds, and 1 kingfisher were observed.

5.1.2 Biodiversity

The species richness of birds within each substrate category is documented in Figure 8 as a metric of biodiversity. Fifteen bird species were observed near sandy off-leash areas, 17 species near sandy on-leash areas, 15 near mixed substrate, and 13 near engineered substrate. There does not appear to be any apparent trends in species richness across substrate types, which is not unexpected given the small study area.

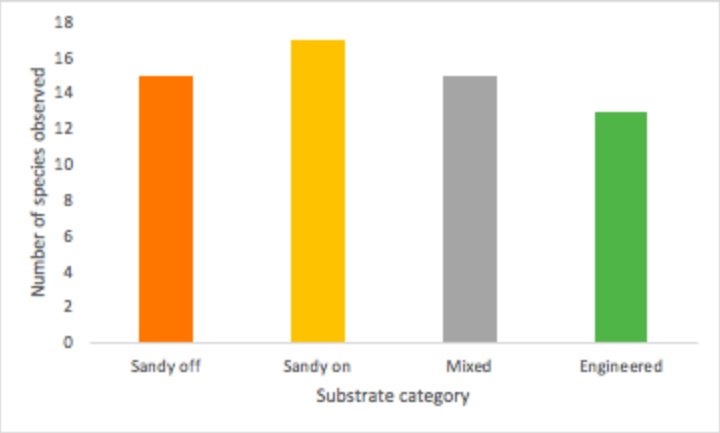

Figure 8. Species richness observed within each substrate category over the duration of the nine field surveys (inclusive of predatory birds and kingfishers).

5.2 Observed Distributions by Subfamilies

5.2.1 Dabbling Ducks

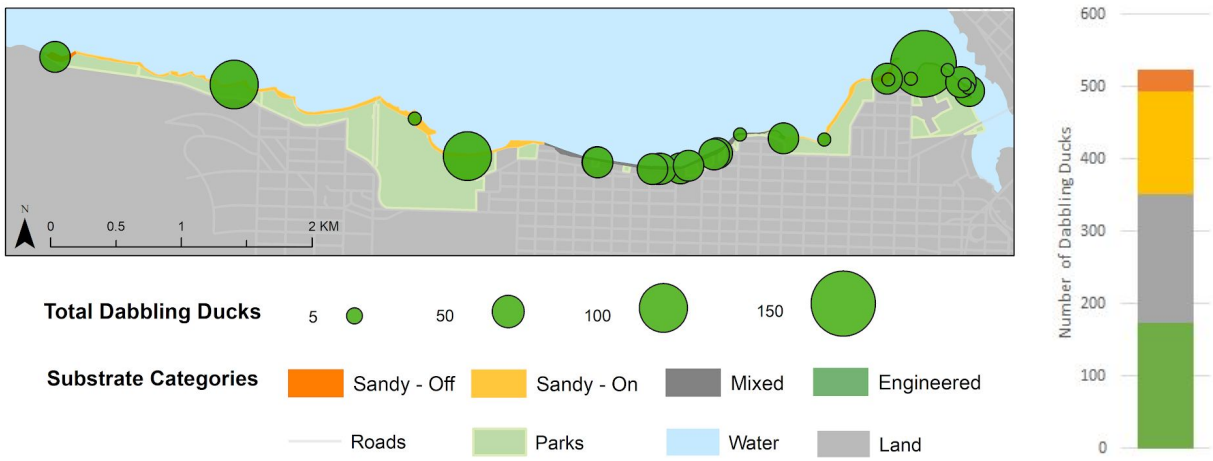

Figure 9. Distribution of dabbling ducks along the Kitsilano shoreline at the 68 survey sites (left) and the observed distribution of dabbling ducks with relation to substrate categories (right). 6% of dabbling ducks were observed near sandy off-leash areas, 27% near sandy on-leash areas, 34% near mixed substrate, and 3% near engineered substrate.

There was a high density of dabbling ducks near Hadden Park (Figure 9). There is relatively equal distribution between the three substrate categories, but most dabbling ducks were observed near sandy on-leash areas rather than sandy off-leash areas.

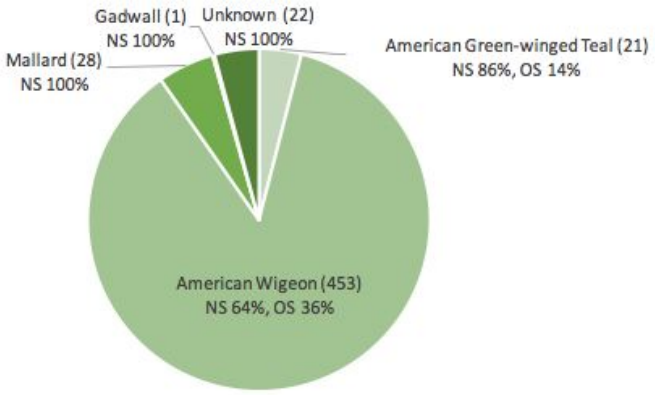

Figure 10. Abundance of different species in the dabbling duck family with the total number of individuals in brackets and the percentage of individuals found either nearshore (NS) or onshore (OS).

Five hundred and twenty five dabbling ducks were observed. They were evenly distributed across the shoreline, with relatively higher density points at Vanier Park near engineered substrate (Figure 10). The observations consisted of 87% American Wigeons, 5% Mallards, 4% American Green-winged Teals, 4% unidentified dabbling ducks and less than 1% Gadwalls. American Wigeons were found to be nearshore in the water for 64% of observations and onshore for 36% of observations. American Green-winged Teals were found nearshore for 86% and onshore for 14% of observations. All Mallards, the individual Gadwall, and all unidentified dabbling ducks were observed in the water nearshore.

5.2.2 Diving Ducks

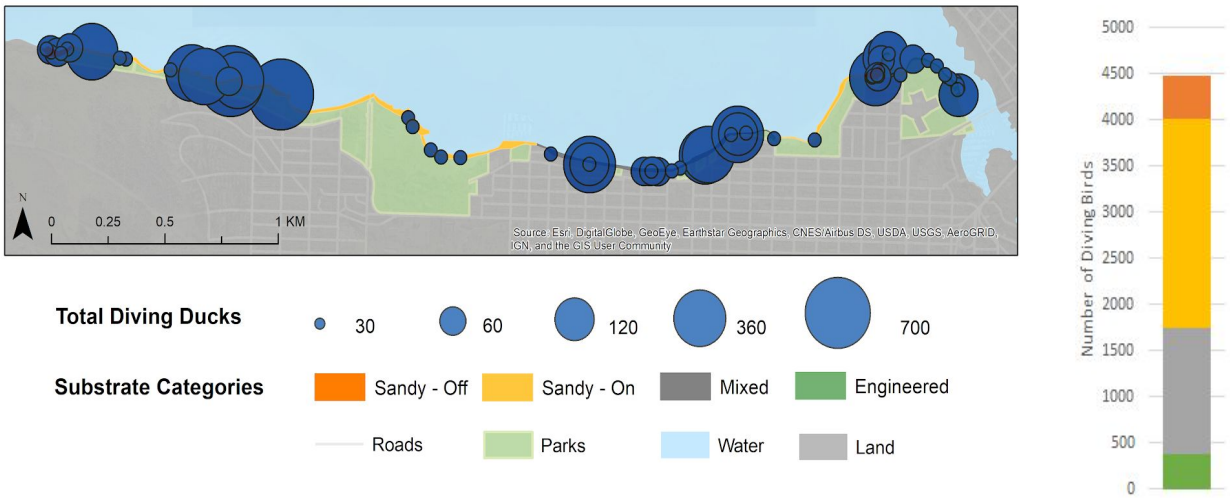

Figure 11. Distribution of diving ducks along the Kitsilano shoreline at the 68 survey sites (left) and the observed distribution of diving ducks by substrate types (right). 10% of diving ducks were observed near sandy off-leash areas, 51% near sandy on-leash areas, 31% near mixed substrate, and 8% near engineered substrate.

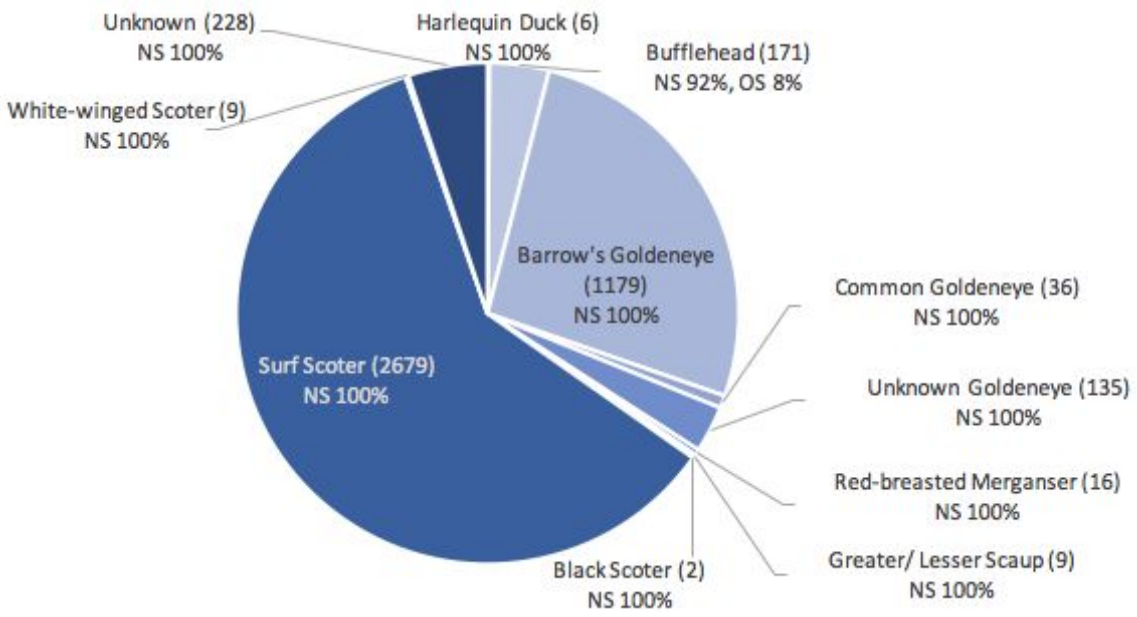

Figure 12. Abundance of different species in the diving duck family with the total number of individuals in brackets and the percentage of individuals found either nearshore (NS) or onshore (OS).

Of the 4470 diving ducks observed, most were found seaward of Spanish Bank Beach Park and Hadden Park near sandy on-leash areas, as well as close to Jericho Beach Park near mixed substrate areas (Figure 11). They consisted of 60% Surf Scoters, 27% Barrow's Goldeneyes, 4% Buffleheads, 1% Common Goldeneyes, 3% unidentified Goldeneyes, and 5% unidentified ducks (Figure 12). Other species observed, but were less than 1% of the observations, include Harlequin Ducks, Black Scoters, White-winged Scoters, Greater or Lesser Scaups, and Red-breasted Mergansers. Buffleheads were found to be nearshore in the water for 92% of observations and onshore for 8% of observations. All other diving ducks were found to be 100% nearshore in the water.

5.2.3 Loons & Grebes

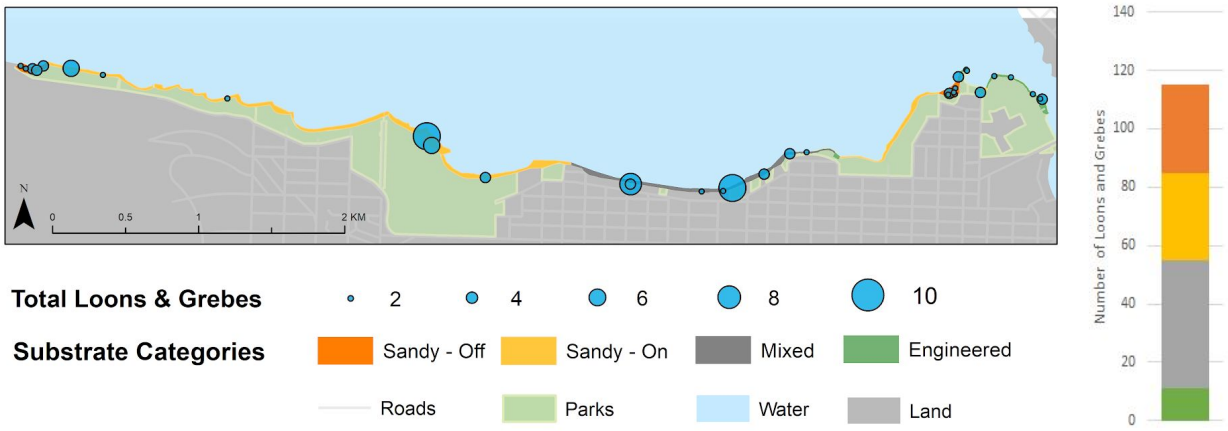

Figure 13. Distribution of loons & grebes along the Kitsilano shoreline at the 68 survey sites (left) and the observed distribution of loons and grebes with relation to substrate types (right). 26% of loons and grebes were observed near sandy off-leash areas, 26% near sandy on-leash areas, 38% near mixed substrate, and 10% near engineered substrate.

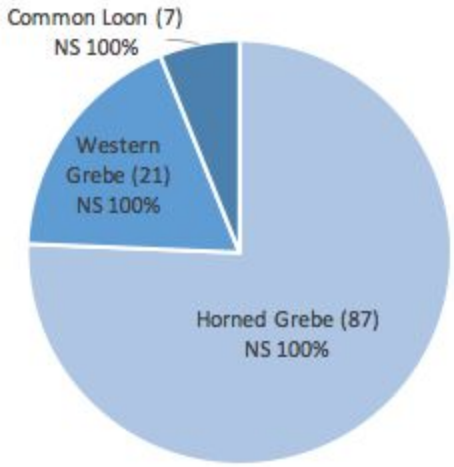

Figure 14. Abundance of different species in the loon and grebe families with the total number of individuals in brackets and the percentage of individuals found either nearshore (NS) or onshore (OS).

Most loons & grebes were observed between Volunteer Park and Point Grey Park near mixed substrates, as well as at Spanish Bank Beach near sandy on-leash areas (Figure 13). The 115 loons and grebes observed consisted of 76% Horned Grebes, 18% Western Grebes, and 6% Common Loons (Figure 14). All of the loons and grebes observed were found nearshore in the water.

5.2.4 Cormorants

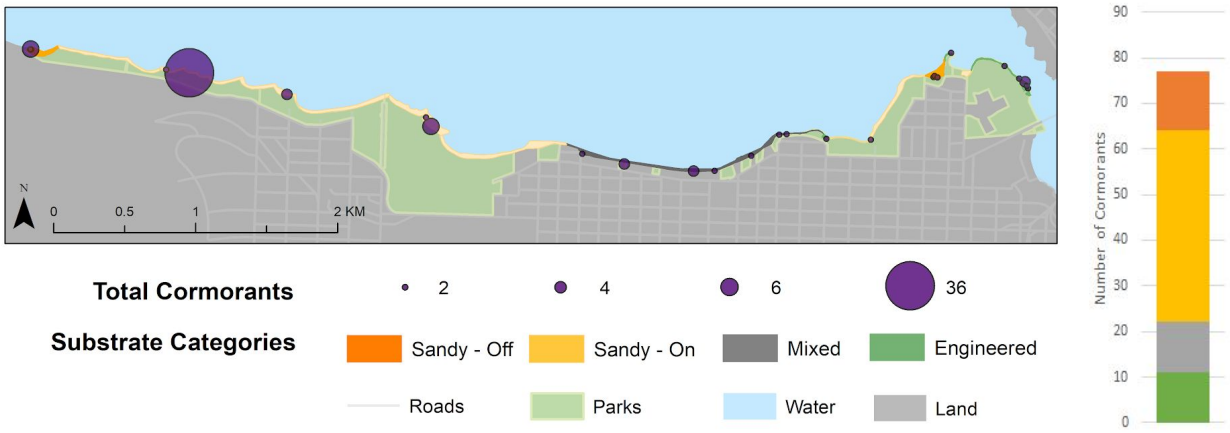

Figure 15. Distribution of cormorants along the Kitsilano shoreline at the 68 survey sites (left) and the observed distribution of cormorants with relation to substrate types (right). 17% of cormorants were observed near sandy off-leash areas, 55% near sandy on-leash areas, 14% near mixed substrate, and 14% near engineered substrate.

Most cormorants were observed at Spanish Bank Beach Park near sandy on-leash areas (Figure 15) with a total of 77 observed during the survey period. An unusually large number of cormorants were observed at Spanish Bank Beach Park since a flock of 31 individuals landed there during one point count.

5.2.5 Gulls

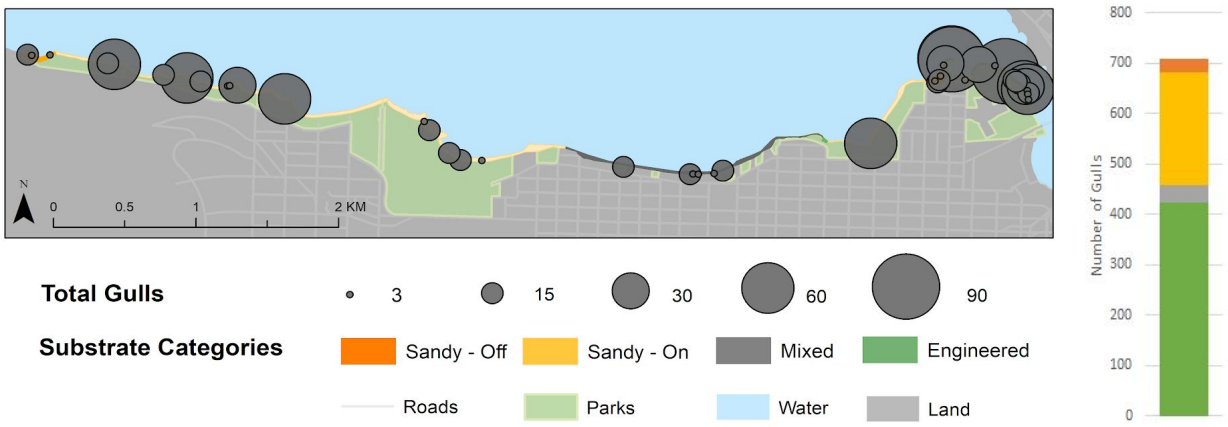

Figure 16. Distribution of gulls along the Kitsilano shoreline at the 68 survey sites (left) and the observed habitat distribution of gulls (right). 4% of gulls were observed near sandy off-leash areas, 31% near sandy on-leash areas, 5% near mixed substrate, and 60% near engineered substrate.

Most gulls were observed at Hadden and Vanier Parks near engineered substrates, with the least amount of gulls found at sandy on-leash substrates followed by mixed substrates (Figure 16). Species of gulls were grouped together into one category in order to minimize potential identification error. Potential

species of gulls seen include Bonaparte's Gull, Mew Gull, Ring-billed Gull, California Gull, Glaucous-winged Gull and Herring Gulls (Butler, Couturier, & Dickson, 2015).

5.2.6 Predatory Birds and Kingfishers

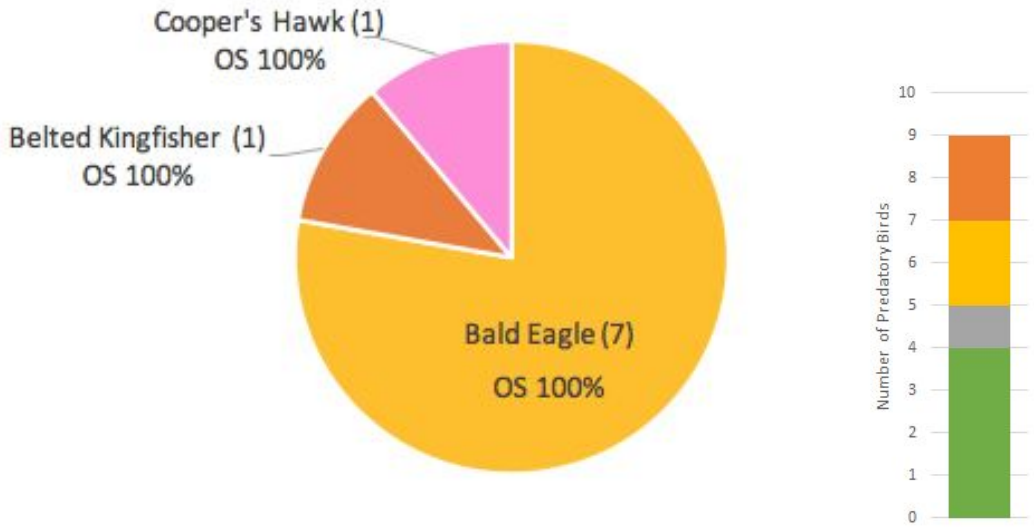

Figure 17. Abundance of different species in predatory bird families and kingfishers with the total number of individuals in brackets and the percentage of individuals found either nearshore (NS) or onshore (OS) (left). Observed distribution of predatory birds and kingfishers: 22% of birds were observed near sandy off-leash areas, 22% near sandy on-leash areas, 11% near mixed substrate, and 45% near engineered substrate (right).

One Cooper's Hawk was observed at Jericho Park near sandy on-leash substrate areas and one Belted Kingfisher was observed at Jean Beaty Park near mixed substrate areas. The seven bald eagles observed were found 57% on engineered, 29% on sandy off-leash and 14% on sandy on-leash substrate areas (Figure 17). All birds were observed onshore.

5.2.7 Other Birds

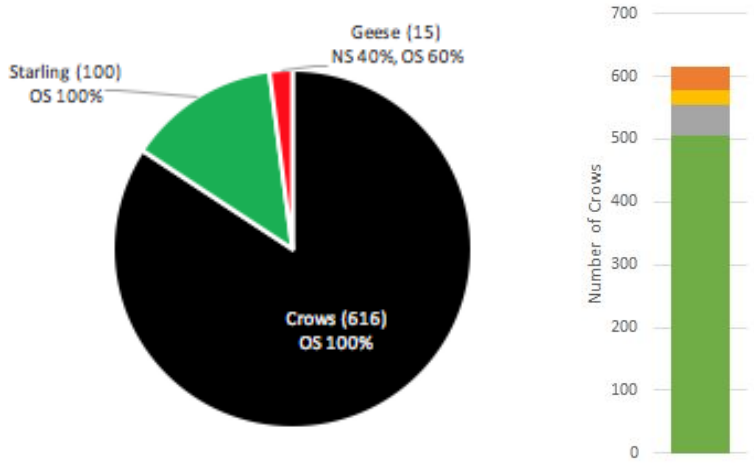

Figure 18. Abundance of different species in other bird families (starling, geese and crows) with the total number of individuals in brackets and the percentage of individuals found either nearshore (NS) or onshore (OS) (left). Observed habitat distribution of crows: 6% of crows were observed near sandy off-leash areas, 4% near sandy on-leash areas, 8% near mixed substrate, and 82% near engineered substrate (right).

Other birds observed included crows, starlings and Canada Geese (Figure 18). The 100 starlings were observed during one survey near a sandy off-leash area. Of the 15 Canada Geese observed, 14 were found near sandy on-leash areas and another near an engineered area. The majority of crows observed were found near engineered substrates, with the remaining 18% of crows distributed across the other three substrate areas. All of the starlings and crows observed were found onshore, whereas 60% of the geese observed were found onshore with the remaining observed in the water nearshore.

5.3 Recreational Activities

5.3.1 Distribution of All Disturbances

Figure 19 shows abundance by substrate type of birds, humans, motor boats, non-motor boats, off leash dogs, on leash dogs, and total dogs. This allows for a visual representation of how individuals are divided by substrate types.

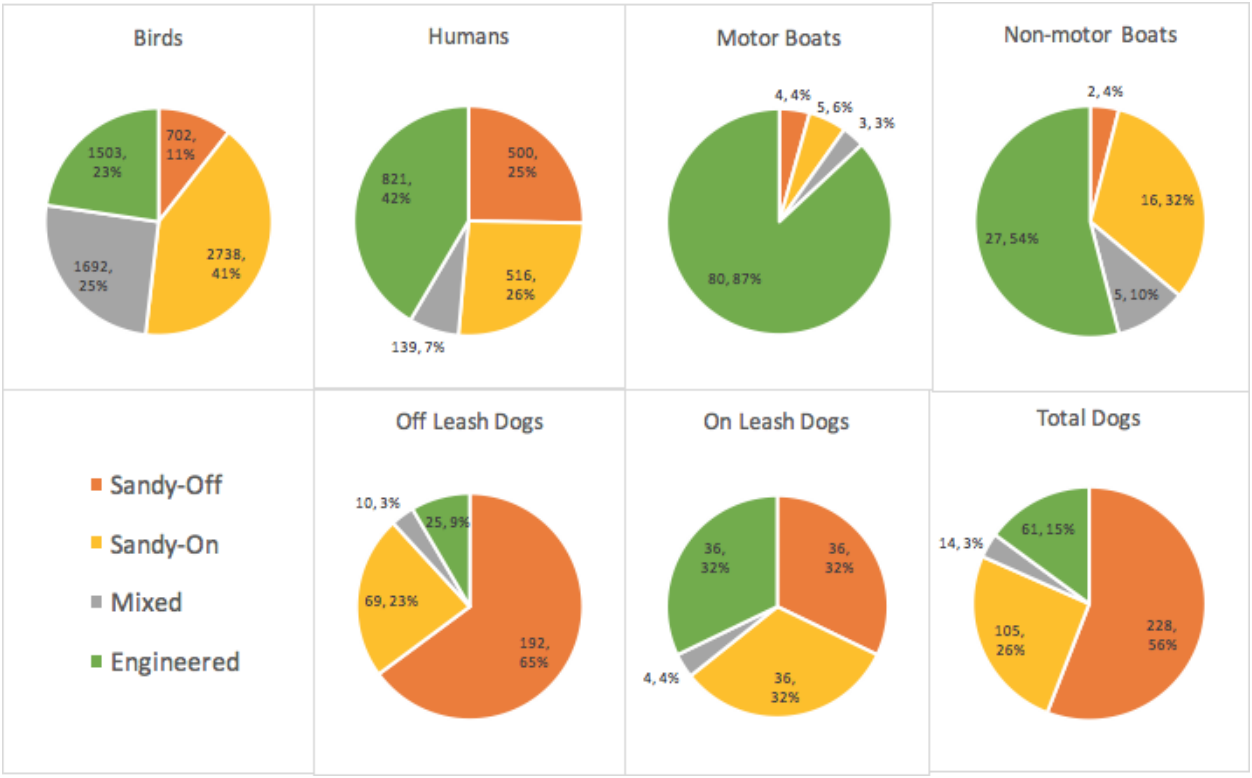

Figure 19. Number and percentage of humans, motorized boats, non-motorized boats, off-leash dogs, on-leash dogs and total dogs compared to total number of birds by substrate and leash law study area.

The main disturbances observed included humans, boats (both motorized and non-motorized) and dogs (both on-leash and off-leash). Most humans were observed at engineered substrates at 42%, followed by sandy on-leash, sandy off-leash and mixed substrates with observed percentages of 26%, 25% and 7% respectively (Figure 19). 87% of 92 observed motorized boats were near engineered substrates . The majority of these boats consisted of public ferries travelling around False Creek. All other substrate types had five or fewer motorized boats observed. 54% of the 50 observed non-motorized boats were near engineered substrates. 32% were observed near sandy on-leash, 10% near mixed and 4% near sandy off-leash areas. The majority (65%) of the 296 observed off-leash dogs were on sandy off-leash substrates. 23% of off-leash dogs were observed on sandy on-leash substrates, 9% on engineered substrates and 3% on mixed substrates. With 36 observations each, sandy off-leash, sandy on-leash and engineered substrate each accounted for 32% of all on-leash dogs observations. The remaining 4% of on-leash dogs were observed on mixed substrates. Considering the total number of dogs, the majority were observed on sandy off-leash areas at 56%, followed by sandy on-leash areas at 26%, engineered substrates at 15% and mixed substrates at 3%.

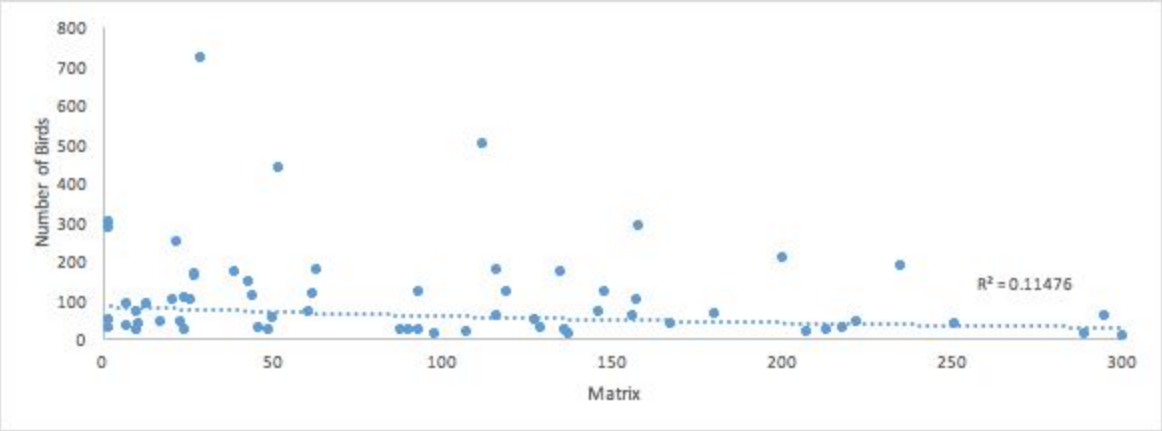

Figure 20. Scatter plot showing the number of observed birds compared to the matrix value. A matrix was created to standardize the impact of multiple disturbances including humans, on-leash dogs, motorized boats, non-motorized boats and off-leash dogs listed in order of smallest to largest impact on bird quantities. The R^2 of 0.115 indicates that there is a low linear relationship.

The number of humans, on-leash dogs, motorized boats, non-motorized boats and off-leash dogs were multiplied by their impact value of 1, 2, 4, 8, and 12, respectively (Table 1). These values were then added together to give a matrix value for each of the 68 survey sites. The matrix value was plotted against total number of birds for each of the 68 survey sites. As indicated in Figure 20, the created matrix values compared to total number of birds shows a negative trend. With higher matrix values, less birds were observed. Lower matrix values do not necessarily associate with higher number of observed birds, considering that humans disturbances are not the only drivers of bird distribution. The level of precipitation, wind, food availability, presence of predatory birds and kingfishers, as well as noise level and other factors could all play a role in the observed bird abundances and distributions. A lower matrix signifies that the birds present would have a lower chance of flushing due to disturbance.

5.3.2 Human and Dog Activities

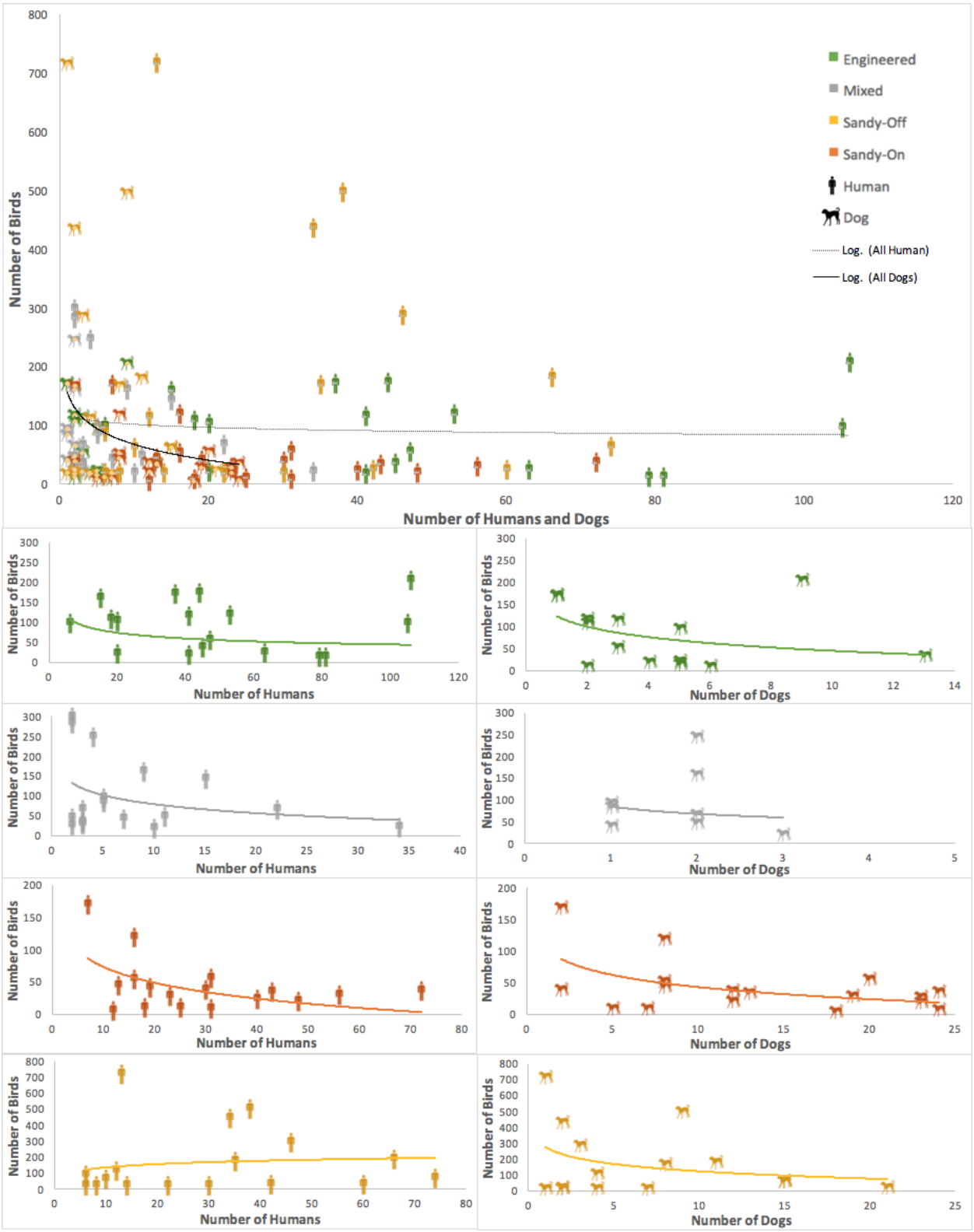

Figure 21. Total number of birds compared to number of humans and dogs. Top graph: substrate types of survey sites are indicated by colour; engineered (green), mixed (grey), sandy off -leash (yellow) and sandy on-leash (orange). Bottom eight graphs: trends between number of (a) humans to birds and (b) dogs to birds, by substrate types. Theses graphs are fitted with a logarithmic trend line. In legal off-leash areas with sandy substrate (orange graphs), there is an apparent negative association; there is relatively low bird density when there is a high density of humans or dogs.

A logarithmic trendline was chosen, considering that the data requires an adjustment for skew towards large values. An example is where there had been few cases of increased disturbance observations leading to trend misrepresentation. The corrected trend can be seen in most of the graphs in Figure 21, except for humans on sandy on-leash substrate areas.

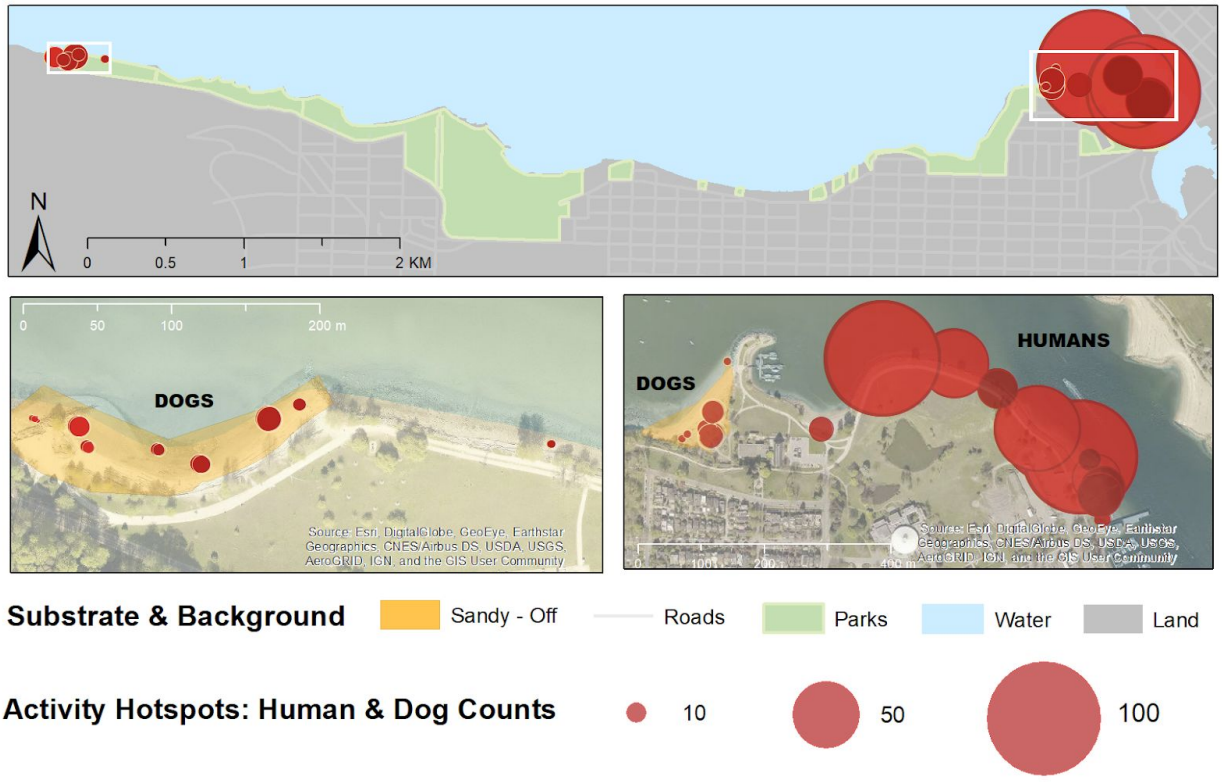

Figure 22. Distribution of 95% significant hotspots of human and dog activities along the Kitsilano shoreline.

There is a significant clustering of high-density humans (hotspots) observed at Hadden and Vanier parks near Burrard Bridge ($p < 0.05$), whereas there is a 95% significant clustering of dogs observed at both off-leash sandy areas at Spanish Bank Beach Park and Hadden Park ($p < 0.05$) (Figure 22).

5.3.3 Boating Activities

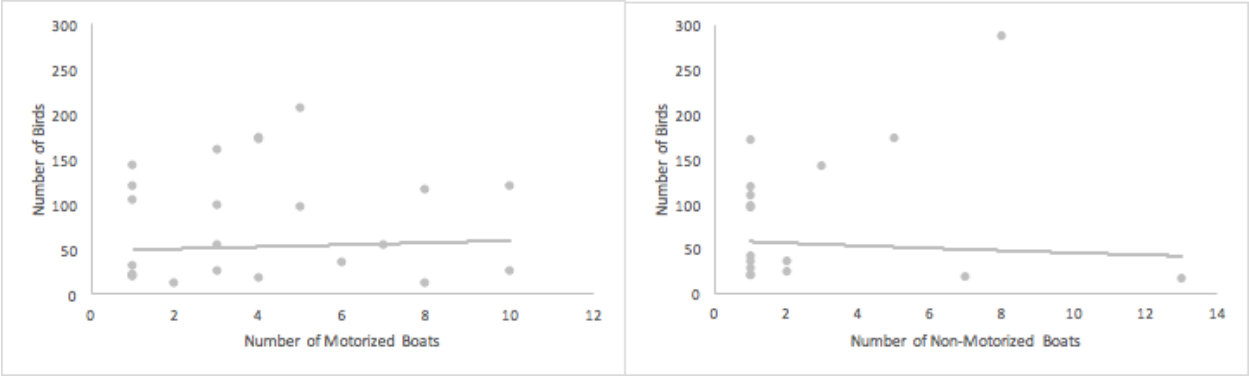

Figure 23. Scatter plots with exponential trendlines showing relationship between number of birds and number of motorized boats (left) and number of birds and number of non-motorized boats (right). This data shows no significant relationship between bird quantity and boating activity.

Although there was no apparent relationship between the number of observed boats and the number of observed birds (Figure 23), boating activity was still considered to be a disturbance due to flushing behavior observed by surveyors. Motorized boats were given a matrix value of 4 and non-motorized boats a value of 8. Although Figure 23 does not support these high matrix values, we found non-motorized and motorized boats to be the 2nd and 3rd most impactful due to observed flushing. After a 15-minute point count survey had started, we may have already counted a large amount of birds before a boat had flushed many away. In these instances, we had to make a note of the 50 or 100 birds we saw flushed due to boating activity.

6. Discussion

6.1 Bird Distributions

A total of 5919 birds were observed along the Kitsilano shoreline from November to February, which included 24 species from nine bird subfamilies.

Dabbling ducks encompassed 9% of total number of birds observed (525 individuals), which were evenly distributed across the three substrate categories. Previous research have suggested that densities of dabbling ducks decline with increasing water depth (Osborn *et. al*., 2017). Density also increases with greater emergent cover, such as vegetation, as they could reduce predation risk, provide thermal cover, and provide isolation for courtship (Osborn *et. al*., 2017). Further research on water depth and emergent cover should be conducted to determine if the even distribution between substrate areas could be attributed to an even distribution of water depth and emergent covers along the shoreline.
It is interesting to note that within sandy substrate areas, most of the observations were made near on-leash areas. This suggests that off-leash dogs may have a negative correlation on the quantity of dabbling ducks; this is further discussed below.

Diving ducks had the highest relative abundance (76% observations; 4456 individuals), where most were found at Spanish Bank Beach Park and Hadden Park. About 60% of diving ducks were observed near sandy substrate areas, of which more than 80% were found near on-leash areas. This suggests that diving birds may be affected by stronger presence of off-leash dogs. 30% of diving ducks were observed at mixed substrate areas, near Jericho Beach Park. Engineered substrate areas are associated with the least number of diving bird observations, which could be partly due to the physical quality of the engineered material, considering that areas near man-made substances (i.e. riprap) are not primary foraging habitats for diving birds.

Loons and grebes, though observed at a much lower abundance (2% observations), had a similar distribution as diving ducks. More than half of the observations were made on sandy substrate areas, namely at Spanish Bank Beach Park, though there is no apparent partition between on or off-leash areas. This suggests that loons and grebes are indifferent to a higher presence of off-leash dogs. This is consistent with qualitative observations from the surveys, during which Horned Grebes have been observed to be swimming about a meter away from on shore dogs.

Cormorants encompassed 1% of the total number of birds observed. About 70% of individuals were observed near sandy substrate areas, whereas the remaining 30% were evenly distributed across mixed and engineered substrate areas. Of the observations made near sandy substrate areas, most cormorants were observed near on-leash areas. It is important to note that there are cormorant nests around the engineered substrate areas near the Burrard Bridge, adjacent to the sandy off-leash area at Hadden Park. Cormorants also rest or preen on the Jericho Crab Dock. Cormorants nesting season is in between April and August but many individuals overwinter in the same locations (Kirschbaum, K., & Ward, E., 2000). While there had been many accounts of flyovers around the surrounding survey sites, individuals tended not to land in water around the area. Similar to the patterns observed with dabbling and diving ducks distributions, this may again suggest a tendency of cormorants to avoid areas occupied by off-leash dogs.

Considering all subfamilies, 52% of total number of birds were found near sandy substrate areas, whereas the least number of birds (23%) were observed near engineered substrate areas. This is potentially due to the high number of anthropogenic disturbances at engineered areas. These areas encompassed the highest number of humans and motorized boat activities observed, which suggests higher level of disturbances from the shore as well as in the water. This is consistent with the observed distributions of gulls and crows. Though observed at a much lower abundance (12% gulls and 9% crows), these subfamilies are often found in populated urban areas with high levels of human activities, where they scavenge urban organic waste.

6.2 Recreational Disturbances

6.2.1 Trends Between Disturbances and Birds

The relationship between total number of birds observed and both human and dog presence is shown in Figure 21. The logarithmic trend lines shown in the eight graphs highlight similar trends of initially having a high rate of decrease and then leveling out. This suggests that the increase of number of dogs

from one to two has a much larger impact on marine birds in the area compared to if the number of off-leash dogs increased from 11 to 12. Fewer birds are therefore observed with a higher abundance of dogs and humans.

Although Figure 23 does not show a specific trend between the presence of boats and the abundance of birds, boats were still considered to be a disturbance due to observed flushing behaviour. Non-motorized boats show an expected negative exponential trend. The outlier point is where eight boats and 286 birds were observed at Spanish Banks in a sandy on-leash area. These boats were part of a sail boat class and were clustered together, minimizing the disturbance to surrounding birds. Motorized boats were present during the four surveys with the largest counts of gulls. The presence of motorized boats may attract gulls as many fishing vessels could provide a source of food when discarding fish waste.

Within sandy substrate areas, there is a higher relative abundance of birds observed in on-leash areas in comparison to off-leash areas. Assuming most dog owners follow the dog-leash regulations, off-leash areas are expected to have significantly more off-leash dogs in legal off-leash areas. From our observations, sandy off-leash areas have more off-leash dogs and is the least preferred habitat for birds (Figure 19). Sandy on-leash areas have relatively fewer off-leash dogs and are the most preferred habitat. Therefore, the presence of more off-leash dogs affects whether birds will be observed in the area.

The matrix found in Figure 20 shows a negative slope. As the matrix value increased, the number of observed birds decreases. This suggests that, a combination of humans, on-leash dogs, motorized boats, non-motorized boats and off-leash dogs do have an affect on the presence of marine birds along the Kitsilano shoreline. The slope of the trendline is shallow due to the many outliers. This indicates that anthropogenic disturbances are not the only impacts affecting abundance and distribution of birds.

6.2.2 Qualitative Observations of Flushing

Though we were unable to quantify the observed flushing behaviour of birds during this project due to our focus on the counts of birds and disturbances, we did record multiple instances of flushing. On February 4, 2018, a flock of over 200 unidentified diving ducks in the water flushed as a result of paddle boarding activity. The paddle boarder was spotted at Volunteer Park (within the mixed substrate of our study area), and paddled directly into the flock, which disturbed the birds and caused them to fly away. On January 26, 2018, a flock of wigeons foraging in the intertidal zone at Point Grey Park (mixed substrate) immediately flushed into the water upon the arrival of our two surveyors at the survey point. On November 12, 2017, a flock of goldeneye ducks at Vanier Park (engineered substrate) was flushed as a result of an approaching motorized boat. These recorded observations of flushing demonstrate the immediate threat that recreational disturbances pose to marine birds. The flushing activity of birds that follows anthropogenic disturbances suggests that, at least to some extent, recreational disturbances alter the natural behaviour of birds. If recreational activity along the shoreline and in the water is not monitored or regulated, the health of marine bird communities may be compromised as a result of interruptions to natural behaviour.

6.2.3 Dog-leash Bylaw Violation Analysis

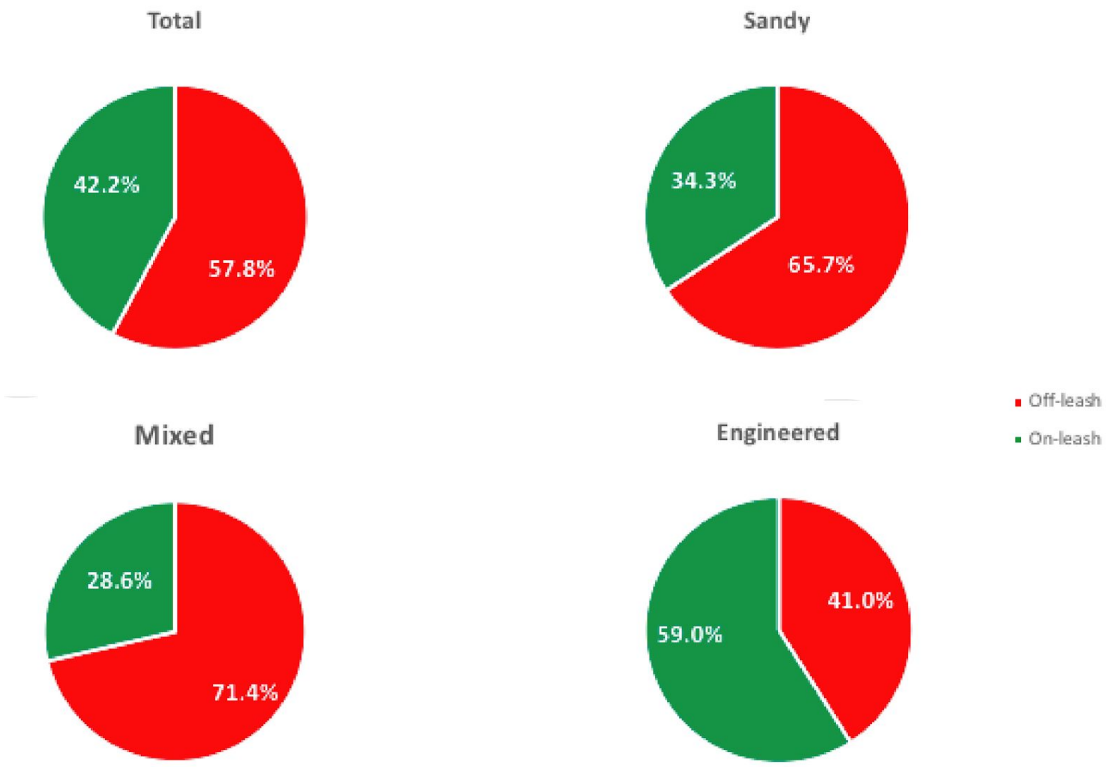

Figure 24. Proportions of on- and off- leash dogs present in the on-leash only sites of the study area, broken down by substrate type. The upper left chart represents the all three substrate categories (total dogs, n = 180), the upper right is the sandy substrate (total dogs, n = 105), the lower left chart is the mixed substrate (total dogs, n = 14), and the lower right chart is the engineered substrate (total dogs, n = 61). The red portions represent off-leash dogs and the green sections represent on-leash dogs.

Throughout the duration of our fieldwork, we observed many off-leash dogs at beaches where off-leash dogs were prohibited. Figure 24 presents the observed break-down of on-leash and off-leash dogs present at on-leash-only beaches; thus, data from off-leash dog beaches is excluded from this analysis. As demonstrated by Figure 24, 57.8% of dog walkers at on-leash-only beaches were violating the dog-leash bylaw. Figure 24 also indicates that 71.4% of the dogs observed within the mixed substrate and 65.7% of the dogs observed at the sandy substrate of the on-leash-only violated the City of Vancouver dog-leash bylaws during our research period. In both cases, this indicates that more than half of the dogs present in these substrate types are in violation with the city bylaw rule. In the engineered substrate, 40.9 % of the dogs were off-leash, and thus in violation with the bylaw regulation, which is also a remarkable contribution to bylaw violations. Thus, a considerable number of dog walkers are violating the beach leash bylaws, which highlights the potential impacts on wildlife, particularly on birds. Dog off-leash areas in Vancouver are strategically located away from ecologically-sensitive areas such as biodiversity hotspots, especially areas that attract and support critical habitat of migratory birds (Vancouver Park

Board, 2017). Additionally, dog behaviour (movement and noise) has been documented to interfere with both migratory and resident birds (Holmberg, 2013). Thus, the violation of dog-leash bylaws at the beaches along the Kitsilano shoreline raises concern for the integrity of bird communities that rely on the beach habitat. Dog-leash bylaw violations may be a result of lack of education, unclear signage, or a combination of these factors. Measures are needed to ensure that beach users are engaging in recreational activity in a way that minimizes disturbance to bird biodiversity, such as through increased education on bird biodiversity in Metro Vancouver and improved delivery of recreational activity regulations.

7. Recommendations

Based on our final maps, quantitative analysis, and anecdotal observations, we have developed the following recommendations to consider in the future development of city planning initiatives within the City of Vancouver.

7.1 Dog-leash Bylaw Signage Consistency

Clearer signage denoting dog off-leash areas are recommended to avoid confusion. Better access to an updated, easily accessible online map showing the different dog leash bylaw areas may help clear confusion about the exact location of the dog off-leash parks. Improved placements of signs are also recommended. In particular, dog-prohibited signs should be placed in more visible areas or should be made more prominent. The hotspots of dog use seen in Figure D1 should be considered when placing new signage. More signage is needed in areas with increased dog use. The signage itself should be standardized, informative, novel, visible, and understandable. With the addition of educational signs, people will have a better understanding on the reasonings behind the implementation of these laws.

7.2 Boating Rentals Warnings

Due to the observed flushing of birds from water-based recreational activities, we suggest that rental companies that distribute equipment for activities such as paddle boarding, canoeing, kayaking, kite- and windsurfing, as well as boating, should be responsible for issuing warnings to customers about the importance of preserving bird habitat. These warnings may be issued verbally or in writing, and should direct recreational users to avoid steering directly into or near bird flocks in order to minimize disturbance to native biodiversity. Educational materials, such as posters and brochures, could be provided for rental companies to hand out to customers to accomplish this.

7.3 Further Research

Further research on water depth, emergent cover, noise level, and food distribution along the Kitsilano shoreline should be conducted to determine the extent to which anthropogenic disturbances could be attributed to variations in bird abundances and distributions. Such research would eliminate uncertainties that stem from confounding factors, and would provide a more comprehensive understanding of the rationale for the distribution of marine birds. Additionally, the data from this project could be compared to previous data collected from the Coastal Waterbird Survey to determine if the data collected for this

project is consistent with long term monitoring data. If enough data is present, a time series could be developed, which could facilitate the identification of temporal distribution trends in bird distributions.

7.4 Citizen Science

We support the citizen science initiatives provided by Bird Studies Canada, such as the Christmas Bird Count (http://www.birdscanada.org/volunteer/cbc/index.jsp?lang=EN) and eBird Canada (https://ebird.org/canada/home). Further monitoring on bird distributions by citizen science programs strengthens conclusions made from our baseline research as programs can be run all year long and other bird or anthropogenic behaviours not present in the winter months could be captured. Enhanced education will raise awareness for bird biodiversity among citizens, which will foster the conservation of critical bird habitat by encouraging citizens to minimize their disturbances to wildlife. Increased participation in such programs may cultivate an urgency to conserve the habitats that support native bird species within Vancouver communities.

8. Conclusions

This project illustrates that a diverse community of marine bird species utilizes the Kitsilano shoreline and adjacent waters. Between November 2017 and February 2018, a total of 5919 birds from 24 species were observed at the 68 point counts during nine field surveys. The observed birds were distributed across the sandy, mixed, and engineered substrates of the study area. Given that the subfamilies occupy unique patches along the Kitsilano shoreline (Figures 9, 11, 13, 15, & 16), it can be concluded that multiple patches along the shoreline are important for bird biodiversity. In those patches where bird density is high, the natural landscape likely provides critical habitat and resources for the birds.

This research further suggests that the Kitsilano shoreline is a popular location for recreational activities. During the nine field surveys, a total of 2533 recreational beach users was recorded. Recreational beach users include on- and off- leash dogs, motorized and non-motorized boats, walkers, runners, bikers, and swimmers. The distribution of recreational activities also varies on a spatial scale (Figures 1 & 22). Although no statistical significance was achieved during this project, the data suggests that the density of birds may be lower when the density of humans and dogs is higher (Figure 21). During the field surveys, multiple instances of bird flushing due to immediate recreational disturbance were qualitatively recorded. Thus, the results strongly suggest that recreational activity can disturb or distress marine birds, which may compromise the integrity of bird biodiversity in Burrard Inlet. This raises serious conservation concerns, especially when considering the birds that are already threatened or at risk of becoming threatened, such as the Western Grebe, Black Scoter, Surf Scoter, Double-crested Cormorant, and Pelagic Cormorant.

We recommend for further research to be undertaken to better understand the potential threats to marine birds and to establish long-term monitoring protocols. Moreover, we suggest increasing citizen awareness for bird biodiversity through increased participation in citizen science initiatives, standardizing the signage of dog-leash bylaws to reduce confusion and increase compliance among dog-walkers, and encouraging rental companies to issue warnings to customers about the importance of minimizing disturbances to birds while engaging in recreational activity. Under these recommendations, we postulate

that recreational beach users will be able to coexist with marine bird communities in such a way that enables beach users to engage in recreational activity while minimizing disturbances to marine bird populations. Adopting city-wide strategies that follow these recommendations will enable recreational beach users of the City of Vancouver to enjoy nature through (1) enhanced appreciation for native wildlife and biodiversity and (2) participation in respectful and mindful practices of outdoor recreational activity, specifically near and within Vancouver's beaches. Ultimately, this will foster conservation practices to protect the habitats of marine birds and enable native birds within the city to thrive.

9. Acknowledgements

We would like to thank our community project partners- Nick Page from the Vancouver Park Board and Ileana Costrut from CityStudio Vancouver- for their guidance and assistance throughout the duration of this project. We would also like to express our gratitude to Teddy Eyster, Tara Ivanochko, and Michael Lipsen, our course instructors, for their assistance, patience, and willingness to obtain funding for our equipment. Finally, we thank Karen Devitt, Mark Drever, and June Ryder for sharing their expertise on ornithology, which greatly improved our project.

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11. Appendix

11.1 Appendix A: Glossary of Important Terms

Anthropogenic	Related to or resulting from human activity.
Engineered Substrate	Substrate has been constructed by man, and contain elements such as grass, large boulders, or riprap.
Flushed	A bird is "flushed" when it is startled, and abandons its natural activity to take flight. This is usually a stress response to disturbances.
Flyover	A bird that is flying in the air and passing through, and does not stop to land in neither the water nor the adjacent land.
Mixed Substrate	Substrate is a combination of sand and rocky materials (bedrocks, boulders, coarse gravels, cobbles).
Recreational Disturbance/Activities	In this report, 'recreational disturbances' will refer to recreational activities (such as walking, running, on- and off- leash dog-walking, and boating) near or in the water that may distress marine bird communities.
Sandy Substrate	Substrate is predominantly made of fine particles, including sand, mud-sand, mud, fine gravel and shells.
Species Richness	Species richness refers to the number of unique species represented in a specified region.
Substrate Zones/Categories	Areas categorized by the physical quality of their substrate (sandy, mixed, engineered).
Nearshore Birds	Birds in the water, within 500 metres.
Onshore Birds	Birds within the terrestrial substrate of the marine habitat.

12. Appendix

Appendix A: Data Collection Sheet

Date:

Start Time:

High Tide Level:

End Time:

High Tide Time:

Site Name:

Current Temperature:

Point ID:

Current Precipitation: None / Light / Moderate / Heavy

Substrate Type: Sandy / Mixed / Engineered

Current Cloud Cover: None / Few / Partial / Mostly / Overcast

Dog Leash Laws: On-leash / Off-leash

Wind: None / Mild / Moderate / Strong

Surveyors: AL / BK / JG / NY

Disturbance	Activity	Count within substrate and nearshore	Count beyond substrate	Notes
Person	At Rest			
	Walking			
	Running			
	Biking			
	Sporting Activity			
	Swimming			
	Paddle Boarding			
	Fishing			
	Other Activity (Specify)			
Off Leash Dog	At Rest			
	Walking			
	Running			
	Swimming			
On Leash Dog	At Rest			
	Walking			
	Running			
Other Animal	Any (Specify)			
Boat	Motor			
	No Motor			
Other				

Subfamily	Species	Onshore	Nearshore	Notes
Geese	Canada Goose			
Dabbling ducks	American Green-winged Teal			
	American Wigeon			
	Mallard			
	Northern Pintail			
	Northern Shoveler			
	Unidentified Dabbling ducks			
Diving ducks	Harlequin Duck			
	Bufflehead			
	Barrow's Goldeneye			
	Common Goldeneye			
	Unidentified Goldeneye			
	Common Merganser			
	Hooded Merganser			
	Red-breasted Merganser			
	Greater or Lesser Scaup			
	Black Scoter			
	Surf Scoter			
	White-winged Scoter			
	Unidentified Diving ducks			
Loons & Grebes	Horned Grebe			
	Pied-billed Grebe			
	Red-necked Grebe			
	Western Grebe			
	Common Loon			
Cormorants	Brandt's Cormorant			
	Double-crested Cormorant			
	Pelagic Cormorant			
	Unidentified Cormorants			
Wading birds	Great Blue Heron			
Shorebirds (Charadriidae)	Dunlin			
	Greater Yellowlegs			
	Killdeer			
	Long-billed Dowitcher			
	Sanderling			
	Semipalmated Plover			
	Spotted Sandpiper			
(Haematopodidae)	Black Oystercatcher			
	Unidentified Shorebirds			
Gulls	Glaucous-winged Gull			
	Mew Gull			
	Ring-billed Gull			
	Hybrid Gull			
	Unidentified Gull			
Murres	Marbled Murrelet			
Eagles	Bald Eagle			
Kingfishers	Belted Kingfisher			
Other birds	Crow			
	Pigeon			
	Other			

Appendix C: Photos

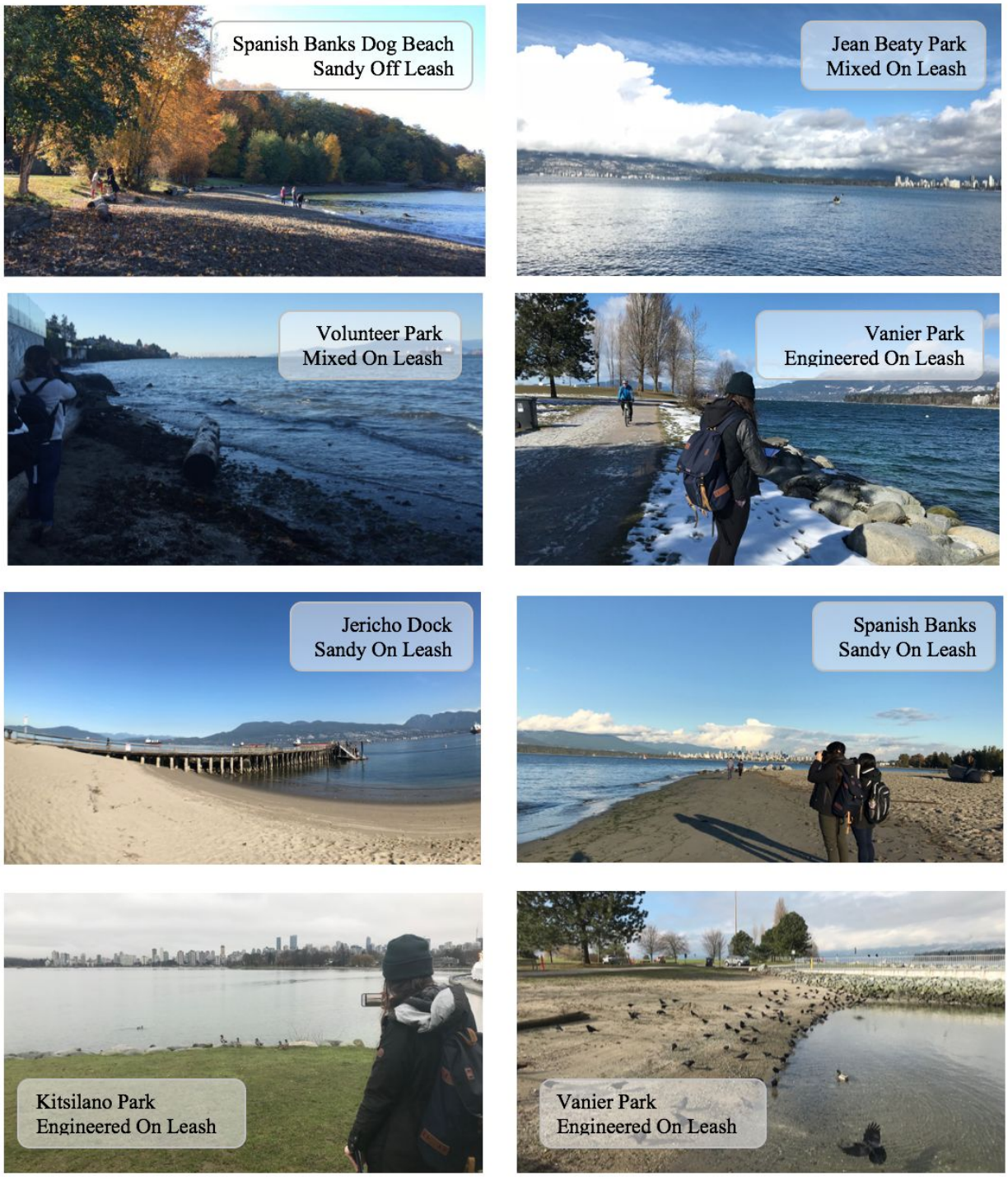

Figure C1. Substrate type and dog leash bylaw for different parks along the Kitsilano shoreline.

Appendix D: Supplementary Maps

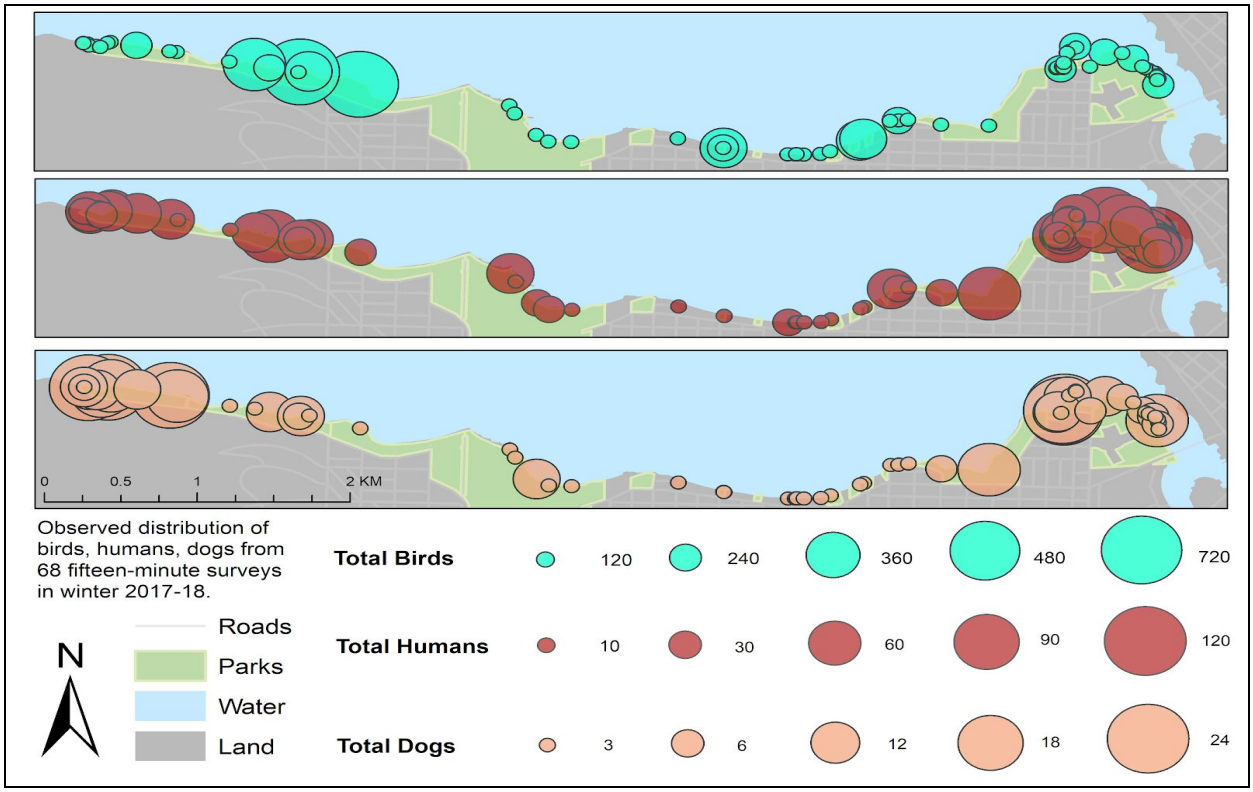

Figure D1. Total observed abundances of marine birds, humans, and dogs during the 68 field surveys.

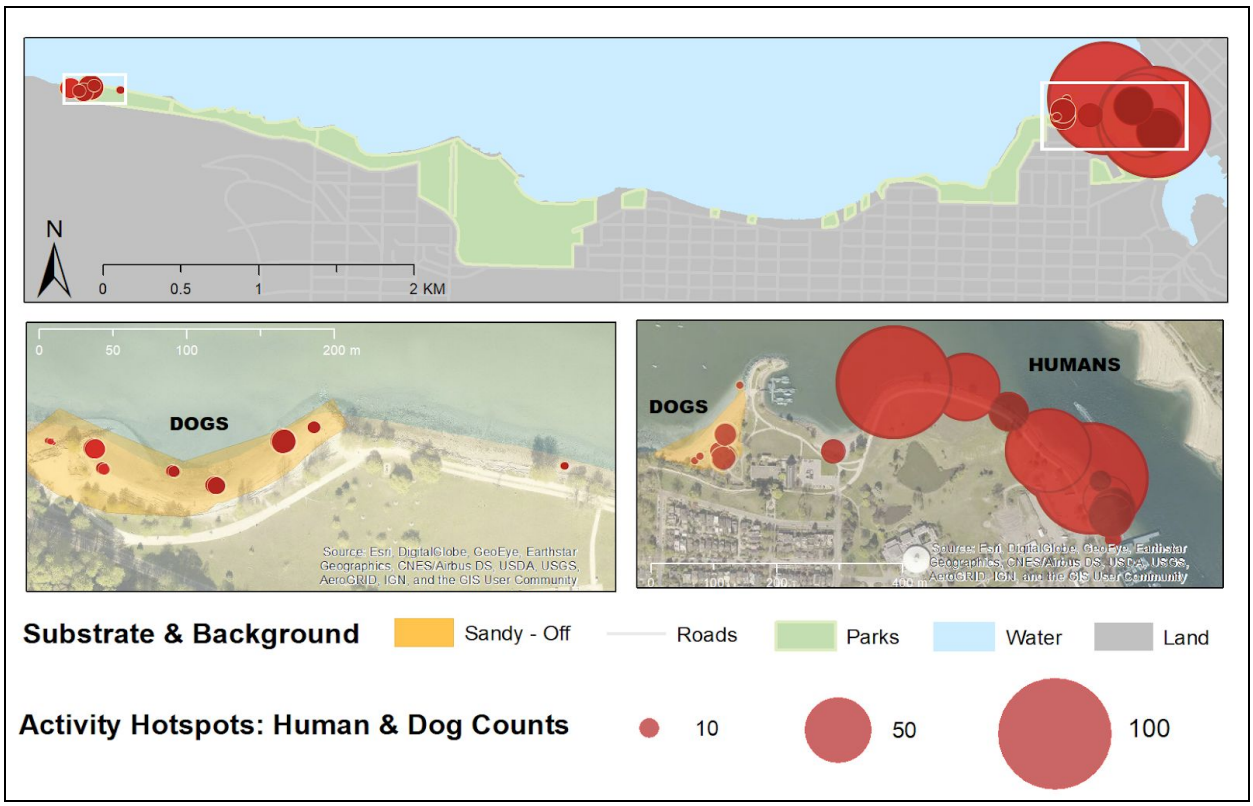

Figure D2. Distribution of 95% significant hotspots of human and dog activities along the Kitsilano shoreline.

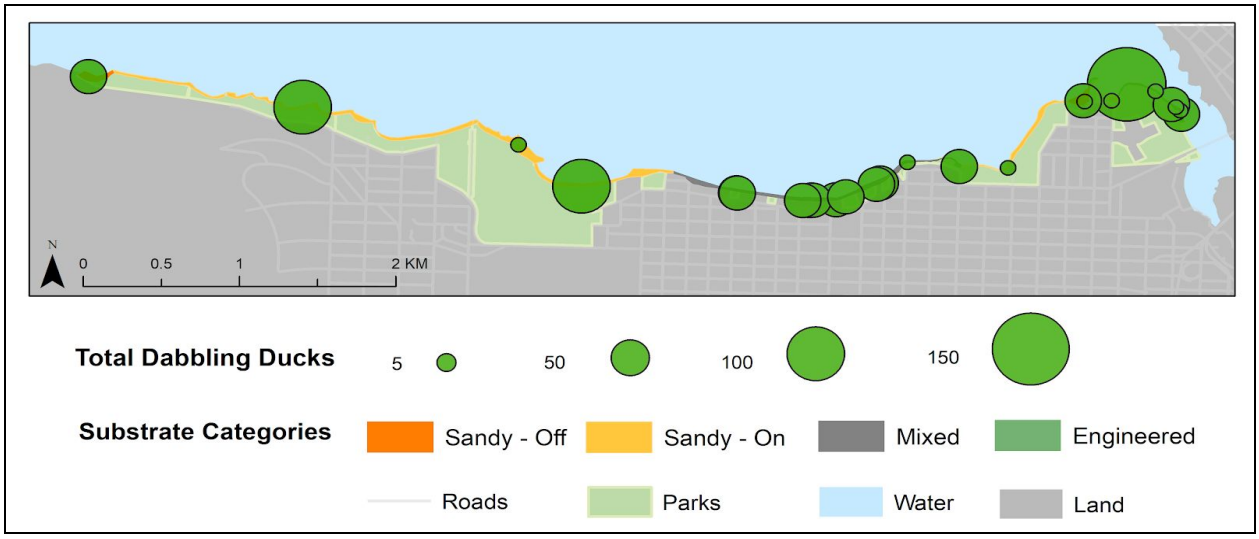

Figure D3. Distribution of dabbling ducks along the Kitsilano shoreline from November 2017 to February 2018.

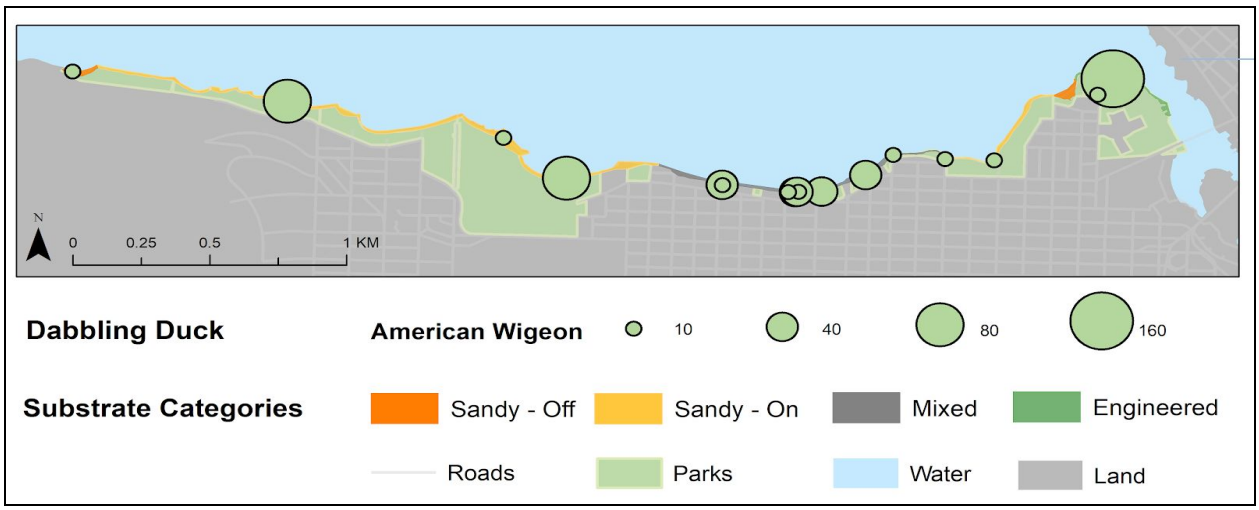

Figure D4. Distribution of American Wigeon along the Kitsilano shoreline from November 2017 to February 2018.

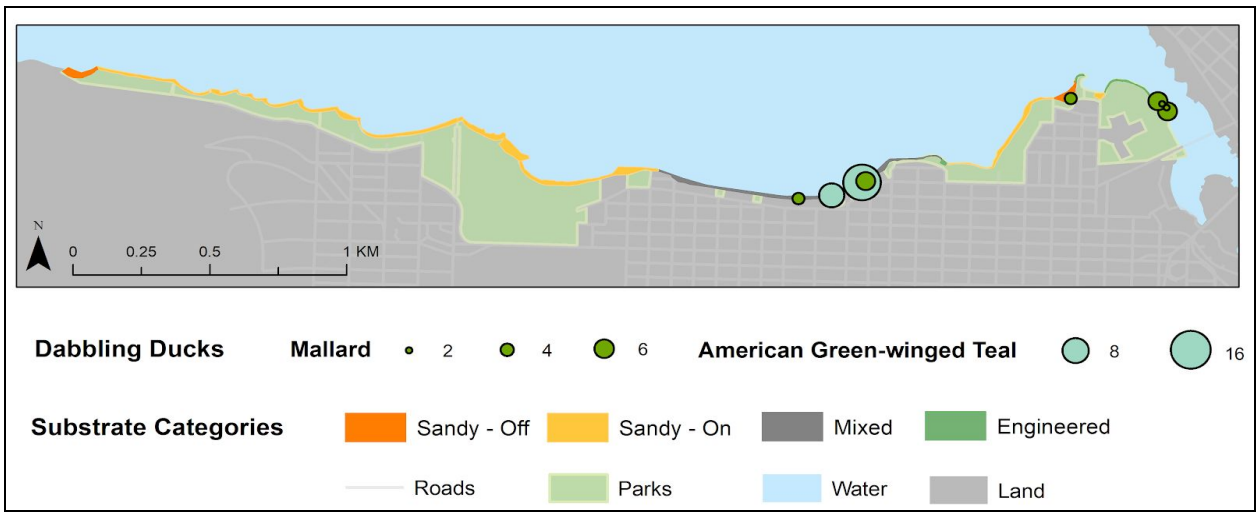

Figure D5. Distribution of Mallard and American Green-winged Teal along the Kitsilano shoreline from November 2017 to February 2018.

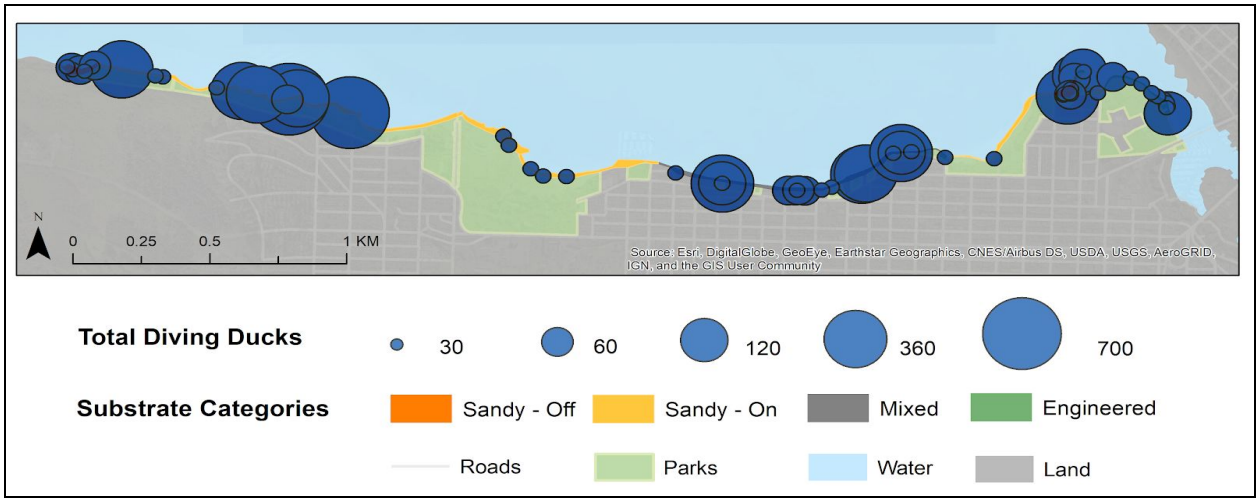

Figure D6. Distribution of diving ducks along the Kitsilano shoreline from November 2017 to February 2018.

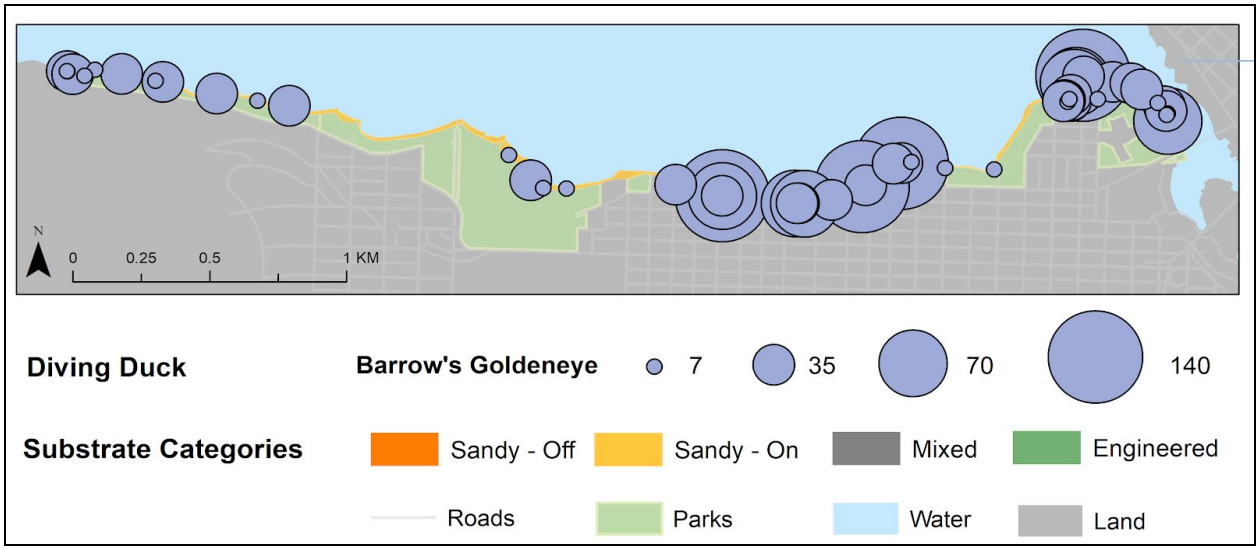

Figure D7. Distribution of Barrow's Goldeneye along the Kitsilano shoreline from November 2017 to February 2018.

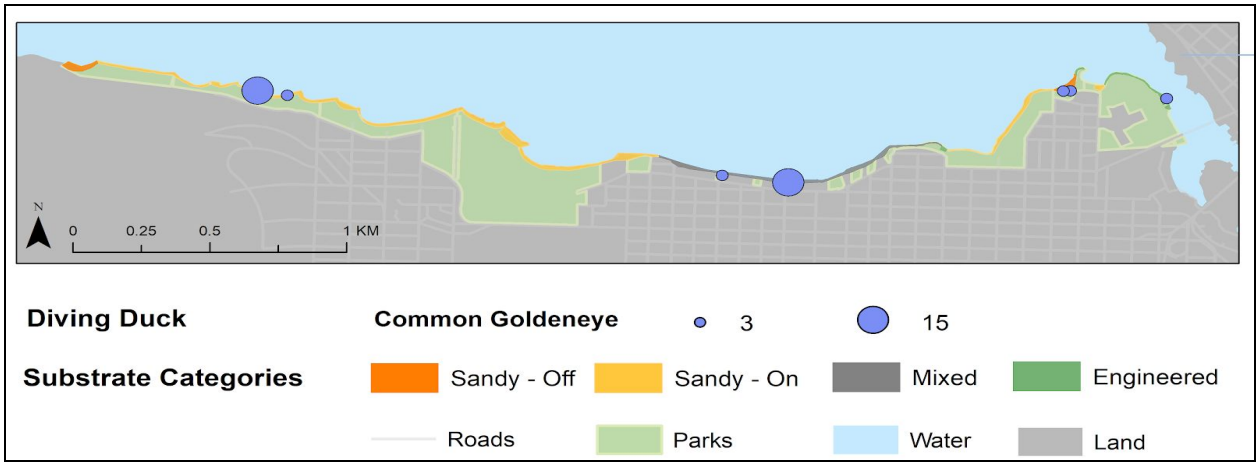

Figure D8. Distribution of Common Goldeneye along the Kitsilano shoreline from November 2017 to February 2018.

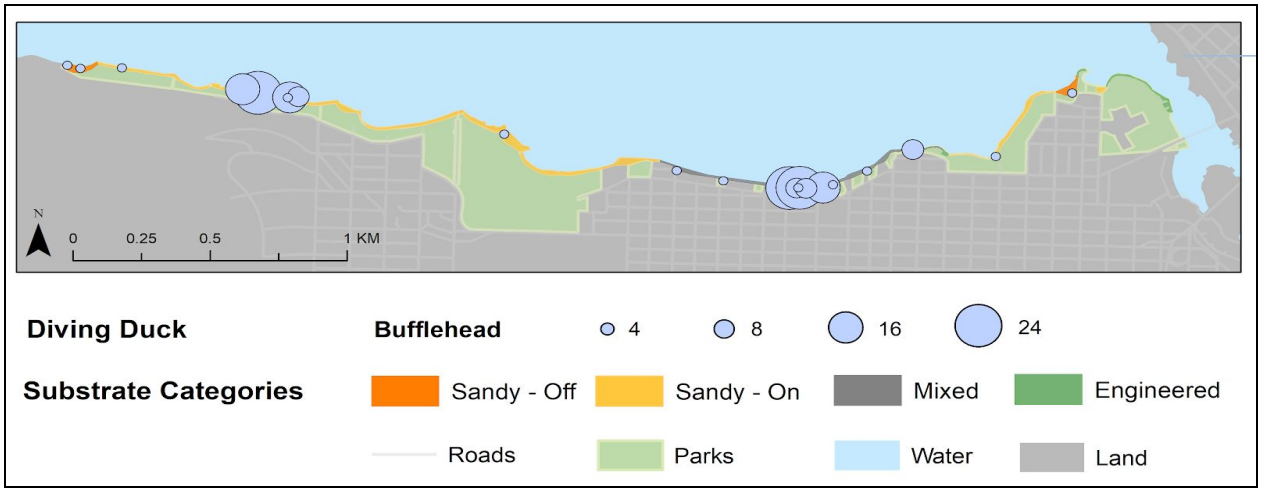

Figure D9. Distribution of Bufflehead along the Kitsilano shoreline from November 2017 to February 2018.

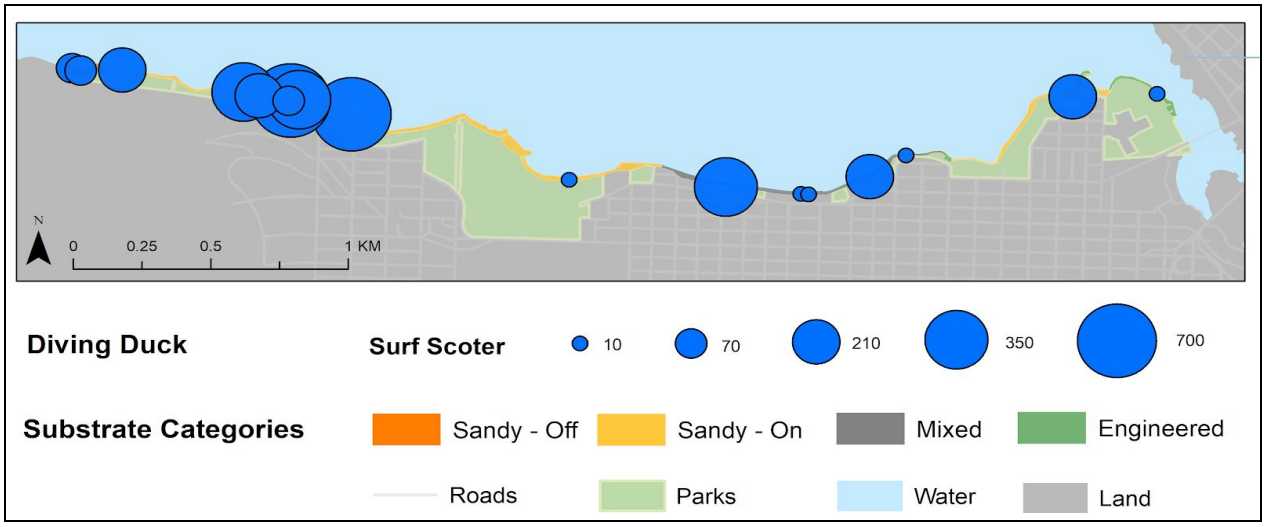

Figure D10. Distribution of Surf Scoter along the Kitsilano shoreline from November 2017 to February 2018.

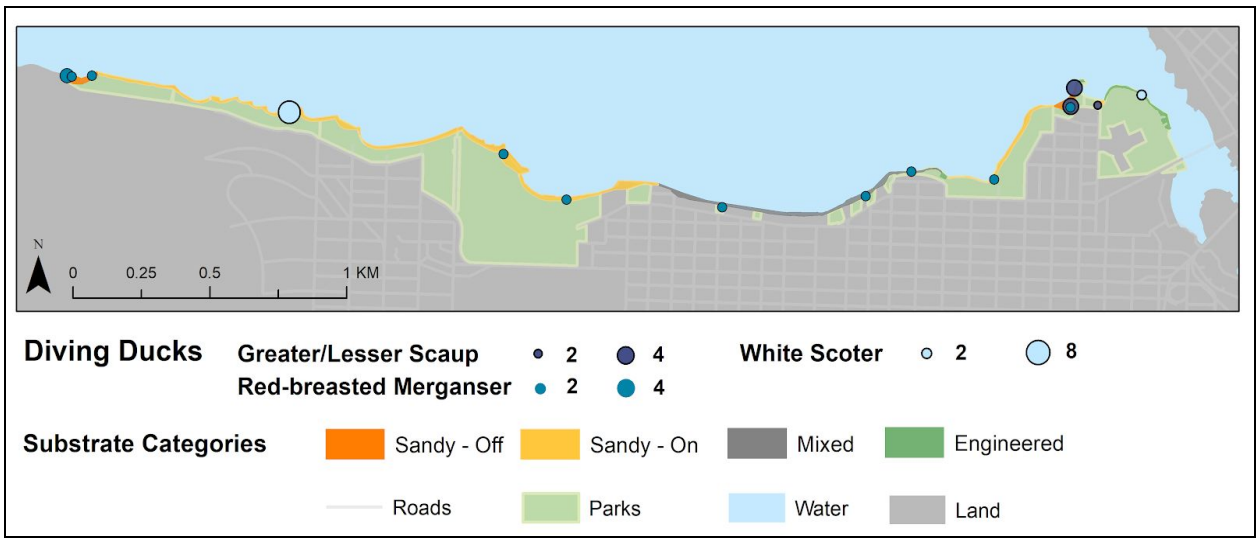

Figure D11. Distribution of Greater or Lesser Scaup, White Scoter and Red-breasted Merganser along the Kitsilano shoreline from November 2017 to February 2018.

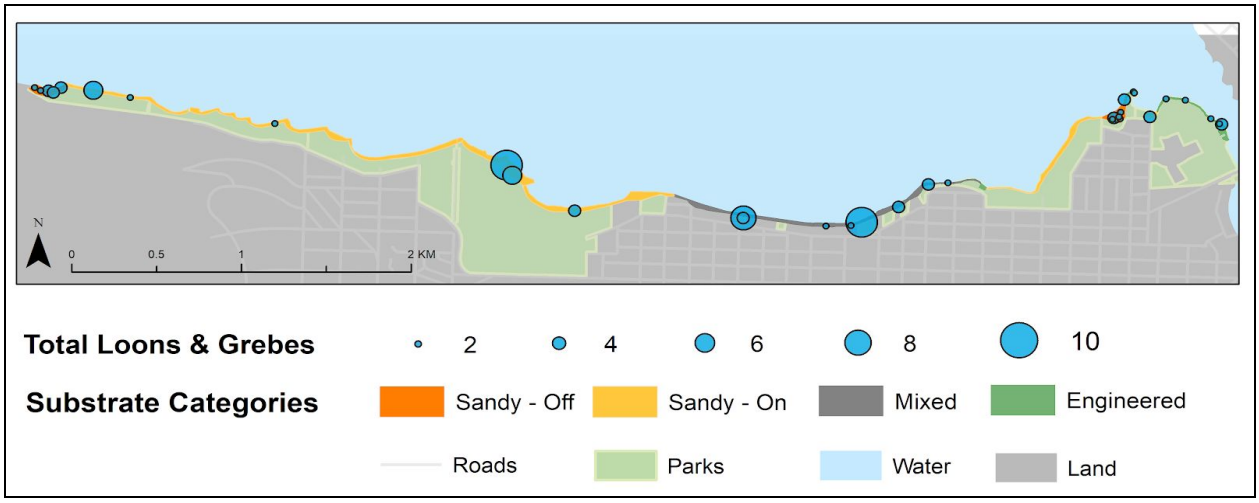

Figure D12. Distribution of loons and grebes along the Kitsilano shoreline from November 2017 to February 2018.

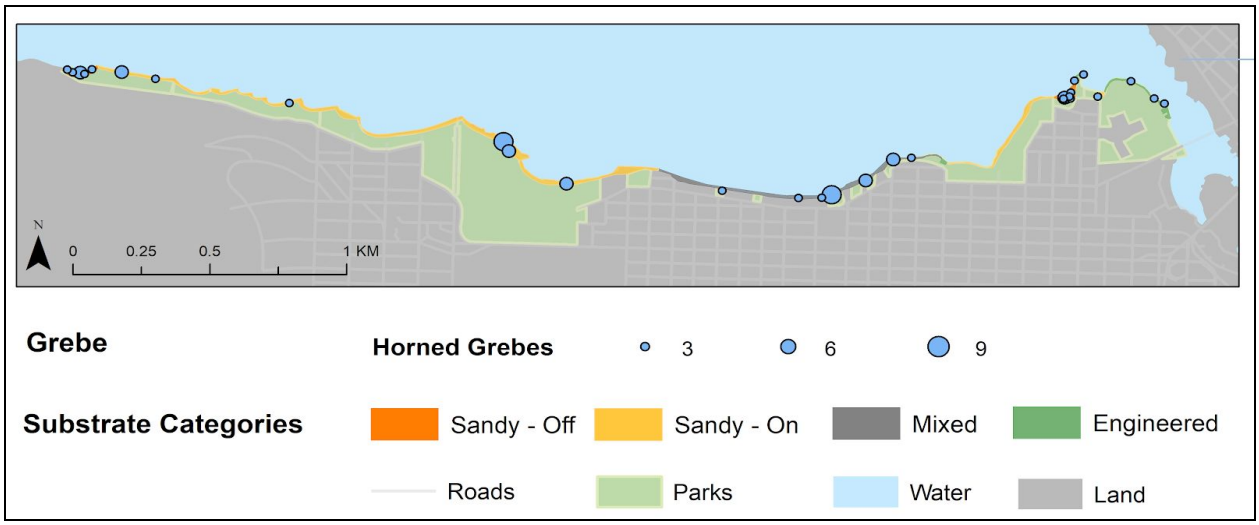

Figure D13. Distribution of Horned Grebes along the Kitsilano shoreline from November 2017 to February 2018.

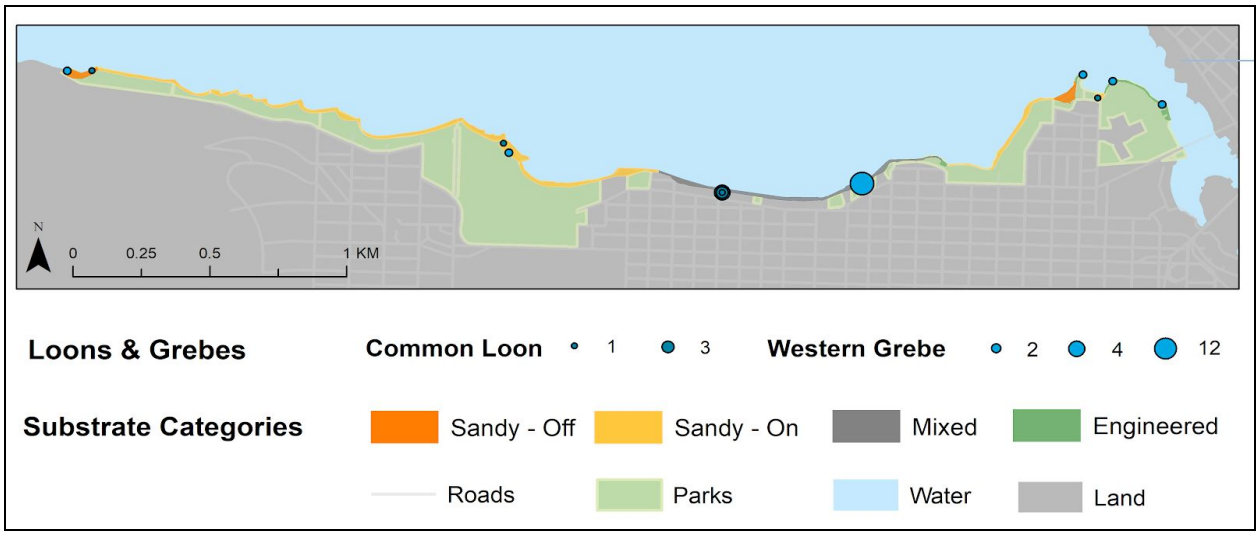

Figure D14. Distribution of Common Loon and Western Grebe along the Kitsilano shoreline from November 2017 to February 2018.

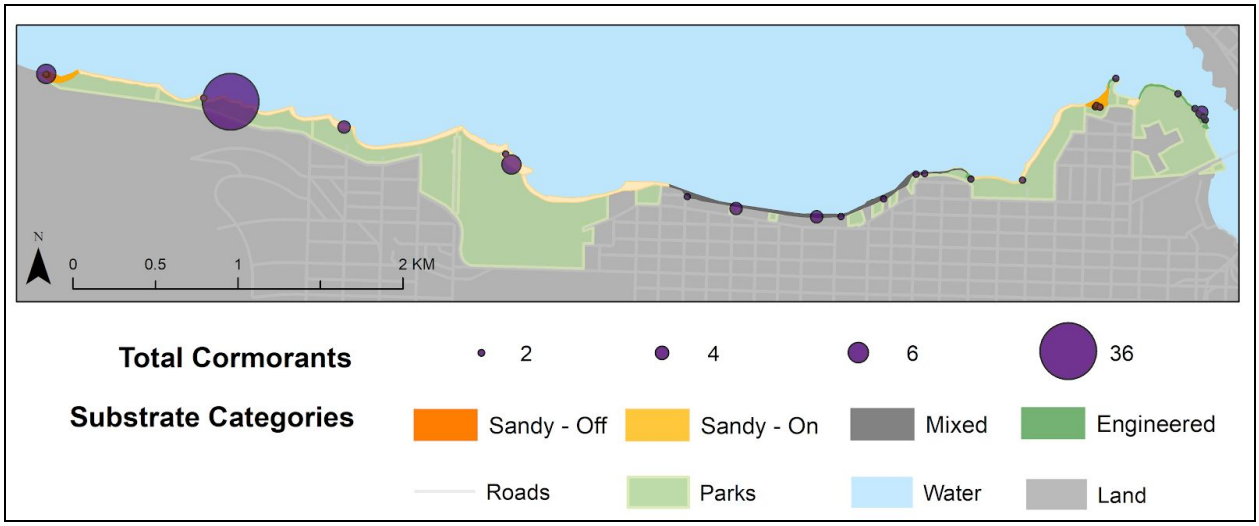

Figure D15. Distribution of cormorants along the Kitsilano shoreline from November 2017 to February 2018.

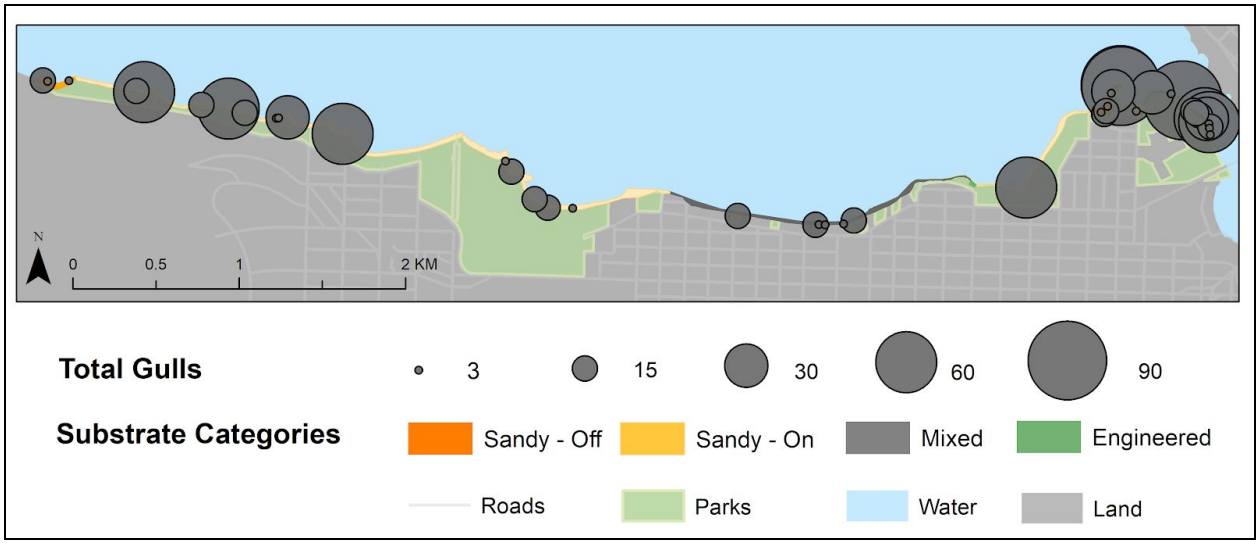

Figure D16. Distribution of gulls along the Kitsilano shoreline from November 2017 to February 2018.