BIODIVERSITY AUDIT OF VANCOUVER PARK BOARD GOLF COURSES

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August 2020

This report was produced as part of the Greenest City or Healthy City Scholars Program, a partnership between the City of Vancouver and the University of British Columbia, in support of the Greenest City Action Plan and the Healthy City Strategy.

This project was conducted under the mentorship of City staff.
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ACKNOWLEDGEMENT

The author would like to thank the following individuals for their contribution, feedback, and support throughout this project:

- Dana McDonald, Environmental Stewardship Coordinator, Vancouver Board of Parks and Recreation
- Karen Taylor, Program Manager, UBC Sustainability Initiative
- Tina Barisky, Planning Analyst, City of Vancouver
- Golf course managers and superintendents Jeff MacLean, John Cartlidge, Dennis Luick, and Pete Rodrigues and their staff
- Vancouver Board of Parks and Recreation Planning Policy and Environment Group

1. INTRODUCTION

Urbanized areas cover approximately 4% of the earth's surface (Niemela, 2011). Urbanization causes habitat loss and fragmentation with negative impacts for flora and fauna (McKinney, 2006), and increases levels of air, soil, and wetland pollution (Hamer & McDonnell, 2008), which makes urbanization, together with climate change, one of the biggest threats to biodiversity and ecosystems (McKinney, 2002). However, well-located and planned green spaces can minimize adverse effects of urbanization on biodiversity and the ecosystem. Also, considering the majority of the global population lives in urban areas, urban green spaces, including golf courses, are vital to experiencing nature for most people. According to Petrosillo (2019), who conducted a literature review of 239 publications (1981-2017) with reference to golf courses, most of the papers (32.6%) were about interactions between golf courses and wildlife target groups, including birds (34%), insects and earthworms (19.4%), amphibians (13.6%), mammals (11.7%), reptiles (9.7%), aquatic and terrestrial vegetation (4.9%), and fishes (2.9%). They also concluded that studies regarding impacts of golf courses on biodiversity have increased in recent decades (Petrosillo et al., 2019). The generalized results of those studies determined that since golf courses are considered as green spaces in urban areas, they have potentially positive effects on biodiversity conservation and ecosystem service provision (i.e., pest regulation, pollination, and seed dispersal) by providing the functional connectivity or bridge between different green spaces and wildlife refuge (Saarikivi et al., 2015; Ortuno et al., 2016; Petrosillo, 2019). Harmony with nature is an essential part of golf's heritage and, with proper management, golf courses can minimize impacts and even make positive contributions to ecology and biodiversity (John & Cheryll, 2004).

The Vancouver Park Board carried a motion directing staff to evaluate the full spectrum of realized and unrealized benefits of Park Board land currently used for golf; one of these benefits includes a contribution to the city's biodiversity. The Park Board's three golf courses – Fraserview, Langara and McCleery – as well as the Pitch and Putt courses at Queen Elizabeth Park, Stanley Park, and Rupert Park - represent about 20% of Vancouver's parkland. Experiencing nature for most people occurs in urban green spaces (Jarmo, 2016); considering this, golf courses that represent a large proportion of park space in Vancouver, serve as an opportunity to access nature for nearby communities Access to nature for Vancouver residents and visitors is a priority for the City of Vancouver (City of Vancouver, 2012) and the Vancouver Park Board (VanPlay, 2019).

The golf courses have been certified under the Audobon Cooperative Sanctuary Program for Golf, recognizing achievements in environmental planning, chemical use reduction, water quality management and other areas; however, the range and number of wildlife and vegetation species found in the golf courses have not been evaluated. This project aimed to establish and apply a method to evaluate the biodiversity of the Park Board's golf and pitch and putt courses and make recommendations for enhancing biodiversity on the golf courses. The results will contribute to the Golf Strategy to be initiated in 2020 and improve understanding of how these spaces contribute to biodiversity, climate change mitigation and access to nature for a growing population.

1.1 Definitions and benefits of biodiversity

Biological diversity includes all living organisms, including terrestrial and marine fauna and flora (United Nations, 1992). The Office of the Auditor General of Canada defines biodiversity as "the variability among living organisms from all sources that includes diversity within species, between species, and of ecosystems of which they are a part – the millions of animals, plants, and smaller organisms that live on the planet" (Bruce, 2013). Biodiversity-human interactions can be complicated and indirect, particularly in urban settings and, as such, the biodiversity-human impacts field of enquiry is still developing (Zari, 2018). Biodiversity supports life on Earth, including providing food, medicine, and supporting various industries (Eniscuola Energy and Environment, 2010). Just as humans impact biodiversity, so too does biodiversity loss have impacts on humans in terms of increased instances of climate change, decreased resilience to changes, and reduced quality and/or quantity of ecosystem services. As such, loss of urban biodiversity has notable impacts on human physical and psychological health, societal and cultural health, and economic health and stability (Figure 1).

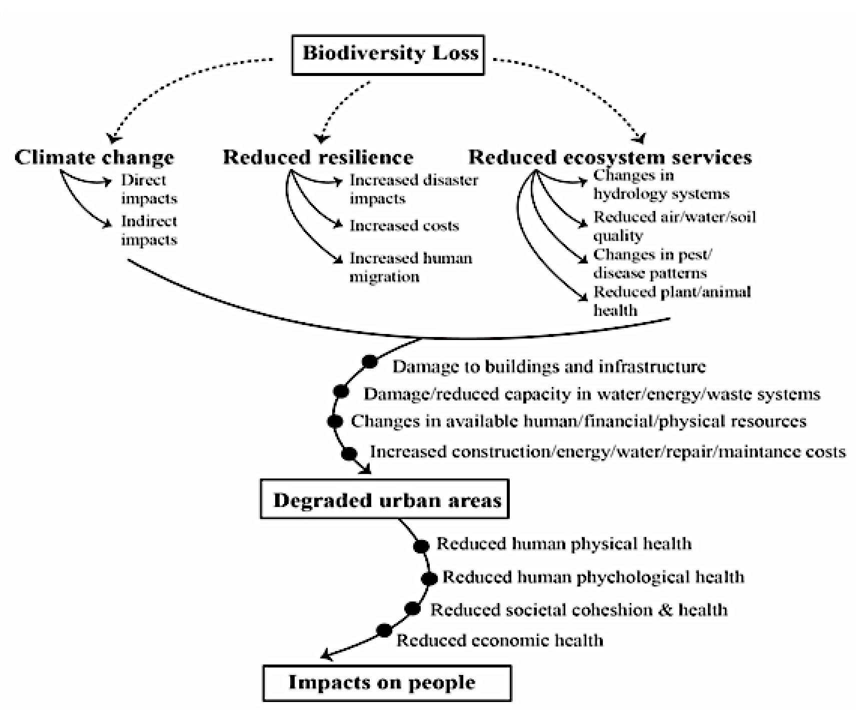

Figure 1. Schematic of relationship between impact on people and urban biodiversity loss (Pederson,2018)

1.2 Importance of golf courses on urban biodiversity

The amount, quality, and configuration of urban green spaces vary between urban areas and countries (Dobbs, Nitschke, & Kendal, 2014). However, there is a common criticism that there is insufficient green space for human needs and that the average size of urban green spaces is too small to foster sufficient biodiversity (Hepcan, 2013). In other words, most urban green spaces are relatively small and, in many regions, are bordered by developed land, limiting the movement of wildlife (Goddard et al., 2010). Also, urbanization causes habitat loss and habitat fragmentation for biodiversity (McKinney, 2006). But all impacts of urbanization should not be considered as negative (Niemela, 2011). One of the components in urban areas that alleviates impacts of urbanization on biodiversity is urban green spaces, which also positively influence human physical and mental health (Kondo, 2018). During recent decades golf courses in urban areas have been increasing around the world (Hammond & Hudson, 2007). There were 33,161 golf facilities and 80 million golfers in 208 countries in 2016 (R&A, 2017). By design, golf courses have several typical components, including ponds, streams, patches of tall grasses, wetland, native plants, wooded areas separating fairways, the tees, and putting greens as backgrounds and boundaries (Dobbs & Potter, 2015). Golf courses can cover landscape units up to 250 ha (Jone et al., 2005) with a typical 18-hole golf course averaging about 54 ha of land (Terman, 2000).

The results of many studies have shown that there are positive effects of golf courses on biodiversity. **First**, golf courses can potentially provide habitat and refuge for wildlife threatened by urbanization (Blair, 2001a; Fischer and Lindenmayer, 2002; Hodgkison et al., 2007) and support ecosystem processes extensively through giving a home to a diversity of species (Jarrett & Shackleton, 2017). **Second,** golf courses have far higher financial and human resources allocated to their management than do other public green spaces; there is consistent watering and planting of vegetation, best management practices in place for eutrophication in ponds, and pest control that can support wildlife habitat (Jarrett & Shackleton, 2017). **Third**, most golf courses have a large proportion (30–70%) of their land subject as out-of-play area with relatively minimal human activity, which reduces human disturbances on biodiversity (Tanner & Gange, 2005). **Fourth**, in most cases, golf courses operate for a long time, as long as more than 50 years, such that the age of a golf course can play an essential role in preserving wooded areas with old and large trees that support various wildlife, which can be protected by tree cover (Tanner and Gange, 2005; Vaz et al., 2011). **Fifth**, golf courses may act as crucial habitat for migratory birds needing a place to stop and refuel or spend the winter (Terman, 1997). **Sixth**, a golf course can promote ecological or functional connectivity between different habitats in an urban area, which can influence the survival of individuals and provide opportunities for gene flow between populations (LaPoint, 2015). Given the pressures to support a increasing populations in cities, urban golf courses are receiving increasing attention regarding their potential for multiple land uses in urban areas; these large areas of land are essential to biodiversity conservation and ecosystem services in urban settings.

2. METHODS

2.1 Study area and focus

This study covers the three golf courses managed by the Vancouver Park Board - McCleery, Fraserview, and Langara, as seen in Figure 2. These golf courses were studied to determine the presence of birds, mammals, amphibians, and reptiles. Additionally, a one-time bird survey was conducted at the Pitch and Putt courses at Queen Elizabeth Park, Stanley Park, and Rupert Park (Figure 2).

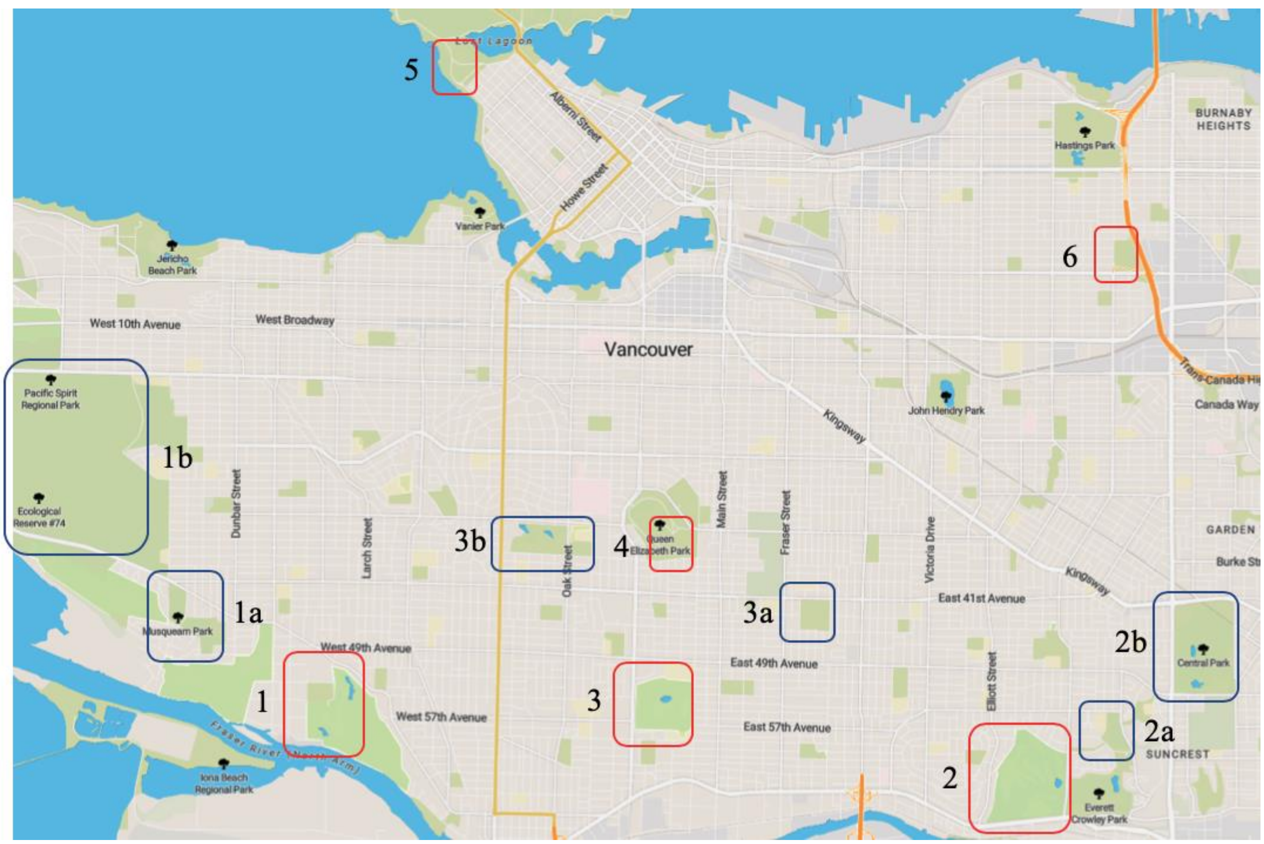

Figure 2. Map of the golf courses, pitch and putts (Vancouver OpenData Portal, 2020). Note: Red color – golf courses and pitch and putts where the study was conducted (1. McCleery golf course, 2. Fraserview golf course, 3. Langara golf course, 4. Queen Elizabeth park pitch and putts, 5. Stanley park pitch and putts, and 6. Rupert park pitch and putts). Blue color- Other nearby green spaces. (1a. Musqueam park, 1b. Pacific Spirit part, 2a. Captain Cook park, 2b. Central Park, 3a. Memorial South Park, 3b VanDusen garden)

McCleery golf course has 15 ponds covering 2.01 hectares and 9.5 hectares of wooded area out of 49 hectares of the golf course as shown in Table 1. Fraserview golf course has a total of 77 hectares, 44.4 hectares of a wooded area, and 0.5 hectares of a pond; this course has relatively more wooded area

(57.3%) than the other courses. Langara golf course has approximately 48 hectares of area, 12.5 hectares of a patchy wooded area, and 0.7 hectares of pond. All golf courses have grassy areas which can be described as open (e.g., greens, fairways and some rough areas) and wooded areas (e.g., deciduous or coniferous or combined canopy cover).

	Study sites	Size of area	Size of wooded area	Size of pond	Number of ponds
1	McCleery golf course	49.0	9.46 (19.3%)	**2.01 (4.1%)**	15
2	Fraserview golf course	77.5	**44.43 (57.3%)**	0.54 (0.7%)	1
3	Langara golf course	45.8	12.48 (27.2%)	0.72 (1.6%)	2
4	Queen Elizabeth park pitch and putts	7.3	-	-	-
5	Stanley park pitch and putts	5.3	-	-	-
6	Rupert park pitch and putts	4.7	-	0.04 (0.8%)	2
	Total				

Table 1. *Comparison between golf courses and pitch and putts: Natural components (by hectares and percentage)*

2.2 Field methodologies for data collection

A field methodology for biodiversity data collection was developed based on techniques applied at other golf courses and similar landscapes. A different field method for each vertebrate class (e.g., bird, mammal, amphibians and reptile) was applied to best capture activities based on landscape, time and budget conditions. Data collection was conducted on foot without golf carts in order to minimize disturbance to wildlife at the golf course.

It is important to note that the study did not investigate microorganisms, fish, invertebrates, bats or vegetation. The study of these animals and plants needs extra personnel and financial resources; thus, they were excluded from the scope of this project. Ultimately, their study would be valuable for a complete picture of biodiversity.

2.2.1 Bird survey

Surveys were conducted on days without rainfall between 05:30 and 10:00 PT to observe birds when they were most active. Bird surveys were performed using the point transect method on three different days at 16 different points at a 5-min interval on each golf course between 19th May 2020 and 08th June 2020 (Hodgkison, 2007). The centre point of each transect is in yellow pins in Figures 3, 4 and 5. Should this survey be repeated in subsequent years, GPS coordinates of all transect points can be found in Appendix 1. Birds were only recorded if they were seen utilizing the sites, i.e., perching, feeding or nesting. The researcher did not record birds by their song alone due to limited ability to identify the species by their sound only. A one-day bird observation was conducted on the Pitch and Putt courses using the same methodology as the multi-day observations on the full courses.

Figure 3. Locations of the surveys at McCleery golf course. Note: Survey locations are pinned by different color. Yellow- point transect method for bird survey. Red- camera trap method for mammals.

Figure 4. Locations of the surveys at Fraserview golf course. Note: Survey locations are pinned by different color. Yellow- point transect method for bird survey. Red- camera trap method for mammals

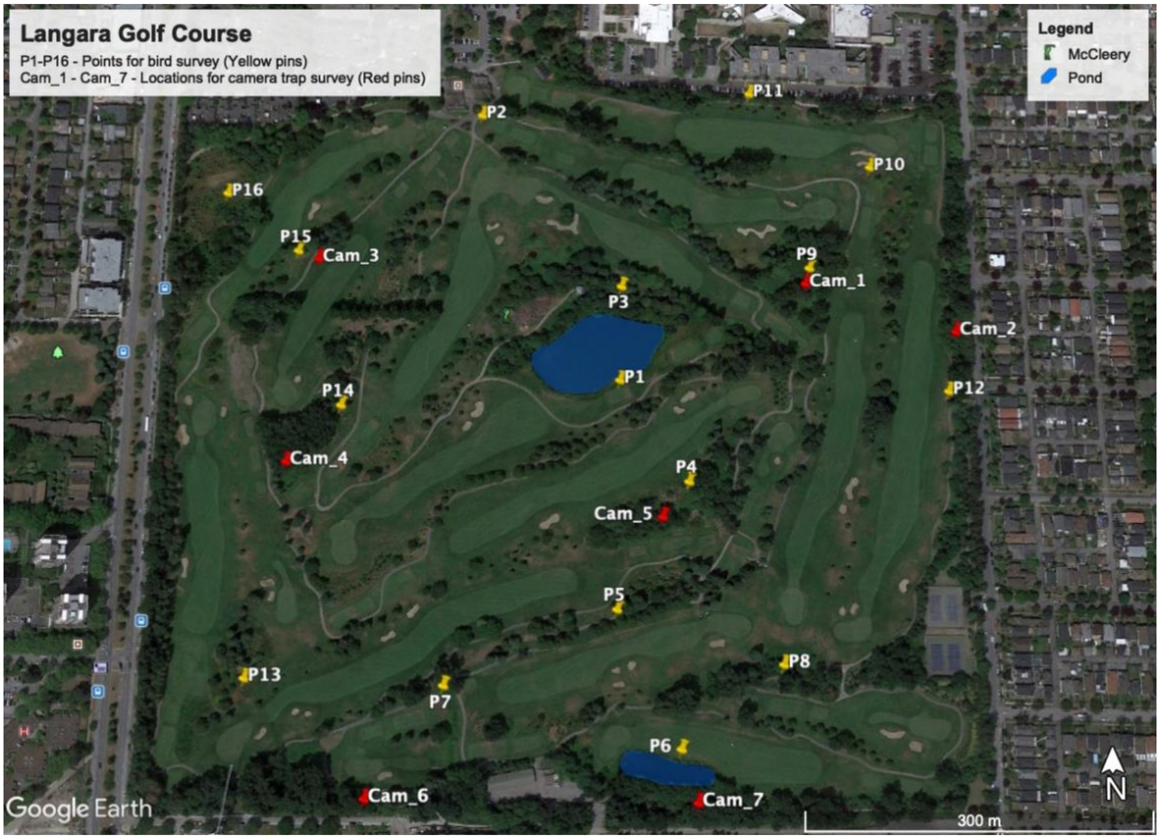

Figure 5. Locations of the surveys at the Langara golf course. Note: Survey locations are pinned by different color. Yellow- point transect method for bird survey. Red- camera trap method for mammals

2.2.2 Mammal survey

Seven camera traps were installed on each golf course between 19th June 2020 and 27th June 2020 at locations shown in Figures 3, 4 and 5 to collect data on mammals. Camera traps were mounted on trees at the height of 0.4-0.6 m above the ground. The primary detection area was approximately 4-12 m^2. Motion-triggered camera traps were active for 24 hours per day, with motion sensors set to trigger immediately when movement was detected (Figure 6).

The researcher used various camera trap brands, including APEMAN, DIYARTS, and ZOPU. The cameras were programmed to take three photographs per activation. The cameras at the 21 locations on three golf courses were functional for a total of 63 camera days. The GPS coordinates of each camera trap can be found in Appendix 2. For illustration purposes, some of the camera trap locations are shown in Figure 6.

A. Langara golf course

B. Fraserview golf course

C. Fraserview golf course

D. McCleery golf course

Figure 6. Illustration of camera traps placed at different golf courses. Note: A. Camera trap at Langara golf course, B and C. Camera traps at Fraserview golf course, D. Camera traps at McCleery golf course.

2.2.3 Amphibians and reptiles

At each golf course, areas with high potential detectability for amphibians and reptiles were identified, including ponds and their surroundings and wooded areas and were the focus of the survey. Each of the golf courses was observed for one 25-min session using active search techniques (i.e., scan searching, visual encounter survey), including overturning rocks and logs, searching vertical substrates, and raking soil and leaf litter (Halliday, 2006). The survey was conducted between 11th June 2020 and 14th June 2020. Searches were conducted using a flashlight between the dusk/nightfall hours of 20:00 and 22:00 PT as this is when most species are most active.

2.3 Suggested modifications to methods for future studies

Due to time constraints, the methodology applied in this study was abbreviated and could be improved upon with the following changes:

Bird surveys: Subsequent surveys should include observations throughout the year to capture populations using the golf courses in different seasons. All courses and recorded points should be surveyed birds for six sessions, two in the summer, one in the autumn, one in the winter, and two in the springtime with three days of observation in each season using the point transect survey method. Also, further research should include more researchers such that one person can observe continuously while a second takes notes to reduce research bias and missing observations. It will also increase the likelihood of taking pictures of birds as additional means of species identification. Each observation should include the species of bird and their sex where possible.

Mammal surveys: Rovero (2013) reviewed literature on 692 camera trapping studies and concluded that ideal the camera trap survey would involve changing the locations of the cameras every 15 to 30 days when using fewer than 30 camera traps. These studies have reported approximately 15-250 camera days or trap nights per camera trap for studies about urban mammals (Ordeñana et al., 2010; Kays & Parsons, 2014; Ehlers et al., 2017; Mella-Mendez et al. 2019). This suggests that camera trap studies on the golf courses should be conducted with increased camera trap days; for example, using the 7 camera traps in this study, the camera trap survey should be conducted over 20 to 30 days for a total of 140-210 camera days.

In addition to the camera traps that are effective at capturing medium and large mammals, a subsequent survey should use live traps for small mammals. Live traps, including Longworth, Sherman, and wire-mesh traps, are most commonly used to assess the abundance of small mammals. Typically, a small mammal survey uses a 10m by 10m trapping grid (Sutherland, 2006), and baits the trap using a variety of foods (e.g., a mixture of oats and peanut butter). Traps should be monitored two times per day in the early morning and evening (Sutherland, 2006). In Vancouver, permits to trap live animals must be obtained in advance of the field study from the Provincial Ministry of Environment.

Amphibian and reptile: To improve the results of the amphibian and reptile survey, opportunities to observe should be increased by conducting 25-min active search technique or visual encounter surveys during three sessions per golf courses over three days. The searches should take place intensively in specific habitats (e.g., logs, bushes, ponds, etc.) and capture the animals by hand to make an identification. Appropriate permits should be obtained for this survey.

A further improvement could be made by using the netting or sweep sampling method to catch frogs and toads in ponds (Halliday, 2006). This method is more suitable for sampling herpetofauna in small aquatic habitats, such as ponds in golf courses, as well as being simple, and inexpensive. A water body is sampled by means of dip nets or seine nets with the aim of catching as many animals as possible for identification and estimation of the population density. Every effort should be made to net all parts of the water body equally thoroughly. Netting methods must be performed carefully, ensuring to avoid falling into ponds and damaging aquatic vegetation, which may provide cover and spawn sites for amphibians (Halliday, 2006).

A subsequent survey for amphibians and reptiles in the terrestrial landscape should, use artificial cover or coverboards made from plywood sized 1.5 m x 2-3 m. One hectare of specific patch habitats (e.g. surrounding area of ponds, wooded area, bushes, etc.) needs 3-8 plywood coverboards (Kjoss & Litvaitis, 2001). The survey should consist of 6 observations between July and September, with one observation every two weeks. Each plywood cover should be checked 6 times per session: 3 times during morning hours between sunrise and 9:00 am and 3 times in evening between 16:00 and sunset. Coverboard checks involve will lifting up one half of the board at a time and collecting all species found underneath by hand to identify species and measurement. Coverboards should be observed by 2 researchers: one lifts up the other collects samples as species are found (Kjoss & Litvaitis, 2001).

Invertebrate – insects: Invertebrates have important functional roles as herbivores, pollinators and as food for a variety of birds (Samways, 2007). The presence of specific species and their abundance in urban green spaces indicates that urban green spaces have healthy ecological networks and ecological functions, such as pollination and a healthy food web (Mata et al., 2017). For instance, urban insects support urban birds because insect is supplementary food for many bird species (British Ecological Society, 2020). Bumblebees and butterflies (Papilionoidae and Hesperiidae) as pollinators can be effective for evaluating insect populations (Blair, 2001b; Carvell, 2002; Tanner & Gange, 2005). As well, carabid beetles can be indicator species on golf courses and useful for comparing golf courses with other urban green spaces (Tanner & Gange, 2005; Colding & Folke, 2009; Saarikivi et al., 2015) because carabid beetles are sensitive to environmental changes and relative easy to collect using simple pitfall traps making long-term data collection possible (Kotze et al., 2011). To evaluate insect populations on the golf courses, subsequent studies should use the following two popular methods:

1. Ground insects (e.g., carabid beetles) can be collected using pitfall traps which are sunk into the ground with their openings at the soil surface. Traps are placed evenly spaced along 5 meter transects. The traps are partly filled with a 70 percent aqueous propylene-glycol solution (25-30 ml per trap) to kill and preserve the trapped insects. Pitfall traps are the most frequently applied and effective traps for catching ground beetles (Southwood and Henderson, 2000).

2. The line transect method is the most frequently used method for pollinator (e.g., bees and butterflies) counting (Walther-Hellwig & Frankl, 2000). The survey should be conducted between 12:00 pm and 3 pm along four 100-meter line transects 15 times over one month in summer, at locations randomly placed on each site using aerial maps like Google Earth. Observations should only be recorded on clear bright days, with low level of wind, when a variety of native and other flowers are in bloom.

3. RESULTS

3.1 Birds

According to the BC Conservation Status (Harper, 1994), each species and ecosystem is ranked and assigned by different colour lists: red, blue or yellow. These lists help set conservation priorities and provide an overview of BC's species and ecosystems. For example, any species or ecosystem that is at risk of being lost (extirpated, endangered, or threatened) are on the red list; any species or ecosystem that is of particular concern are in the blue list, and any species or ecosystem that is at the least risk of being lost are in the yellow list. Ninety bird species were identified at the six golf courses, with the species and locations listed in Appendix 3. Six blue listed bird species (Barn swallow, Caspian tern, Double-crested cormorant, Great blue heron, Green Heron, and Olive-sided flycatcher) were identified across all golf courses (Figure 7). The exotic species observed were European starling, House sparrow, and Rock pigeon across all golf courses.

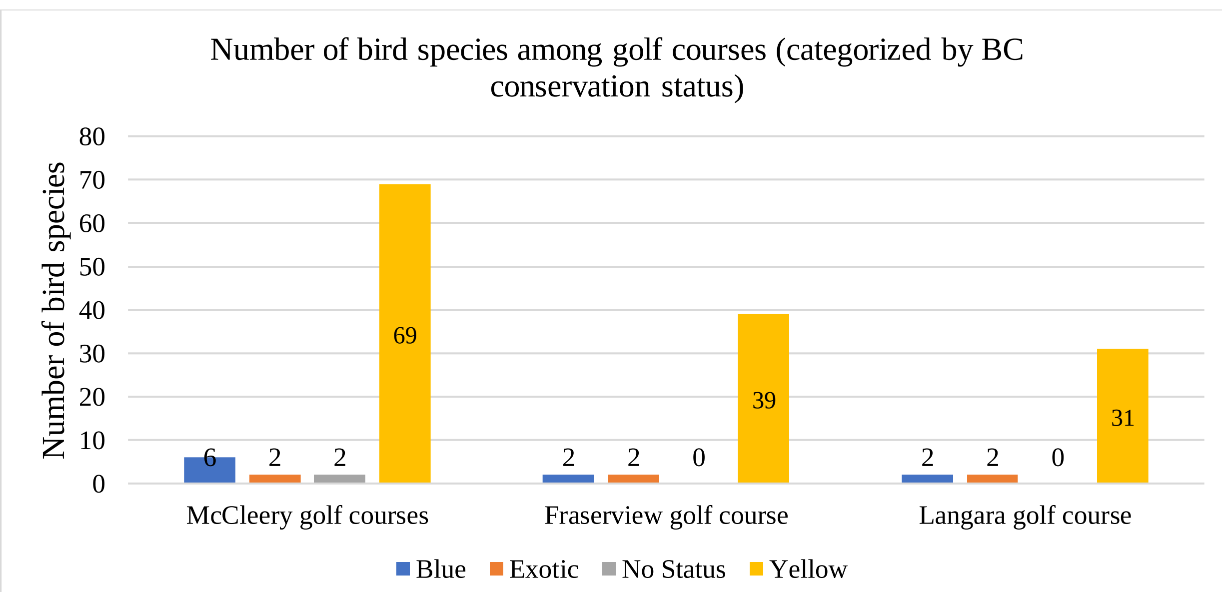

Figure 7. The number of bird species among the golf courses. Note: Any species or ecosystem that is at risk of being lost (extirpated, endangered, or threatened) are in the red list; any species or ecosystem that is of particular concern are in the blue list, and any species or ecosystem that is at the least risk of being lost are in the yellow list

Golf courses	Number of bird species	Course area (hectares)	Pond size (hectares)	Size of wooded area (hectares)
McCleery	79	47	2.01	9.46
Fraserview	47	77	0.54	44.43
Langara	35	48	0.72	12.48

Table 2. Detailed information on bird species and its habitat

The field survey was augmented by year-around data from the eBird data portal to offer comparisons between bird diversity in golf courses and nearby green spaces because this survey observed bird diversity for only a short time from the end of May to the beginning of July. According to data from eBird, which is the world's largest bird-related database with more than 100 million bird sightings contributed each year by eBirders around the world (eBird, 2020), more species have been observed in McCleery golf course than in nearby large natural areas, including Musqueam Park and Pacific Spirit Park (Figure 8). Moreover, the Fraserview golf course supported a considerably higher number of bird species than nearby green spaces, such as Central Park and Captain Cook Park (Figure 9). The same is true at Langara golf course, the number of bird species in the Langara golf course was higher than that of nearby green spaces, including VanDusen garden and Memorial South Park (Figure 10). However, the comparable number at VanDusen and its controlled number of visitors relative to parks without ticketed entrance suggest that it might share some characteristics with golf courses related to limited human disturbance. Overall, golf courses supported a greater number of bird species compared to nearby green spaces. The results obtained from a one-day bird observation in pitch and putts courses are presented in Figure 11. There were 26 bird species in Queen Elizabeth park pitch and putts course, 20 bird species in Stanley park pitch and putts course, and 18 bird species in Rupert park pitch and putts course as seen in Appendix 3.

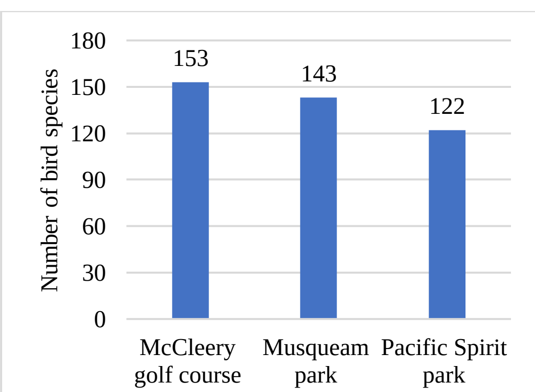

Figure 8. Comparison between the number of bird species found in the McCleery golf course and other near green spaces. (Year-around, All years). Source: www.eBird.org

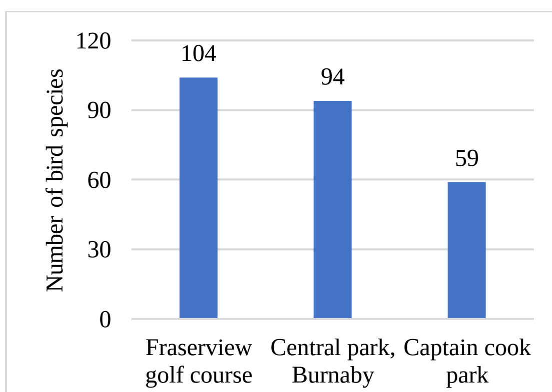

Figure 9. Comparison between the number of bird species in the Fraserview golf course and other near green spaces. (Year-around, All years). Source: www.eBird.org

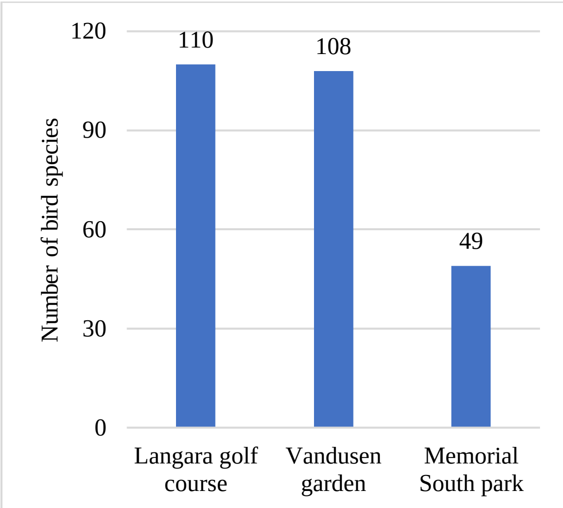

Figure 10. Comparison between the number of bird species found in the Langara golf course and other near green spaces. (Year-around, All years). Source: www.eBird.org

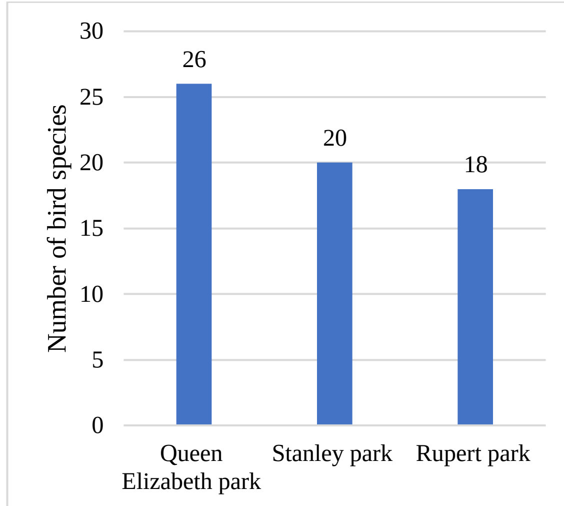

Figure 11. Total number of bird species observed at the pitch and putts.

3.2 Mammals

The survey identified five mammal species across the three golf courses from a total of 63 camera days (Table 3). Seven camera traps captured 185 individuals of five species in total including beaver (*Castor canadensis*) (McCleery only, Figure 3), eastern squirrel (*Sciurus carolinensis*), black rat (*Rattus rattus*), coyotes (*Canis latrans*), and the raccoon (*Procyon lotor*). For illustration purposes, images of five mammal species identified in the survey are shown in Appendix 4.

Species	**Number of photos taken by camera trap**		
	McCleery	**Fraserview**	**Langara**
Beaver (*Castor canadensis*)	3	0	0
Eastern squirrel (*Sciurus carolinensis*)	0	43	2
Black rat (*Rattus rattus*)	0	0	122
Coyotes (*Canis latrans*)	0	12	0
Raccoon (*Procyon lotor*)	0	3	0

Table 3. Detailed information on mammals at the golf courses.

3.3 Amphibians and reptiles

Anuran's (frog or toad) male calls were heard at only one location at the McCleery golf courses (Figure 12) and the species was not identifiable. No salamanders were observed at any of the golf courses. The survey did not detect any individuals from seven species of reptiles that could exist in Vancouver (Worcester et al., 2010).

Figure 12. Location of anurans at the McCleery golf course.

4. DISCUSSION AND CONCLUSIONS

Urban green spaces have significant potential to support urban biodiversity and biodiversity conservation (Shwartz et al., 2014). Notably, golf courses play a vital role in conserving urban biodiversity in several ways, including providing refuge for wildlife as a result of less human disturbance and preserved large old trees, a place to stop and refuel for migratory birds, and potential to provide ecological or functional connectivity among green spaces in an urban area. This field study used birds, mammals, amphibians, and reptiles on Vancouver Park Board golf courses to evaluate the current status of biodiversity in spring and summer 2020.

4.1 Birds

The results indicate that the golf courses provided a habitat for 90 species of birds from nine days of observations from this study and 153 species (year-around) of birds from the eBird data portal. This finding is consistent with past studies' findings that golf courses can provide suitable habitats for many bird species (Smith & Conway 2005, Cristol & Rodewald 2005, Cornell et al. 2011) including, in the case of Vancouver Park Board golf courses, six blue listed bird species of concern in BC. Blue listed species are considered to be of conservation concern because they have a limited distribution or low abundance in the province and have shown provincial declines or are perceived to have long-term threats to their populations (Vennesland et al., 2002). This finding corroborates the ideas of Cristol and Rodewald (2005), who suggest that "golf courses may provide supplementary resources like specific habitat components to some declining habitat specialists." Interestingly, it is apparent from eBird data that more species have been observed on Vancouver park board golf courses than in nearby large natural areas (Figure 3-5). In other words, this study confirms (Green 1984; Merola-Zwartjes & DeLong 2005; Colding & Folke, 2009) previous studies' suggestions that golf courses can have greater ecological value for birds than surrounding green spaces. As well, the survey found that golf courses with a greater cumulative pond area supported the highest numbers of bird species. A possible explanation to support this finding is that that greater landscape heterogeneity, which refers to variety among land covers including wooded areas, ponds, wetlands, greenways, rocks, etc., can support a greater diversity of bird species (Hodgkison et al., 2007).

4.2 Mammal

This survey results indicate that there are five mammal species among all three golf courses (Table 3). The mammals captured by the camera trap survey represent 20% of mammals that potentially exist in the City of Vancouver (Page, 2012) suggesting that the golf courses do not provide suitable habitat for all of these mammals or that the methodology must be modified to capture the full range of mammals using the courses. With respect to methodology, it is likely the limited number of camera days and unavailability of live traps limited observation of some mammals. Recent studies have reported that the number of camera days was approximately 15-250 camera days or trap nights per camera trap for studies about urban mammals (Ordeñana et al., 2010; Kays & Parsons, 2014; Ehlers et al., 2017; Mella-Mendez et al. 2019). This survey had only three camera days or trap nights per camera trap, 63 camera days in total. However, the camera trap survey did capture beaver (Castor canadensis) (McCleery only, Figure 3), eastern squirrel (Sciurus carolinensis), black rat (Rattus rattus), coyotes (Canis latrans), and the raccoon (Procyon lotor). Pierce (2016) found that there were up to 3 beavers in the McCleery golf course (Pierce, 2016). Beavers help to create the most biologically productive wetlands and support a variety of wildlife. They also improve water quality, stabilize the water table, and maintain stream flows during droughts in streams (Callahan & Perryman, 2018). Beavers provide watering holes for wildlife needs, encourage essential breeding areas for amphibians and fishes, and provide essential edge and vegetation openings for other wildlife (Zero & Murphy, 2016).

4.3 Amphibians and reptiles

This survey found amphibians in one pond at the McCleery golf course, which included an approximately 100m long section of vegetated stream landscape. The results of the field surveys at the golf courses agrees with a previous study Worcester (2010), which showed that only one reptile species (red-eared slider) was found in Stanley Park while other reptiles have not been seen for many years in Stanley park, one of the other most intact habitats in the city (Worcester et al., 2010). It is difficult to explain the limited presence of amphibians and reptiles; however, it might be related to limited mobility of amphibians (Ficetola & DeBernardi, 2004), and vulnerability of amphibians and reptiles to the isolating effects of habitat fragmentation (Furman et al., 2016), which may negatively affect the capacity of amphibians and reptiles to colonize or re-colonize habitats.

5. RECOMMENDATIONS

5.1 Connectivity or green corridor

The movement of individual species in urban green spaces influences the annual migration, daily foraging activities, survival of individuals and the transfer of genes, conclusively affecting population dynamic, the distribution of species (Stephens et al., 2007; Cushman & Lewis, 2010; Jeltsch et al., 2013). Connectivity on the golf course and between the golf course and other green spaces plays a vital role in allowing populations and individuals to move between green spaces within the urban ecosystem (Saarikivi, 2013).

Recommendations:

- Include golf courses in considerations of connectivity during implementation of VanPlay. Given the importance of golf courses from biodiversity and ecological standpoints, and the links between limited human disturbance and enriched biodiversity, the role of golf courses in a connected ecological, transportation, recreation and cultural system should be considered carefully (VanPlay, 2019).
- Conduct a survey on landscape connectivity between golf courses and other green spaces, using suitable methodologies to evaluate wildlife movement, such as direct tracking (high-frequency radiotracking, GPS collar) or capture-mark-re-sight/recapture methods (LaPoint, 2015).
- Golf courses are essential urban green spaces that provide ecological and functional connectivity as part of a network of green spaces. Consider the overall benefits of the ecology and biodiversity of golf courses in conversations about land use change.

- Plant native trees and vegetation at locations that will allow wildlife to continue normal foraging and dispersal movements, such as enhancing connection between isolated wooded areas.
- Ensure vegetation patches are as wide and round as possible

5.2 Partner with local organizations to study and conserve biodiversity in Vancouver Park Board golf courses

Many international biodiversity conservation organizations agree that effective biodiversity conservation needs a successful and mutually beneficial partnership among local biodiversity conservation institutions (IUCN, 2014). In other words, the best biodiversity conservation results will be achieved through partnership rather than by working alone. For example, one of the leading organizations to observe urban biodiversity is in Vancouver is the Vancouver Natural History Society (Nature Vancouver), founded in 1918 to promote the enjoyment and conservation of nature in Vancouver (NatureVancouver, 2020).

Recommendations:

- Cooperate with the members of the bird section of Nature Vancouver to share data from ongoing bird surveys and nest box monitoring in golf courses (e.g., conducting monthly bird survey by members of Nature Vancouver at Vancouver Park Board golf courses and Pitch and Putt courses), as well as supporting them to expand their study area to include other parks and green spaces.
- Work with the members of the conservation section of Nature Vancouver and other local organizations to promote a better understanding of golf courses as part of urban biodiversity conservation. This includes developing more coherent messaging and consistent communication about the importance of golf courses for biodiversity and developing evidence-based analysis of the long-term economic values of ecosystem services.

5.3 Planning for biodiversity enhancement

5.3.1 Type of habitats to protect as priority

There are following three kinds of priority habitats on golf courses.

Understorey vegetation has several benefits to bird habitat, including enhancement of the diversity of foraging and nesting habitats, and reduction of exposure to predation, noise pollution, and human disturbances (French et al., 2005). A recent study by Threlfall (2016) involved that the volume of understorey vegetation with up to a half-meter height has significant positive effects on bird richness and specifically insectivorous bird species richness while the amount of local indigenous plants has a robust positive effect on bird species richness, native bird breeding, and insectivorous bird species richness (Threlfall et al., 2016).

Recommendations for enhancing understory:

- Decrease the clearance of understorey as much as possible
- Maintain healthy understorey near the edge of wooded areas or within a wooded area as much as possible
- Avoid planting a stand of equal age trees. This can result in a dense crown that shades out the understorey and can reduce vegetation success.

Water bodies, such as lakes, ponds, marshes, and streams are essential habitats for conserving some important wildlife. Clean, well-oxygenated water is aesthetically pleasing and promotes greater numbers of living organisms while polluted, muddy or eutrophic water is harmful to aquatic organisms, creates undesirable smells, and a breeding ground for mosquitoes and dangerous bacteria (John & Cheryll, 2004). Considering the ecological and biodiversity benefits beavers can offer, it would be beneficial to encourage their presence on the golf courses and make efforts to manage the potentially negative impacts they may have on the landscape.

Recommendations:

- Apply best management practices for eutrophication with monitoring and a reduction plan.
- Ensure natural or artificial filtration and enough water flow for aeration using pond bubbler aerator (Dyer, 2020)
- Ensure a variety of habitats on water bodies and wetlands, which are keystone to supporting high biodiversity. For example, a stream can have sections that differ in the depth of water, degree of shade, flow speed, and substrate type (e.g., mud, sand, rocks, concrete) while ponds can have areas of different depths, shore steepness, shoreline shadow, and vegetation (John & Cheryll, 2004).

Wooded areas support ecological connectivity inside the golf course and within an urban ecosystem, while also providing critical resources and habitats for biodiversity (Jarrett & Shackleton, 2017). There are three main components to keep or protect in a wooded area:

a. **Coarse woody debris (CWD)**, which contains significant carbon and energy stores and is the foundation of a critical forest food web (Riffell et al., 2010). Most surveys defined CWD as >10 cm diameter at Breast Height (DBH) and >60 cm in length (Jones et al., 2009). For instance, small mammals often use CWD for travel corridors (Waldien et al., 2006), mainly when predation risk is high (Zollner & Crane, 2003). Furthermore, forest reptiles use CWD for refugia, foraging (i.e., insect and small mammal prey), for the mating area, and basking (Riffell et al., 2011). As for amphibians, CWD provides moist habitat where amphibians have reduced the risk of desiccation (i.e., removal of moisture), which is vital for their survival rate (Semlitsch et al., 2009).

b. **Snags (i.e., standing dead tree)** with a height of more than 1.8 m and diameter at breast height of more than 10.2 cm (Riffell et al., 2010). Birds use as sites for perching, nesting, foraging, and so forth. For instance, large snags as large and dead trees are excavated by primary cavity nesters while secondary cavity nesters use those existing cavities for breeding sites (Martin et al., 2004).

c. **Large old trees**, which are key structures in the urban green spaces as they provide essential resources and structures, including complex canopies, cavities, hollows, fissured bark, seeds, nectar, and pollen (Laurance et al., 2014). Notably, the density of large native trees with >81 cm DBH positively influenced bird breeding activity (Threlfall et al., 2016).

Recommendations:

- Save as much original natural vegetation in a wooded area as possible
- Leave coarse woody debris in place or strategically place it from other sites
- Leave snags (i.e., standing dead tree) >1.8 m in height and >10.2 cm DBH in place
- Keep and protect a large old tree with greater than 81 cm of diameter at breast height

5.3.2 Encouraging functional groups (pollinators and seed disperser) on golf courses

Pollination is the most crucial process for most flowering plants to reproduce and grow fruits (GCSAA, 2019). Bees pollinate almost 20% of the world's flowering plant species (Waser & Ollerton, 2006) with measurable contributions from other insects.

Birds as seed dispersers are not only aesthetic to see and hear their songs but also play a vital role in controlling insect species that can lead to reducing the need for insecticides (John & Cheryll, 2004). There are means of attracting particular bird communities based on gaps in the population or your needs (e.g., insect control, seed dispersal). If a golf course can meet the needs of a particular species present in the region, birds are likely to live and breed on those habitats.

Recommendations:

- Use native or local wildflower seed mixes, shrubs and trees to encourage bees as a pollinator (Gilliland et al., 2013).

- Encourage golf course superintendents to engage with players, members, and communities on their environmental projects and initiatives (Lohmann, 2015).
- Promote educational workshops and research opportunities.
- Some recommendations for attracting particular bird communities are listed in Table 4 (John & Cheryll, 2004).

Feeding niche	Example Families (*Italics – birds that exist in Vancouver*)	Remarks and ways to encourage
Nectar feeders	hummingbirds	Often spectacularly coloured birds. Attract by planting flowering trees and shrubs. Try to get a mist of species.
Small canopy insects	Flycatchers, nuthatches, wrens, warblers	Maintain healthy diverse woodlands and plenty of flowering trees and plants known to harbour caterpillars. Plant flowering trees that attract pollinating insects. Provide small nest boxes.
Small fruits, nuts	Thrushes, Starlings, jays, nuthatches, doves	Include many of the
Fish eaters	Some kingfishers, herons	Maintain clear water bodies and healthy woodland to encourage good fish population.
Raptors	Owls, hawks, falcons	Raptors require large trees as perches or nest sites. They also require no persecution and a rich biodiversity on which to prey.
Aerial insectivores	Swallows, martins, swifts, wood swallows	Maintain clear water bodies and healthy woodlands
Migrant generalist songbirds	Robins, thrushes, flycatchers	Maintain good woodlands and provide food in winter on bird feeders.
Ground feeders	Grouse, mallard	Leave patches of dense ground cover for breeding and tail trees for roosting.
Wetland herbivores	Ducks, geese, swans, grebes, storks, cranes	Maintain rich wetland habitat with variety of habitat such as water depth, substrate, and vegetation cover. Provide safe roosting islands.
Resident generalist songbirds	Robins, thrushes, orioles	Maintain diverse parkland and woodland habitat with variety of berries and insect attracting flowers. Provide winter food, water and nest boxes.
Wood-boring insects	Woodpeckers, treecreepers	Maintain mixed woodlands and leave dead or dying trees in place as food for growing grubs on which birds depend. Erect nest boxes of suitable size.

Table 4. Different ways to attracting birds. (John & Cheryll, 2004)

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APPENDIX

Appendix 1. Locations of point transects for bird survey

	McCleery golf course		Fraserview golf course		Langara golf course	
	Latitude	**Longitude**	**Latitude**	**Longitude**	**Latitude**	**Longitude**
Point 1	49°13'25.39"N	123°10'2.08"W	49°12'47.00"N	123° 2'55.36"W	49°13'16.20"N	123° 6'38.45"W
Point 2	49°13'21.47"N	123° 9'59.46"W	49°12'43.05"N	123° 2'46.76"W	49°13'24.50"N	123° 6'44.68"W
Point 3	49°13'23.50"N	123° 9'56.06"W	49°12'47.23"N	123° 2'44.23"W	49°13'19.04"N	123° 6'38.30"W
Point 4	49°13'18.31"N	123° 9'54.62"W	49°12'55.36"N	123° 2'57.00"W	49°13'13.17"N	123° 6'35.45"W
Point 5	49°13'12.84"N	123° 9'53.64"W	49°13'2.61"N	123° 2'55.58"W	49°13'9.54"N	123° 6'38.77"W
Point 6	49°13'7.63"N	123°10'0.30"W	49°12'54.75"N	123° 2'43.45"W	49°13'5.64"N	123° 6'36.08"W
Point 7	49°13'2.82"N	123° 9'53.08"W	49°12'51.48"N	123° 2'35.67"W	49°13'7.48"N	123° 6'46.42"W
Point 8	49°13'2.08"N	123° 9'57.15"W	49°12'45.63"N	123° 2'36.35"W	49°13'7.93"N	123° 6'31.53"W
Point 9	49°12'56.63"N	123° 9'57.69"W	49°12'42.25"N	123° 2'34.05"W	49°13'19.55"N	123° 6'29.62"W
Point 10	49°12'57.61"N	123°10'6.69"W	49°12'40.70"N	123° 2'39.98"W	49°13'22.74"N	123° 6'26.53"W
Point 11	49°13'4.60"N	123°10'4.26"W	49°12'35.99"N	123° 2'36.44"W	49°13'25.18"N	123° 6'32.05"W
Point 12	49°13'3.45"N	123°10'12.73"W	49°12'35.18"N	123° 2'43.46"W	49°13'15.75"N	123° 6'23.54"W
Point 13	49°13'3.72"N	123°10'17.83"W	49°12'31.48"N	123° 2'53.11"W	49°13'7.76"N	123° 6'55.06"W
Point 14	49°13'7.09"N	123°10'17.81"W	49°12'38.42"N	123° 3'1.60"W	49°13'15.56"N	123° 6'51.07"W
Point 15	49°13'11.11"N	123°10'15.46"W	49°12'33.36"N	123° 3'7.44"W	49°13'20.28"N	123° 6'53.17"W
Point 16	49°13'13.33"N	123°10'20.37"W	49°12'28.62"N	123° 3'15.90"W	49°13'22.10"N	123° 6'56.51"W

Appendix 2. Locations of camera traps among golf courses

	McCleery golf course		Fraserview golf course		Langara golf course	
	Latitude	**Longitude**	**Latitude**	**Longitude**	**Latitude**	**Longitude**
Cam 1	49°13'1.40"N	123°10'16.86"W	49°13'1.36"N	123° 2'54.75"W	49°13'19.07"N	123° 6'29.83"W
Cam 2	49°13'1.54"N	123°10'10.91"W	49°12'51.17"N	123° 2'38.27"W	49°13'17.54"N	123° 6'23.05"W
Cam 3	49°13'10.87"N	123°10'22.18"W	49°12'32.61"N	123° 3'6.57"W	49°13'20.02"N	123° 6'52.22"W
Cam 4	49°12'59.31"N	123° 9'51.43"W	49°12'45.91"N	123° 2'59.69"W	49°13'13.91"N	123° 6'53.46"W
Cam 5	49°12'59.74"N	123° 9'58.32"W	49°12'52.97"N	123° 2'59.66"W	49°13'12.16"N	123° 6'36.67"W
Cam 6	49°13'21.49"N	123° 9'54.29"W	49°12'34.95"N	123° 2'59.70"W	49°13'4.42"N	123° 6'49.78"W
Cam 7	49°13'28.63"N	123°10'3.18"W	49°12'34.85"N	123° 2'36.38"W	49°13'4.18"N	123° 6'35.43"W

Appendix 3. Bird species observed on three golf courses between 19th May 2020 and 08th June 2020 (Blue-listed species (**Blue**) in BC conservation status)

	Species name	Scientific name	BC status	Golf courses		
				McCleery	**Fraserview**	**Langara**
1	American Goldfinch	*Spinus tristis*	yellow	+		+
2	American Pipit	*Anthus rubescens*	yellow	+		
3	American Robin	*Turdus migratorius*	yellow	+	+	+
4	American Wigeon	*Mareca americana*	yellow	+		
5	Anna's Hummingbird	*Calypte anna*	yellow	+	+	+
6	Bald Eagle	*Haliaeetus leucocephalus*	yellow	+	+	
7	**Barn Swallow**	***Hirundo rustica***	**Blue**	+	+	+

8	Barred owl	*Strix varia*	yellow		+	
9	Belted Kingfisher	*Megaceryle alcyon*	yellow	+		
10	Bewick's Wren	*Thryomanes bewickii*	yellow	+	+	+
11	Black-capped Chickadee	*Poecile atricapillus*	yellow	+	+	+
12	Black-headed Grosbeak	*Pheucticus melanocephalus*	yellow	+	+	+
13	Black-throated Gray Warbler	*Setophaga nigrescens*	yellow	+		
14	Blue-winged Teal	*Anas discors*	yellow	+		
15	Brewer's Blackbird	*Euphagus cyanocephalus*	yellow	+		
16	Brown Creeper	*Certhia americana*	yellow	+	+	
17	Brown-headed Cowbird	*Molothrus ater*	yellow	+	+	+
18	Bufflehead	*Bucephala albeola*	yellow	+		+
19	Bushtit	*Psaltriparus minimus*	yellow	+	+	+
20	Canada Goose	*Branta canadensis*	yellow	+		
21	**Caspian Tern**	***Hydroprogne caspia***	**Blue**	+		
22	Cassin's Vireo	*Vireo cassinii*	yellow	+		
23	Cedar Waxwing	*Bombycilla cedrorum*	yellow	+		
24	Chestnut-backed Chickadee	*Poecile rufescens*	yellow		+	
25	Chipping Sparrow	*Spizella passerine*	yellow	+		+
26	Cinnamon Teal	*Anas cyanoptera*	yellow	+		
27	Common Loon	*Gavia immer*	yellow	+		
28	Common Yellowthroat	*Geothlypis trichas*	yellow	+		
29	Cooper's Hawk	*Accipiter cooperii*	yellow	+	+	+
30	Dark-eyed Junco	*Junco hyemalis*	yellow		+	
31	**Double-crested Cormorant**	***Phalacrocorax auratus***	**Blue**	+		
32	Downy Woodpecker	*Picoides pubescens*	yellow	+	+	+
33	European Starling	*Sturnus vulgaris*	Exotic	+	+	+
34	Gadwall	*Mareca strepera*	yellow	+		
35	Glaucous-winged Gull	*Larus glaucescens*	yellow	+		
36	Golden-crowned Kinglet	*Regulus satrapa*	yellow	+		
37	Golden-crowned Sparrow	*Zonotrichia atricapilla*	yellow	+		
38	**Great Blue Heron**	***Ardea Herodias***	**Blue**	+		
39	**Green Heron**	***Butorides virescens***	**Blue**	+		
40	Green-winged Teal	*Anas carolinensis*	yellow	+		
41	Hermit Thrush	*Catharus guttatus*	yellow	+		
42	Hooded Merganser	*Lophodytes cucullatus*	yellow	+		
43	House Finch	*Haemorhous mexicanus*	yellow	+	+	+
44	House Sparrow	*Passer domesticus*	exotic	+		
45	Hutton's Vireo	*Vireo huttoni*	yellow	+	+	+
46	Lincoln's Sparrow	*Melospiza lincolnii*	yellow	+		
47	Mallard	*Anas platyrhynchos*	yellow	+	+	+
48	Marsh Wren	*Cistothorus palustris*	yellow	+		
49	Mourning Dove	*Zenaida macroura*	yellow	+		
50	Northern Flicker	*Colaptes auratus*	yellow	+	+	+
51	Northwestern Crow	*Corvus caurinus*	yellow	+	+	+
52	**Olive-sided Flycatcher**	***Contopus cooperi***	**Blue**	+	+	+
53	Orange-crowned Warbler	*Vermivora celata*	yellow	+	+	+
54	Osprey	*Pandion haliaetus*	yellow	+		
55	Pacific Wren	*Troglodytes pacificus*	yellow	+	+	+
56	Pacific-slope Flycatcher	*Empidonax difficilis*	yellow	+		
57	Peregrine Falcon	*Falco peregrinus*	No status	+		
58	Pied-billed Grebe	*Podilymbus podiceps*	yellow	+		
59	Pileated woodpecker	*Dryocopus pileatus*	yellow		+	
59	Pine Siskin	*Spinus pinus*	yellow	+	+	+
60	Purple Finch	*Haemorhous purpureus*	yellow	+		
61	Red crossbill	*Loxia curvirostra*	yellow		+	
62	Red-breasted Nuthatch	*Sitta canadensis*	yellow	+	+	+
63	Red-tailed Hawk	*Buteo jamaicensis*	yellow	+		
64	Red-winged Blackbird	*Agelaius phoeniceus*	yellow	+		
65	Ring-necked Duck	*Aythya collaris*	yellow	+		
66	Rock pigeon	*Columba livia*	exotic		+	+
67	Ruby-crowned Kinglet	*Regulus calendula*	yellow	+		
68	Rufous Hummingbird	*Selasphorus rufus*	yellow	+	+	

69	Savannah Sparrow	*Passerculus sandwichensis*	yellow	+		
70	Song Sparrow	*Melospiza melodia*	yellow	+	+	+
71	Spotted Sandpiper	*Actitis macularius*	yellow	+		
72	Spotted Towhee	*Pipilo maculatus*	yellow	+	+	+
73	Swainson's Thrush	*Catharus ustulatus*	yellow		+	+
74	Townsend's Warbler	*Setophaga townsendi*	yellow	+	+	
75	Tree Swallow	*Tachycineta bicolor*	yellow	+	+	+
76	Vaux's Swift	*Chaetura vauxi*	yellow	+		
77	Violet-green Swallow	*Tachycineta thalassina*	yellow	+	+	+
78	Virginia Rail	*Rallus limicola*	yellow	+		
79	Warbling Vireo	*Vireo gilvus*	yellow	+	+	+
80	Western Tanager	*Piranga ludoviciana*	yellow	+	+	
81	Western Wood-Pewee	*Contopus sordidulus*	yellow	+	+	
82	White-crowned Sparrow	*Zonotrichia leucophrys*	yellow	+	+	+
83	Wilson's Warbler	*Cardellina pusilla*	yellow	+	+	+
84	Yellow Warbler	*Setophaga petechia*	yellow	+	+	+
85	Yellow-throated Warbler	*Setophaga dominica*	Accidental	+		

Appendix 4. Some photos captured by camera traps.

Beaver (Castor canadensis) caught at the McCleery golf course by camera trap 6.

Coyote (Canis latrans) caught at the Fraserview golf course by camera trap 1.

Coyote (Canis latrans) caught at the Fraserview golf course by camera trap 3.

Two northern raccoon (Procyon lotor) caught at the Fraserview golf course by camera trap 6.

Two eastern grey squirrels (Sciurus carolinensis) caught at the Langara golf course by camera trap 1.

Two black rats (Rattus rattus) caught at the Langara golf course by camera trap 1.