UBC Social Ecological Economic Development Studies (SEEDS) Sustainability Program
Student Research Report

UBC Wildlife Biodiversity Baseline: How can UBC campus grow with minimal or positive impacts on bird populations?

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ABSTRACT

The University of British Columbia is recognized as a global leader in sustainability, currently operating a 20 year strategic plan intended to guide towards campus activities having a positive impact on the environment. These impacts should include campus influence on native birds as vertebrate populations are influenced by campus structure and only a portion of native species can cope with habitat change. In order to understand bird species distribution on campus, we assessed bird species richness across the four most common habitat types and recommended campus planning decisions to facilitate bird populations between habitat corridors. We catalogued bird species richness by surveying in eight locations around campus representing the four most common habitat types determined by Dyck (2016). A total of 29 species were observed in all survey locations. Higher species richness was found in habitats of varied vegetation cover compared to uniformly spatially arranged vegetation cover, locations close the border of campus, areas with fewer instances of human interaction, and areas open to bird movement in and out of other areas of campus. In order to mitigate the impact of development on campus and even improve habitat availability for bird populations, UBC should make efforts to avoid the disruption of bird movements. This can be met by maintaining open habitat corridors, installing bird collision prevention measures on windows throughout campus, increasing water availability for birds on campus, and planting native flora in heterogeneous patterns in potential bird habitats. These recommendations should be taken into consideration when developing projects on campus. Recommendations for the new UBC Library Garden project is discussed as it provides the opportunity to create new habitat corridors and bird refuges in the northern portion of campus as a timely project to revitalize sustainability to enhance biodiversity.

AUTHOR BIOS

Linnea Harder is a fourth-year Environmental Sciences student with a focus on Ecology and Conservation. She has a keen interest for wildlife biodiversity, and has conducted wildlife surveys in previous ecology courses and developed vertebrate identification skills in her taxonomy courses. Linnea also has experience using GIS software through her success in an advanced GIS course.

Kathy Miao is a fourth-year Environmental Sciences student with a focus on Land, Air and Water systems. Although she is interested in the study of physical environments, she has developed ecological survey skills in a number of ecology courses and developed her statistical skills in statistics courses.

Michael Oh is a fourth-year Environmental Sciences student with focus on Ecology and Conservation. His past courses and experience in ecology involving fieldwork and labs have influenced interest in assessing biodiversity of birds, especially in the context of UBC campus. Through this research, Michael hopes to apply skills in scientific report writing, and fundamental ecological concepts to contribute to UBC SEEDS' overall project.

Erin Pippus is a fourth-year Environmental Sciences student with a focus on Ecology and Conservation. She has previously conducted research with Agriculture and Agri-food Canada, developing her skills in project creation and data analysis. She has conducted basic wildlife surveys in previous ecology courses and honed her vertebrate identification in vertebrate taxonomy courses.

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INTRODUCTION

The University of British Columbia is widely recognized as a leader in sustainability at an international level. In 2015, UBC developed a 20-year Sustainability Strategy intended to aid in the development of a regeneratively sustainable campus, where sustainability is intended to mean simultaneous enhancements to human and environmental well being (UBC Sustainability: Our Commitment, 2016). The Strategy denotes a specific change to the institutional approach for sustainability: the goal is no longer to reduce damage or harm to the environment but to make positive impacts on environmental health. These goals are particularly important as campus and enrollment numbers grow. It is important to remember that the health of UBC's campus is not limited to greenhouse gas emissions and waste management protocols, but includes the maintenance of plant and animal populations within their current, historical, and potential range of habitats.

Vertebrate populations on campus are heavily influenced by campus structure (Dearborn & Kark, 2010) and require special consideration as only a portion of native species can cope with major habitat changes (Kark *et al.*, 2007). Buildings and landscaping choices can cause isolation for species, particularly birds, by breaking the links between viable habitats (Dearborn & Kark, 2010). Bird species richness is dependent on resource availability and the ability to travel from habitat to habitat, so they are extremely susceptible to human induced habitat changes. At this point, bird species distribution on campus is little understood. UBC cannot make sustainable campus development decisions if it does not know what birds live where. In order to best address these concerns, we surveyed birds across campus with the following objectives:

- Assess species richness of bird populations in the four most common habitat types on campus.
- Create a map with visual representation on bird species distribution on campus.
- Recommend campus development strategies based on concepts of landscape ecology for Campus Planning and Landscape Operations to minimize impact on campus bird populations or promote/facilitate movement of key bird species between habitat fragments.

METHODS

Eight survey locations were chosen across UBC campus representing the four most common habitat types: urban park, urban old field, mixed wood forest, coniferous forest (Dyck, 2016). Survey locations were intended to represent a variety of scenarios on campus, representing human activity levels, potential for development and/or potential as a habitat corridor. Survey locations were also areas where there was previous evidence of bird presence. These locations were the UBC Hospital, Acadia Park, East Campus Park, the Chan Centre, the Museum of Anthropology, the UBC Longhouse, Main Mall, and the Old Student Union Building (Figure 2). Survey sites were chosen within each survey location. Each survey site was centred on a point and extended to a 10 meter radius, creating a circle with a 20 metre diameter. The number of survey sites within a survey location was dependent on the size and variability of the location's vegetation. A small location, such as UBC Hospital, may only be able to fit three survey sites while a large location, such as Acadia Park, could support more. The number of survey sites within a location ranged from three to five sites (Figures 3-10).

- Survey location selection
  - Two survey locations for each of the four most common habitat types on campus: coniferous forest, mixed wood forest, urban park, urban old field. Eight in total.

- ○ Parameters for location choice:
  - Human activity in or around location
  - Plans/potential for campus development
  - Preliminary survey results
  - Potential as a habitat corridor
- ○ Chosen survey locations
  - Museum of Anthropology, Urban Old Field
  - First Nations Longhouse, Urban Old Field
  - Old Student Union Building, Urban Park
  - Main Mall, Urban Park
  - The Chan Centre, Coniferous Forest
  - East Campus Park, Coniferous Forest
  - UBC Hospital, Mixed-wood Forest
  - Acadia Park, Mixed-wood Forest
- Survey site selection
  - ○ 3-5 survey sites per survey location
  - ○ Survey sites are 10 meter circles with no overlap
  - ○ Survey sites distributed to create equal distribution of sites across the survey location
- Field surveys
  - ○ Point-count survey method
    - Identify birds within survey location during survey period. Intended for identification, not population counts.
    - 10 minute survey period for each survey site
    - Conducted with binocular observance, proxies (feathers, nests, deceased birds, etc.), and bird call recordings
    - Conducted in concert the American Birding Association Code of Birding Ethics (American Birding Association, 2017)
  - ○ Two survey day weeks beginning January 17, 2017 to March 7, 2017
    - Two locations per survey day, based on habitat type
    - Survey at daybreak and midday
    - When habitat type surveyed again, survey time was switched to minimize impact of time of day on survey results
- Case study and recommendations
  - ○ Overlay species count and bird-window collision frequency data at each of the eight study sites with satellite imagery of UBC campus
  - ○ Generate species count heat map (QGIS)
    - Add point vectors corresponding to number of unique species observed at each study site, using vegetation type map (Dyck, 2016) as background layer
    - Convert points to heat map visuals, setting radius to 20mm
    - Manually define colour contour ranges, at intervals of 3 species
  - ○ Offer recommendations to enhance movement of birds in and out of case study site (Library Garden) based on field data, observations, and generated figures
    - Outline boundaries of case study site at spatial contexts of within the site and campus as a whole using Google Earth (Fig. 16, 17, 19)

Figure 1. Determining the number of survey sites by measuring out areas of at least 10 m. Erin and Linnea at the First Nations Longhouse and the Old Student Union Building.
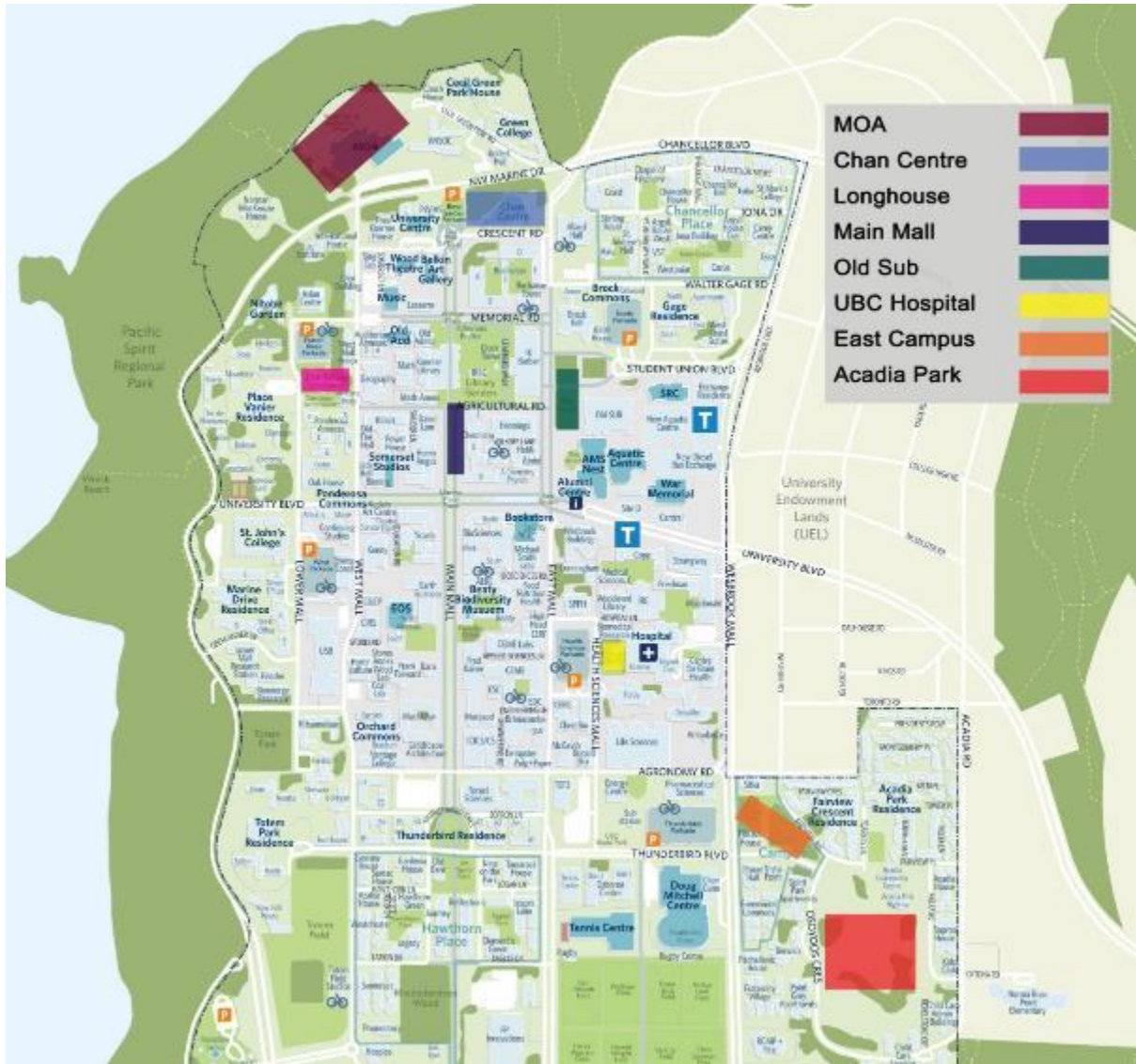
Figure 2. Survey locations for each of the habitat types at the University of British Columbia Vancouver Campus. Each symbol denotes a survey location in one of the habitat types including the Museum of Anthropology and the First Nations Longhouse are urban old field; Chan Centre and East Campus Park are coniferous forest; Acadia Park and UBC Hospital are mixed-wood forest; Main Mall and the Old Sub are urban park.
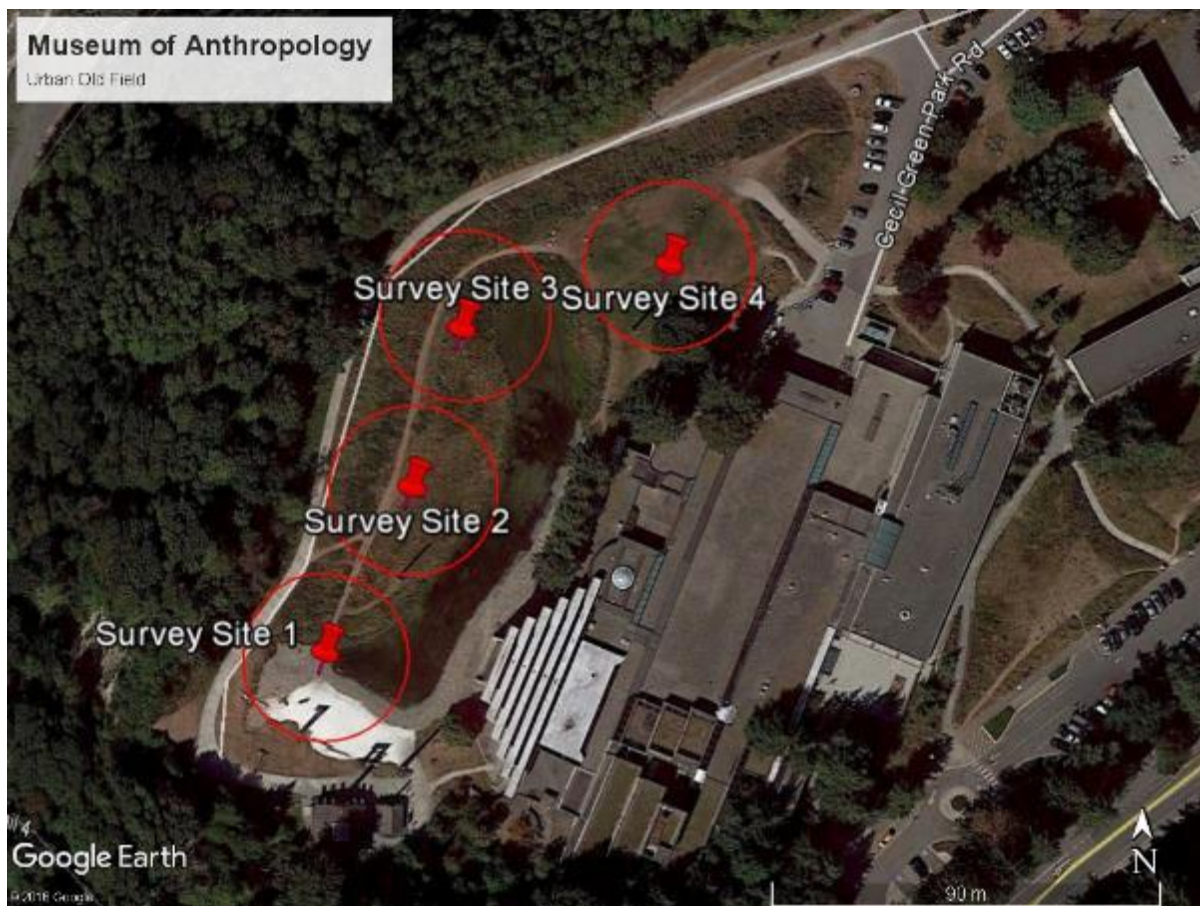
Figure 3. The Museum of Anthropology survey location of the urban old field habitat type was divided into four survey sites. Birds were sampled within a 20 meter radius from each survey site.

Figure 4. The First Nations Longhouse survey location of the urban old field habitat type was divided into three survey sites. Birds were sampled within a 10 meter radius around each survey site.

Figure 5. The Old Sub survey location of the urban park habitat type was divided into four survey sites. Birds were sampled within a 10 meter radius around each survey site.

Figure 6. The Main Mall survey location of the urban park habitat type was divided into four survey sites. Birds were sampled within a 10 meter radius around each survey site.

Figure 7. The Chan Centre survey location of the coniferous forest habitat type was divided into four survey sites. Birds were sampled within a 10 meter radius around each survey site.

Figure 8. The East Campus Park survey location of the coniferous forest habitat type was divided into four survey sites. Birds were sampled within a 10 meter radius around each survey site.

Figure 9. The UBC Hospital survey location of the mixed-wood habitat type was divided into three survey sites. Birds were sampled within a 10 meter radius around each survey site.
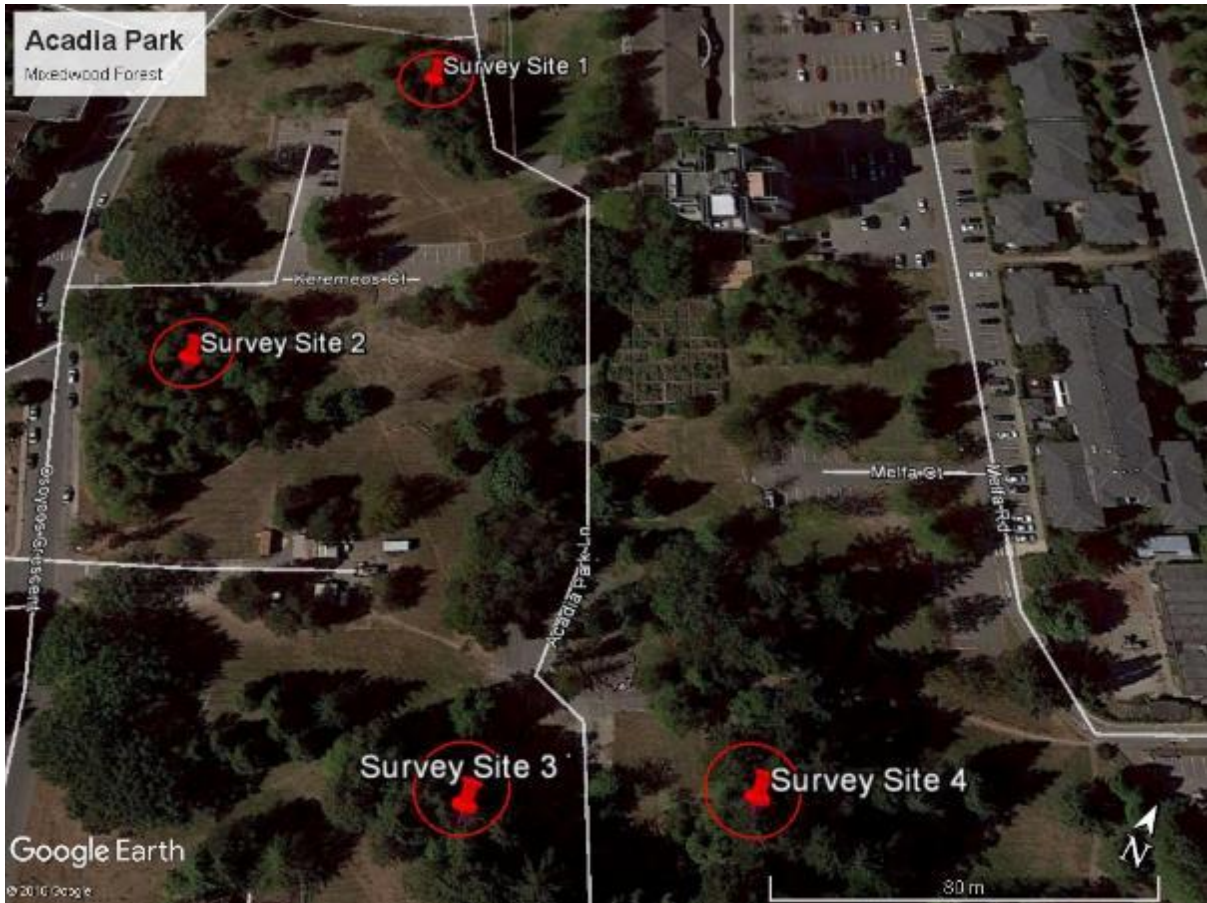
Figure 10. The Acadia Park survey location of the mixed-wood habitat type was divided into four survey sites. Birds were sampled within a 10 meter radius around each survey site.

RESULTS

Each survey location was surveyed a total of 8 to 10 times. After this number of surveys, the cumulative number of bird species seen at each survey site started to plateau, suggesting that the birds seen represented the total species present at the site. This trend is seen in the **Figure 11** accumulation graphs, demonstrating the drop off of new species sightings as the number of survey days increased. Based on the plateau and the knowledge that there would be an influx of spring species in mid-March that would skew our winter data and accumulation charts, it was decided by visual estimate that 8 survey days would provide a sufficient view of species presence for the winter months.
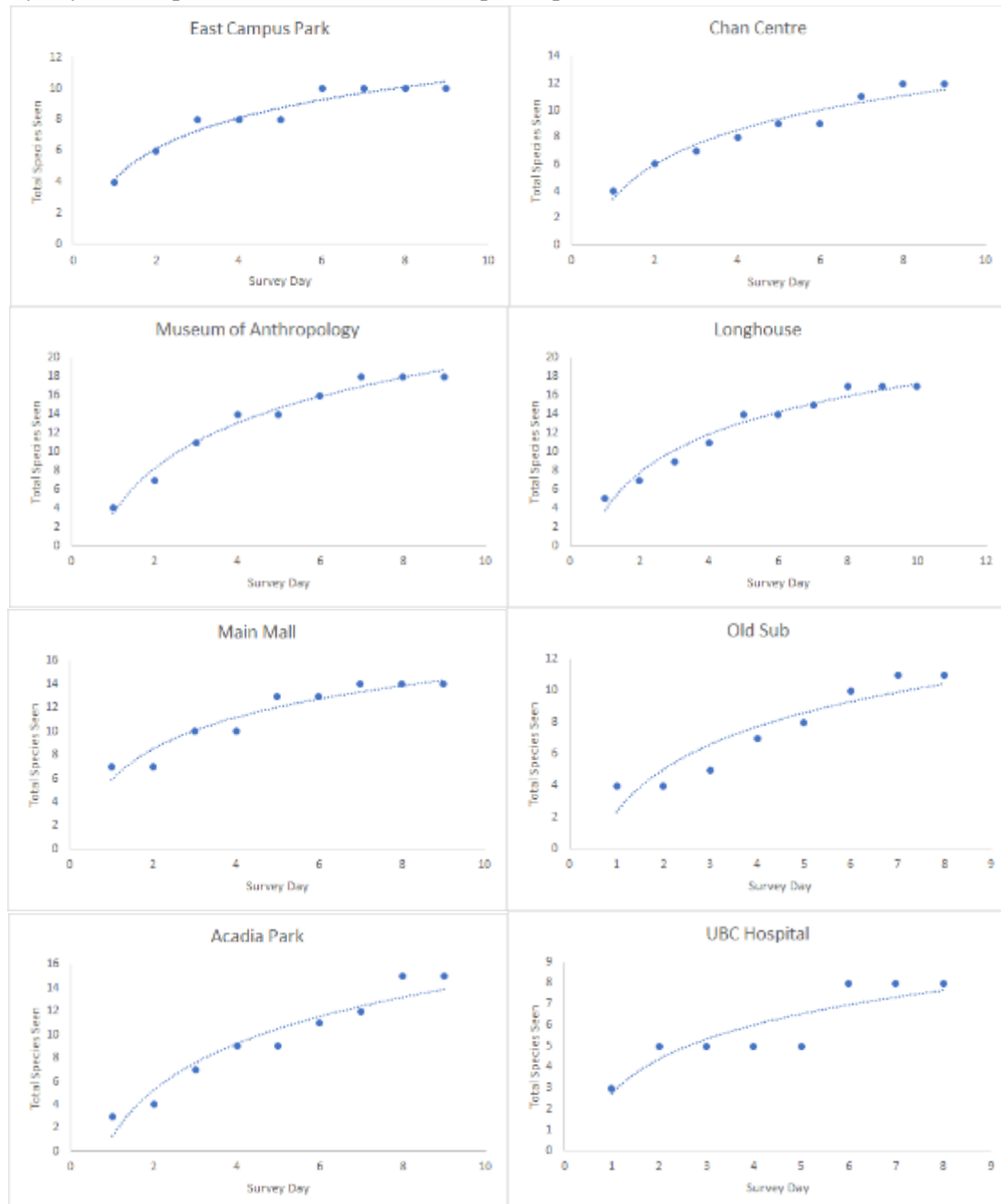

Figure 11. Accumulation curves for each survey site, showing the cumulative number of species seen at each survey site by survey day. The beginning of the plateau shows that the total number of species found in each area had been seen or was very close to the actual total number of species present.

A total of 29 species were seen at the 8 survey sites. The types of birds seen varied widely from understory to canopy birds, and small generalists to large raptors, and all birds were listed as least concern by the IUCN (International Union for Conservation of Nature). **Table 1** provides a list of species seen at each survey site, and a list of species with scientific names and conservation status can be found in the appendix. The number of species seen at a site ranged from 9 at the UBC Hospital to 19 at the Museum of Anthropology. The average number of species seen at a survey site was 12.875.

Species	East Campus Park	Chan Centre	Museum of Anthropology	Longhouse	Main Mall	Old Sub	Acadia Park	UBC Hospital
Canadian Goose				X	X			
Mallard			X					
Glaucous-winged Gull	X	X	X	X	X	X	X	X
Western Gull			X					
Rock Pigeon				X	X	X		
Bald Eagle	X		X			X		X
Cooper's Hawk			X					
Red-tailed Hawk			X					
Anna's Hummingbird			X	X	X		X	X
Red-breasted Sapsucker							X	X
Downy Woodpecker				X				
Northern Flicker		X	X				X	
Northwestern Crow	X	X	X	X	X	X	X	X
Common Raven			X		X			
Spotted Towhee			X	X	X		X	
Song Sparrow	X	X	X	X	X	X	X	X
Fox Sparrow		X	X	X			X	
Dark-eyed Junco	X		X	X	X	X		
Black-capped Chickadee	X	X	X	X	X	X	X	X
Chestnut-backed Chickadee							X	
Brown Creeper		X						
Red-breasted Nuthatch							X	
Pacific Wren	X	X	X	X			X	X
Golden-crowned Kinglet	X							X
Ruby-crowned Kinglet		X				X		
American Robin		X	X	X	X	X	X	
Varied Thrush	X	X	X	X	X		X	
European Starling					X			
Pine Siskin	X	X	X	X	X	X		

Table 1. Location at which species were seen on UBC Campus from January to March 2017. A total of 10 species were seen at East Campus Park, 12 at Chan Centre, 19 at the Museum of Anthropology, 15 at Longhouse, 14 at Main Mall, 10 at Old Sub, 14 at Acadia Park, and 9 at UBC Hospital.

Table 2 provides a list of species seen based on habitat type. There was less variability between the number of species seen by habitat types, with 22 seen at Urban Old Field and 15 at Coniferous Forest. The average number of species seen at each habitat type was 17.25.

Species	Coniferous Forest	Urban Old Field	Urban Park	Mixed Forest
Canadian Goose		X	X	
Mallard		X		
Glaucous-winged Gull	X	X	X	X
Western Gull		X		
Rock Pigeon		X	X	
Bald Eagle	X	X	X	X
Cooper's Hawk		X		
Red-tailed Hawk		X		
Anna's Hummingbird		X	X	X
Red-breasted Sapsucker				X
Downy Woodpecker		X		
Northern Flicker	X	X		X
Northwestern Crow	X	X	X	X
Common Raven		X	X	
Spotted Towhee		X	X	X
Song Sparrow	X	X	X	X
Fox Sparrow	X	X		X
Dark-eyed Junco	X	X	X	
Black-capped Chickadee	X	X	X	X
Chestnut-backed Chickadee				X
Brown Creeper	X			
Red-breasted Nuthatch				X
Pacific Wren	X	X		X
Golden-Crowned Kinglet	X			X
Ruby-crowned Kinglet	X		X	
American Robin	X	X	X	X
Varied Thrush	X	X	X	X
European Starling			X	
Pine Siskins	X	X	X	

Table 2. Habitat types in which species were seen on UBC Campus from January to March 2017. A total of 15 species were seen in coniferous forest, 22 species in urban old field, 16 species in urban park, and 16 species in mixed forest.

Bird species richness varied across the four distinct habitat types (Figure 14). Urban park, the habitat type of Old Sub and Main Mall survey locations had reportedly lower species richness at 10 and 13 species, respectively, compared to the urban old field habitat type of survey locations Museum of Anthropology and First Nations Longhouse at 19 and 15 species, respectively.
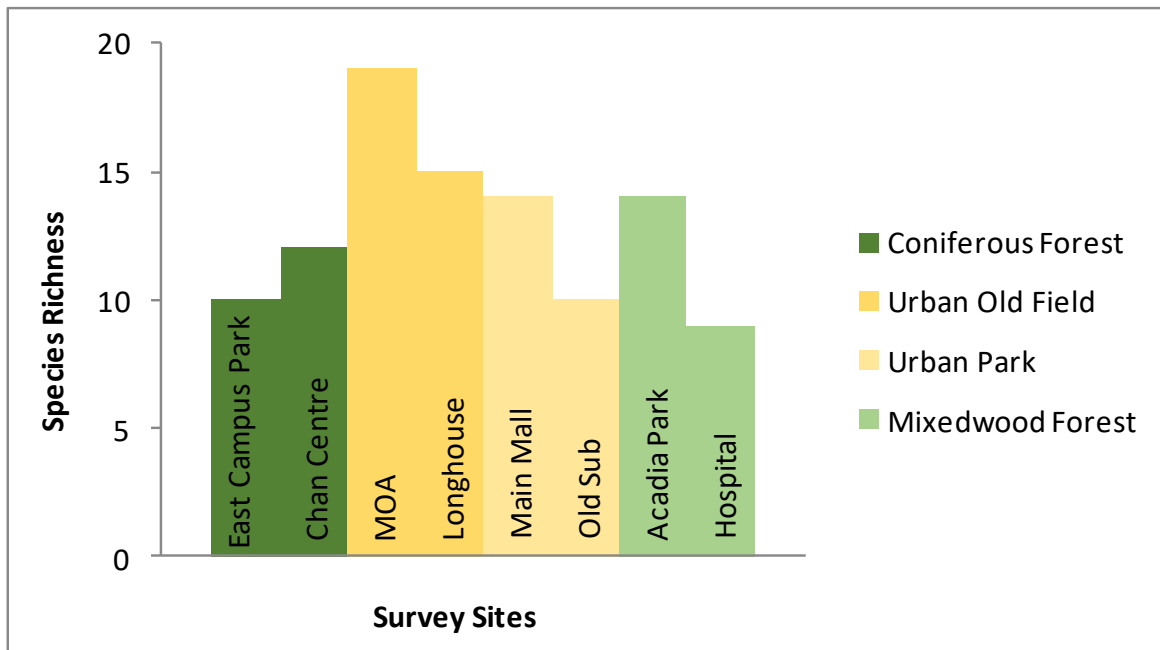

Figure 14. Species richness for each survey location and habitat type from January - March 2017. Species richness denotes the number of species seen over the course of sampling in a given location. The Museum of Anthropology has the highest species richness at 19 species.

To analyze species relationships with campus survey sites, we developed a cluster graph based on species frequency and survey location (Figure 12) or habitat type (Figure 13). The graph is intended to show which birds are seen together most frequently.
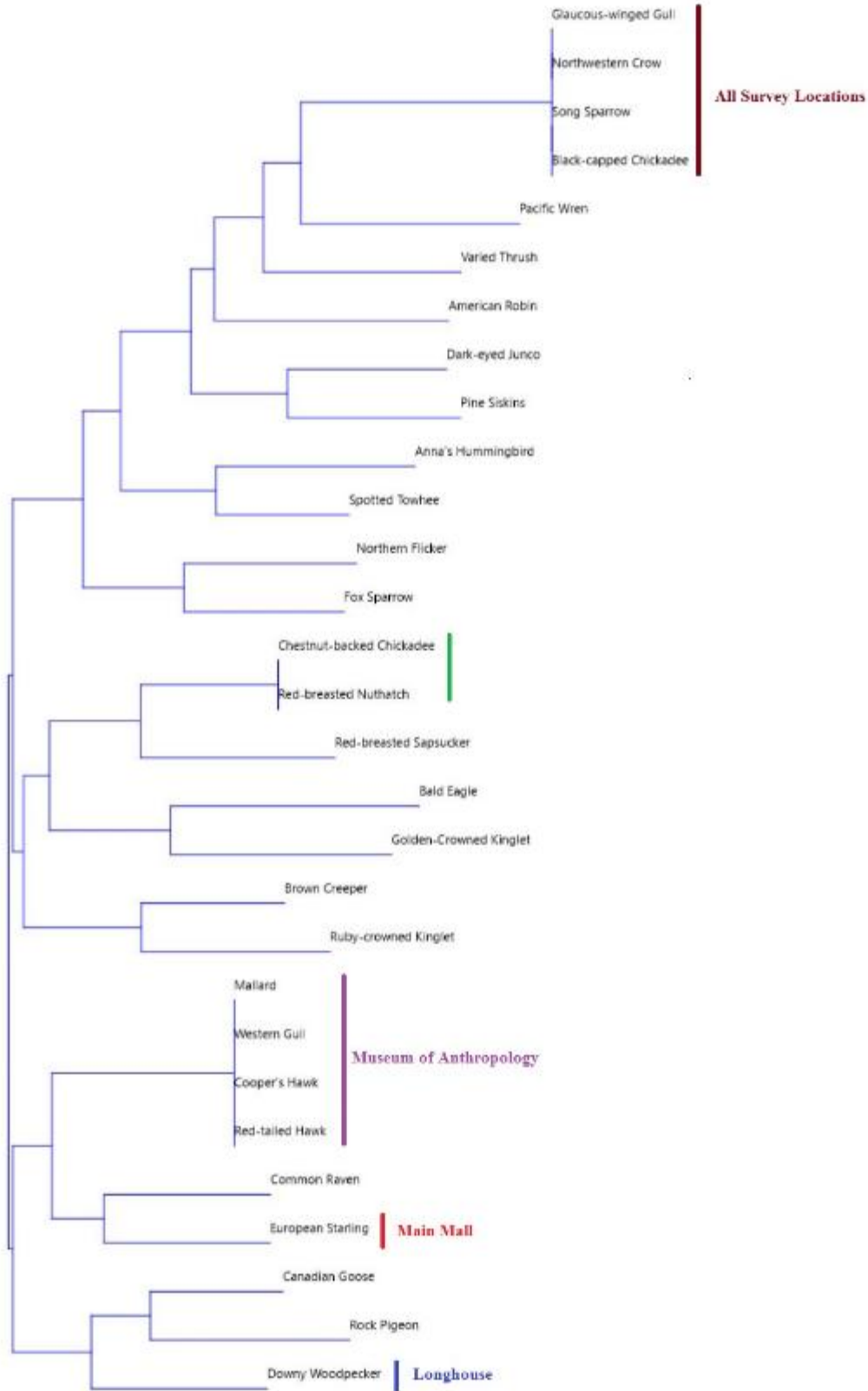
Figure 12. Cluster graph showing the relationship between species and the frequency at which they were seen at different survey locations. Species the farthest to the right are seen most frequently while species located to the left are seen least frequently. Node placement is dependent on if the species have been seen in the same survey location.
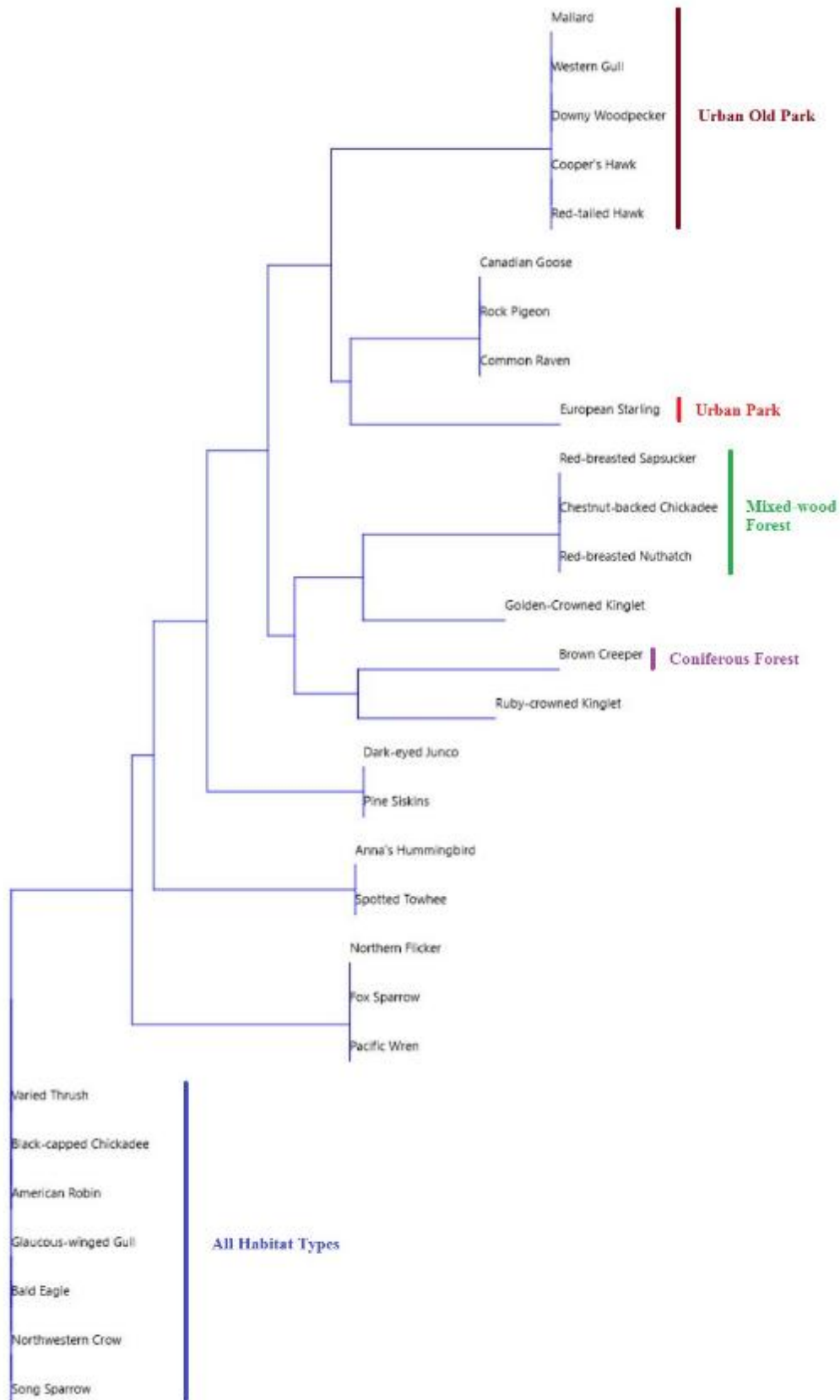
Figure 13. Cluster graph showing the relationship between species and the frequency at which they were seen in different habitat types. Node placement is dependent on if the species have been seen in the same survey site.

DISCUSSION

There are four bird species that were seen at every survey site: Glaucous-winged gulls, Northwestern crows, song sparrows, and black-capped chickadees. All of these species are known to easily adapt to human presence. Gulls and crows often use human resources to scavenge food and are large enough to avoid most predation. Song sparrows and chickadees are generalists who adapt well to a variety of situations and are too small for birds of prey to take interest in if in open areas (like urban parks or old urban fields). It is not surprising that they are so abundant on campus.

Birds tend to prefer areas that have varied cover and vegetation structure compared to uniform arrangements of trees with little understory vegetation (Melles *et al.* 2003) as observed at the Old Sub. The Museum of Anthropology had the highest species richness likely because of the habitat surrounding the field with a border of dense brackets and tall trees. Areas of refuge provide habitat for understory birds such as fox sparrow and dark-eyed junco. As well, varied vegetation types allow for foraging (Landcaster & Rees, 1979).

The cluster graphs serve as a good indicators as to which bird species tend to use the same areas or habitat types. For instance, the species that are seen in all survey areas or are found in all habitat types tend to be hardy generalists that are well adapted to use a variety of resources and withstand the pressures of urban development. Many of the raptors (Cooper's hawk, red-tailed hawk) are only seen at the Museum of Anthropology, the survey area closest to undeveloped land and an abundance of prey. While the other raptor on campus, the bald eagle, was seen in other places, the Museum of Anthropology was the only survey area where they came close enough to be identified without binoculars. Brown creepers were only seen in coniferous forest habitat types, as those are among the few places on campus that have the evergreen trees they use for foraging and nesting (Cornell Lab of Ornithology, 2009a).

Certain species were only seen at one survey site: downy woodpeckers, European starlings, and mallards. The lack of mallard presence on campus can be explained by the lack of natural standing water on campus. Most ducks prefer bodies of water that have a developed plant system with plenty of room to swim and no body of water on campus fits those needs. While they are fairly common in the region, we would not expect to see them on campus frequently. Woodpeckers are often hard to find as they utilize the trunks of trees and are often obscured from view. To only see them once during our survey period is not surprising.

During each sampling period, bird behavior was observed and recorded to aid bird identification. Behavioural traits may provide clues to a species identity (Dunn & Alderfer, 2008). From our survey data we identified various types of behavior including flying overhead, foraging, perching, calling, jumping from branches and bushes, and circling. Throughout sampling, not all birds were located by sight as some birds may hide their identity and only call from within the trees or bushes. When birds assemble or travel in flocks, they may keep in touch with a contact or flight call, which was observed during sampling. Various behavioural traits were observed for each species or particular bird. For example, song sparrows would hop (Cornell Lab of Ornithology, 2009b), brown creepers would often be hidden in the trees, hitching upward, and American robins would bounce up to perch on a branch. The mallard ducks seen in the pond at the Museum of Anthropology would tip up or dabble to reach submerged vegetation (Cornell Lab of Ornithology, 2009b). Flight behaviour was observed during sampling; in particular, small birds would have bouncy flight and flitter between

branches and bushes, or fly straight with a blur of little wings like the wrens and sparrows (Michael Price, personal communication, January 15, 2017). Comparatively, birds of prey such as hawks and eagles were often sighted from a distance soaring in circles or perched at the top of a tree observing the ground below them. To distinguish between common ravens and crows in flight, we found that the raven would soar and fly with infrequent wing beats, while the crow would flap quite methodically.

In an effort to determine how birds use habitats on campus, we observed their feeding and foraging styles. For example, sparrows and towhees would "chicken scratch" (Michael Price, personal communication, December 9, 2016) by looking for insects and seeds on the ground, while thrushes would hop low to the ground eating insects and fruit. Red-breasted sapsuckers are bark foragers (Walters *et al.*, 2002) that forages for insects by gleaning, probing, prying, tapping, and flycatching, and will drill a series of shallow holes into the bark of the tree. Urban adapters such as gulls and crows would often be seen feeding on garbage and food remnants left by humans often in the urban park habitats.

The reaction of birds to human presence was also noted in our surveys. Birds were seen at a higher frequency in areas that had minimal human movement. If a survey location had heavily used pathways through them, birds were primarily seen in the canopy and exhibited minimal foraging behaviour. If birds were utilizing the understory in a survey area, they would move to the canopy if people moved through the area. Birds typically have a flight response associated with the approach of humans, which can effectively degrade habitat quality for birds by interrupting breeding, foraging and nesting activities (Mayo and Paton, 2015). Our bird behaviour observations on campus have been consistent with this interpretation, suggesting that the constant movement of people through potential habitats on campus may be detrimental to bird populations on campus.

Figure 15. Heat map of species richness at all eight study sites around UBC campus: Museum of Anthropology, Chan Centre, Old Sub, Main Mall, Longhouse, UBC Hospital, East Campus Park, and Acadia Park. Blue edges represent relatively low species richness within each site, with gradually intense red color indicating high species richness. Bird species richness data is overlaid over a habitat type distribution of campus (Base map courtesy of Dyck, 2016).

Species richness for each survey location is shown in Figure 15 to visually contrast areas of high species richness (red) and low species richness (blue) overlaid on a campus map of habitat types. The data from each individual survey site, as shown in Figures 3-10, was compiled to show the species richness distribution within each survey location. The habitat type of urban old field had the highest species richness of the survey locations Museum of Anthropology and First Nations Longhouse as denoted by the red "hotspots" on the map. Survey sites of lower species richness such as Main Mall and Acadia Park are denoted by lighter colours on the map. Due to the varied areas and sizes of the survey locations, some locations may have a smaller area and thus more concentrated species richness on the map. This is seen in Main Mall where there may be a more uniform distribution of species richness between each survey site. This information provides a visual representation of location specific bird species richness, and can provide a proxy for other areas on campus of the same habitat types that we surveyed.

Figure 16. Bubble sizes proportional to the total number of species observed, represented as green bubbles, juxtaposed with bird-window collision strike frequencies, represented as pink bubbles. (Bird collision data courtesy of Cavers et al., 2015)

In general, the number of different species spatially correlates the number of bird window collisions (Figure 16). In zones of high species richness there are relatively high numbers of collisions. In addition, the large vegetation patches along the north cliffside of the Museum of Anthropology is a fairly significant habitat patch, which suggests there may be high aerial traffic near the Museum. There is a large, reflective wall of windows on the north side of the Museum. Windows are known to reflect their surroundings in ways that make them dangerous to birds, to which they become effectively invisible, leading to lethal bird collisions (Klem Jr., 2015). Corridors between buildings are also common collision sites as the birds have limited options for movement through them (Klem Jr., 2015). This trend is also seen at UBC in the relatively high bird collision sites at the Neville Scarfe Building and Biological Science Building in the center of campus. Both buildings had

11 reported bird collisions in 2015, some of the highest collision rates on campus. Furthermore, the Scarfe buildings east facing glass wall is well covered by trees with dense leaves and extensive branches, reducing the windows' visibility and further increasing vulnerability for bird collision. Short term preventative methods for these collisions include adding indicators to window panes in the form of retrofitting windows with external decals, tapes, strings, nettings, and/or external films across the entire panel of windows (Klem Jr., 2015).

Taking these points into consideration, we expect to see relatively high bird collisions within the zone surrounded by the Museum of Anthropology, Chan Centre, Main Mall, and Longhouse study sites. All of these areas have high species richness and a collection of windows. Buildings near each survey area have large arrays of windows with minimal signals to birds of their presence. As species richness generally correlates with spatial proximity to buildings characterized by many windows and low window visibility, we can reasonably expect high collision rates in these areas.

RECOMMENDATIONS

Based on our bird surveys across campus, we have identified the following recommendations to aid campus building and landscape planning in order to promote bird species richness. By avoiding habitat simplification and reduced habitat complexity through incorporating varied vegetation structure in the design of campus vegetation, bird species richness can be promoted. The connectivity between patches of habitat is important such that vulnerable bird species have the ability to move between areas in order to access resources such as fresh water, seeds, and insects. Installing bird friendly window designs such as small markers on windows will help reduce bird collisions, and reduce unnecessary bird mortality. A specific case study will address recommendations in order to create a bird friendly habitat in the new Library Garden.

Case Study: UBC Library Garden Project

Figure 17. Proposed area of the new UBC Library Garden Design project with the development of the Indian Residential School History and Dialogue Center to revitalize the garden area to develop sustainable landscapes.

UBC is in the process of redesigning the Library Garden located behind Irving K. Barber Learning Centre in conjunction with the development of the Indian Residential School History and Dialogue Center. To revitalize this space and promote sustainability on campus, the following recommendations may improve bird habitats in the garden. By increasing the vertical vegetation structure along with native berries and shrubs, there are more opportunities for foraging, breeding, and nesting for birds. Vegetation can be enhanced by incorporating ground cover, shrub, understory, and canopy layers (Landcaster and Rees, 1979). Tall trees, berry-producing shrubs, and sources of freshwater are particularly important to promote preferential habitat (Melles & Glenn, 2003). A dependable supply of fresh, clean water is attractive to most birds and can improve the quality of the habitat (Cornell Lab of Ornithology, 2004). If installing a water feature in the garden, it is important to ensure that the design has shallow edges for a gentle slope to allow birds to wade into the water (Cornell Lab of Ornithology, 2004). A shady location is preferential to provide cover and protection from predators. If the design of a new water feature is implemented in the garden, the feature will enhance the bird habitat and promote a quiet, reflective place for bird watching.

Social sustainability is a component of the three sustainability pillars (UBC Sustainability: Our Commitment, 2016). The location of the Library Garden is a prime place to promote education of birds and highlight their importance in the ecosystem. Figure 18 shows an example of an infographic poster that can be posted in the garden to promote education on bird identification of the common species in the area. In addition, bulletin boards could be installed around the garden educating the public on the life cycle and behavior of these specific native species, facilitated by bird-watching tips such as bird feeder spots, brief field guide in form of brochures, recommendation of bird identification apps, and ways to reduce noise.

Figure 18. Example of an infographic that can be posted as a sign in the garden to promote awareness of species that may inhabit the garden. The six species on the poster were sighted during our sampling period from January - March 2017. Pictures courtesy of the National Audubon Society.

	Species richness	Noise level (dB) (1 hour average)	Vegetation area (m³)
Old SUB	9	65	5,313
Main Mall	14	70	3392
Chan Centre	18	55	3614
FN Longhouse	13	60	1754

Figure 19. Outline of the Library Garden Space and its surrounding study sites in context of larger scale UBC campus. Areas and paths limiting and/or prohibiting bird movement are shown in red, while areas that facilitate movement are represented by green. The supporting table with additional information on each study area's richness, noise level, and area is included to show these variables. (Map created courtesy of Google Earth Pro).

Survey locations surrounding the garden included the Old Student Union Building, Main Mall, Chan Centre, and Longhouse. Certain corridors between our survey areas and the revitalized Library Garden may not be preferable for bird movement due to obstruction by buildings, high levels of human traffic, or large distances between habitats. Ideal habitat corridors for birds are indicated by the green corridors, while potential but not preferred habitat corridors are indicated by red corridors in Figure 19. Based on these restrictions, Main Mall and the Old Sub bird habitats are most likely to influence bird movement to and from the Library Garden.

Bird species found in the surrounding survey locations can be extrapolated to species that may inhabit the garden. One case of the effect of canopy layers on bird habitat can be seen through

comparing relative species richness of Old Sub compared to Chan Centre and Longhouse. Out of the four study sites, Old Sub has the highest vegetation area of 5313 meters^2, but with a low species richness of 10 (Fig. 19). One possible indicator of this contrasting trend may be the lack of vegetation heterogeneity both in terms of space and species diversity, as well as relative lack of canopy layers. The Old Sub is characterized by spatially homogeneous trees laid out systematically 10 meters by 10 meters. The whole site consists of a single tree species, leading to limited canopy cover. The lack of canopy is exacerbated in winter when the trees are bare. In contrast, Longhouse and Chan Center are characterized by dense above-ground canopy, high variety of vegetation species in a spatially heterogeneous layout and mix of low-canopy and high-canopy layers within a study area. This variability in vegetation is better for supporting bird populations (Landcaster and Rees, 1979).

A second factor that may explain the differences in species richness of survey areas may be noise levels. Old Sub is located in close proximity to the new bus loop construction site, which is a significant source of noise pollution. This area of noise is not preferable for birds as it can interfere with mating and social calls, potentially having a negative impact on their nesting species richness (Francis et al., 2009). Thus, this construction zone may act as a potential barrier for bird movement to and from the UBC Endowment Lands and Pacific Spirit Park. Similarly, the Main Mall site is directly exposed to constant noise at a level of 70 decibels from a high traffic of UBC students as they walk to and from class, with peaks of up to 75 decibels occurring every 50 minutes during the 10 minute breaks between classes on Monday, Wednesday, and Fridays (1-hour classes). Similar periodic peaks occur on Tuesdays and Thursdays every 80 minutes (1.5hr classes); with the same 10 minute break timeframe. This level of noise intensity could create short-term movement barriers for birds that do not tolerate high noise levels and it is likely that the Library Garden will also experience these peaks in sound intensity due to its close proximity to both locations.

Another boundary for bird movement is Irving K Barber Library itself (Fig. 16). This area is of significant concern since the western side of the building was observed to have relatively high frequency (9) of bird collisions (Fig. 14) and is the eastern barrier of the Library Garden project. The tall vegetation mirrored in the window reflection resulted in the highest number of bird window collisions per distance surveyed on campus (Porter and Huang, 2015). This suggests that in order to prevent an ecological trap as the birds move from the Old Sub to the Library Garden, it is essential to consider measures to enhance the visibility of these windows that are covered by the high canopy trees along the side of the library. There are already several ongoing research projects initiated by UBC SEEDS exploring innovative ways to address this issue. One relatively feasible and minimal-impact method to increase visibility of windows by installing visual markers with gaps at maximum 50mm wide and 100 mm high (UBC Sustainability, 2015). Specifically, these markers should be placed in critical zones: the areas of windows where there are highest bird collision concentrations. Currently, citizen science-oriented research is being carried out by a Biology 448 team to assess the effectiveness of placing dotted markers on windows of the Beaty Biodiversity Museum's south-facing wall.

CONCLUSION

Birds are an important part of any habitat and are heavily impacted by human activity. From January to March 2017, 29 bird species were seen in our 8 survey locations distributed around UBC Campus. Species richness in a survey area correlates with the type and distribution of vegetative cover, proximity to the borders of campus, human activity, and accessibility by habitat corridors. The survey area with the highest species richness was the Museum of Anthropology, with a cumulative 19

species seen. The survey area with the lowest species richness was UBC Hospital, with a cumulative 9 species seen. The habitat type with the highest species richness was Urban Old Field and the habitat type with the lowest species richness was Coniferous Forest with 15 cumulative species seen. In order to emphasize the protection and promotion of bird populations on campus, UBC Campus Planning and Landscape Operations should make efforts to avoid the disruption of bird movements between habitats by maintaining open corridors, installing bird collision prevention measures on windows throughout campus, increase the number of bodies of water on campus with shallow edges, and emphasize the planting of native flora in heterogeneous patterns. These recommendations should be brought into play in the development of the new UBC Library Garden project, as it provides the opportunity to create new habitat corridors and bird refuges in the northern portion of campus. If UBC is to be truly sustainable, campus planning decisions must be made to promote the health of bird populations in the area. Further monitoring of bird populations in other areas of campus is recommended, as well as a continual project to assess bird species richness during different times of the year such as spring/summer migration in order to assess nesting populations. Beyond birds, a full vertebrate survey to include mammals and amphibians is needed in order to assess the current biodiversity on campus in order to meet sustainability objectives.
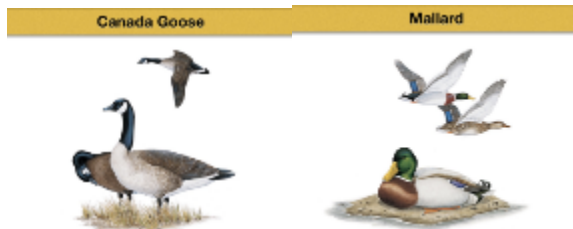
ACKNOWLEDGEMENTS

APPENDIX

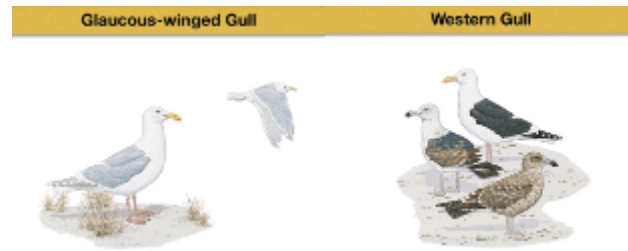**Bird species sighted from January - March 2017**
Non-Passerines

Ducks & Geese:

Canada goose, *Branta canadensis* IUCN status: least concern
Mallard Duck (female and male), *Anas platyrhynchos* IUCN status: least concern

Gulls:

Glaucous-winged gull, *Larus glaucescens* IUCN status: least concern
Western Gull, *Larus occidentalis* IUCN status: least concern

Pigeons:

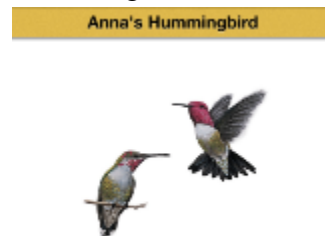Rock pigeon, *Columba livia* IUCN: least concern

Hawks & Eagles:

Bald Eagle, *Haliaeetus leucocephalus* IUCN: least concern
Cooper's Hawk, *Accipiter cooperii* IUCN: least concern
Red-tailed Hawk, *Buteo jamaicensis* IUCN: least concern

Hummingbirds:

Anna's Hummingbird, *Calypte anna* IUCN: least concern

Woodpeckers:

Red-breasted sapsucker, *Sphyrapicus ruber* IUCN: least concern
Downy Woodpecker, *Picoides pubescens* IUCN: least concern
Northern Flicker, *Colaptes auratus* IUCN: least concern

Passerines

Corvids:

Northwestern Crow, *Corvus caurinus* IUCN: least concern
Common Raven, *Corvus corax* IUCN: least concern

Towhees, Sparrows, and Juncos:

Spotted Towhee, *Pipilo maculatus* IUCN: least concern
Song sparrow, *Melospiza melodia* IUCN: least concern
Fox sparrow, *Passerella iliaca* IUCN: least concern
Dark-eyed Junco (Oregon), *Junco hyemalis* IUCN: least concern

Chickadees:

Black-capped chickadee, *Poecile atricapillus* IUCN: least concern
Chestnut-backed chickadee, *Poecile rufescens* IUCN: least concern

Creepers:

Brown creeper, *Certhia americana* IUCN: least concern

Nuthatches:

Red-breasted Nuthatch, *Sitta canadensis* IUCN: least concern

Wrens:

Pacific Wren, *Troglodytes pacificus* IUCN: least concern

Kinglets:

Golden-crowned Kinglet, *Regulus satrapa* IUCN: least concern
Ruby-crowned Kinglet, *Regulus calendula* IUCN: least concern

Thrushes:

American Robin, *Turdus migratorius* IUCN: least concern
Varied Thrush, *Ixoreus naevius* IUCN: least concern

Starlings:

European Starling, *Sturnus vulgaris* IUCN: least concern

Finches:

Pine Siskins, *Carduelis pinus* IUCN: least concern

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