Special Management in the Human Dominated Landscape: Bird Species of the Georgia Basin

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Abstract

The expansion of urban and rural areas is likely to effect bird species within these areas because some do well in these habitat types while others do not. I used size, nesting substrate, diet, migratory pattern, and sociability to investigate if these life history traits determine the presence or absence of species in habitats dominated by humans and what native species will not as a consequence require special management. Based on the 5 traits size, diet, nesting substrate, migratory pattern and sociability, 47 species of birds found in the Georgia Basin were organized into guilds to determine whether or not the individual traits were associated with the presence or absence of the species within a human dominated habitat. Organizing the species into guilds was also used to determine if the 47 species could be used to represent the response of all native species. The association of each individual species to human dominated habitats was also determined. Size and nesting substrate were found to be significant while the three other traits were not. However, the trends obtained from all traits indicate that medium sized, omnivorous, migratory, social species that nest above 2 metres in height and on man-made structures are more likely to be found in human dominated habitats.

Key words: Life History traits, species guilds, Novel ecosystems

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Introduction

Ecosystems are dynamic entities, and as a result are changing through time. Humans are an incredible force as they help guide the changing ecosystem by modifying the rates, and the types, of changes that occur (Hobbs *et al.* 2006). Landscape changes play a major role in determining the biodiversity within a region. As reported by Bender *et al.* (1998), these changes may fragment the landscape by increasing the number of patches and decreasing the contiguity of the habitat as well as reduce any available habitat or degrade what habitat is left, as found by Hepinstall *et al.* (2008). A major influence on plant and animal diversity of a region is human expansion (Marzluff 2008) and the settlement by humans on the landscape has long lasting and extreme effects (Marzluff and Ewing 2001). Human settlement at a local scale may result in increased diversity, as new or exotic species may now be found along with the native species already present in the area (Marzluff 2008). This assumes, however, that native species are not replaced or outcompeted by the exotics or new species that are later established (Marzluff 2008). As defined by Hobbs *et al.* (2006), a novel ecosystem involves new relative species abundances and compositions that have yet to be seen in the ecosystem found within that particular biome as well as changes in the function of the particular system. It is important to note that the temporal context is key in determining the “novelty” of the ecosystem, as any ecosystem could be novel given the appropriate time frame (Hobbs *et al.* 2009).

There may be direct and indirect effects on the species present in a novel ecosystem. The dispersal ability of species may be altered as a result of altered abiotic conditions and the abundances of species may change with the introduction of new species (Hobbs *et al.* 2006). Species communities, will reflect a change in the landscape, however, this may not be a predictable change (Lindenmayer *et al.* 2008). Furthermore, certain species may no longer be found in the novel ecosystem as they may not display behavioural, or demographic plasticity to adapt to the changes (Luniak 2004). Alternatively, there can be the extirpation, due to human activities, of a species that was originally present in an area (Hobbs *et al.* 2006). Novel ecosystems may arise as a result of heavily managed land by humans (Hobbs *et al.* 2006) and so the ecosystems that are present in these areas may form a fragmented network across the landscape and affect the distribution of habitats and which habitat types are available. As such, trying to return an ecosystem to its historical state, or trying to remove unwanted species will not be efficient (Seastedt *et al.* 2008).

Urbanization results in splitting a natural area into smaller segments, and the effects on wildlife in the area differ from species to species (Marzluff and Ewing 2001). Urbanization, spread out over the landscape, has profound effects as this type of land cover is drastically different from the natural land cover (Marzluff and Ewing 2001; McKinney 2006; Lepzyck *et al.* 2007). A critical component of species not being found in urban landscapes is habitat availability, as urbanization may alter the type and amount of food and, the size, and the quality habitat patches (Croci *et al.* 2008).

Changes in forest cover, through urban expansion, has been shown to have an effect on neotropical migrant bird species, such as influencing the habitat available, the size of the patches of forest, increasing the amount of “edge” in the patches, and even increasing the distance between forested patches (Robinson *et al.* 1995). Fragmentation was found, on a temporal scale, by Boulinier *et al.* (1998b) to result in very variable species diversity. Andrén (1994) found that fragmentation, along with loss of habitat tends to lower species richness and increase the probability of extinction of certain species. Furthermore, forest breeding bird species, especially those that require large forest habitat patches, were found to have higher turnover and extinction rates as well as a reduced species richness (Boulinier *et al.* 2001). As noted by Blair (1996), woodland species would gradually decrease in abundance approaching urban areas.

Housing development has a large impact at varying scales (Lepczyk *et al.* 2007), and as a type of habitat alteration, urbanization is an important player in species extinction and homogenization as it is linked with the establishment of exotic species (McKinney 2006; McKinney and Lockwood 1999). In general, most urban areas are similar to each other so similar species are favoured in urban areas (McKinney 2006). This is presumed to be due to the fact that similar local factors are present in urban areas and act in a way to favour similar local diversity (Ricklefs 1987). The effects of urbanization are also dependent on the species (Blair 1996). As such, regions in which development is occurring at the fastest rates should be focused on with regards to management, research and conservation (Lepczyk *et al.* 2007). Agriculture is also involved in the simplification of bird communities due to the introduction of new resources and a differential ability of species to utilize these resources (La Sorte 2006). Child *et al.* (2009) notes that in South Africa there is a balance between the amount of natural and agricultural land to maintain high bird species richness and this balance should be taken into consideration with any sort of expansion.

Bird species are good indicators of ecosystem integrity (Branton and Richardson 2011) and their abundance and diversity are tightly linked to the amount of human influence (Lepczyk *et al.* 2008). Native species richness and abundance tends to decrease as human settlement increases (Lepczyk *et al.* 2008; Pidgeon *et al.* 2007). Human settlement has been found to be a good predictor of species presence (Lepczyk *et al.* 2008). The presence or absence of species will change as an area gradually becomes urbanized and native species typically become less prominent (Blair 1996). Development, however, was found to have different effects on bird diversity. Landowners have been found to influence bird populations by providing seeds in feeders or bird houses for cavity nesters (Lepczyk *et al.* 2004). Even applying fertilizer may result in a change in the structure of the vegetation affecting nesting sites (Lepczyk *et al.* 2004). These actions may positively affect certain species, but the effects of urbanization are still felt even after 60 years since development as species richness continue to decrease (Hansen *et al.* 2005).

Maestas *et al.* (2003) found that on reserves, shrub and ground nesters typically do quite well, while in more exurban areas, tree nesters, human commensal species do better and even cavity nesters could be supported with the presence of nest boxes. In residential areas, human commensal species also did quite well due to the presence of resources such as bird feeders (Maestas *et al.* 2003).

Raptors, scavengers, pollinators, and insectivores are typically negatively affected by conversion of natural land cover to agriculture while granivores do not appear to be affected (Child *et al.* 2009). Synanthropes are species that are specifically linked to humans and human settlement (Francis and Chadwick 2012) and found to do well in urbanized areas (Hansen *et al.* 2005). At an intermediate level of disturbance, along the urban-rural gradient, overall bird species richness peaked, despite resulting in a drop of native species richness (Blair 1996). Alternatively, at greater levels of disturbance both types of species richness decreased (Blair 1996). Clergeau *et al.* (2001) suggest that features that may be unique to an urban area affect species' richness in that area.

What then, allows a species to persist in a human dominated landscape? Croci *et al.* (2008) looked at biological traits of bird species to determine if urban landscapes selected for certain species based on particular biological traits. Species traits have been found to play an important role in determining the range of a species (Laube *et al.* 2013). Croci *et al.* (2008) created a list of traits that was found to be associated with ‘urban adapters’ in Europe and that a combination of these traits help determine the presence of the species in urban environments.

Although studies have been conducted in Europe and Chile on bird abundance and distribution linked to life history and biological traits (Blackburn *et al.* 1996; Cofre *et al.* 2007; Böhning-Gaese and Bauer 1996), the Georgia Basin, in British Columbia, Canada in particular, has not been investigated using this method. This study intends on looking at which species in the human dominated landscape of the Georgia Basin are expected to be abundant, by grouping the species into guilds based on the list of biological traits created by Croci *et al.* (2008). The organizing of the species into guilds will also be examined for appropriateness to predict occurrence in a human dominated landscape.

In Canada, human populations have been more recently established and natural areas have been managed for shorter periods of time compared to Europe, this allows to compare if the same biological traits yield similar results to what was obtained by Croci *et al.* (2008). It was hypothesized that large, social, omnivorous, sedentary, or species that nest at or above 2 metres are more likely to be present in human dominated habitats. These traits were selected from the list created by Croci *et al.* (2008). By looking at the biological traits, and grouping species into guilds, this may allow for greater predictive power for future conservation efforts such as better land-use planning and efficient allocation of funding. Also, using human and non-human commensal species abundances may allow quantifying the changes to the landscape due to human activities (Manor *et al.* 2008).

Methods

The Coastal Douglas Fir (CDF) Biogeoclimatic zone is an ecosystem found below 150 metres in elevation, and mainly found on the islands in the Gulf of Georgia, small portions on the mainland as well as on the southeast tip of Vancouver Island in British Columbia (Meidinger and Pojar 1991; Figure 1).

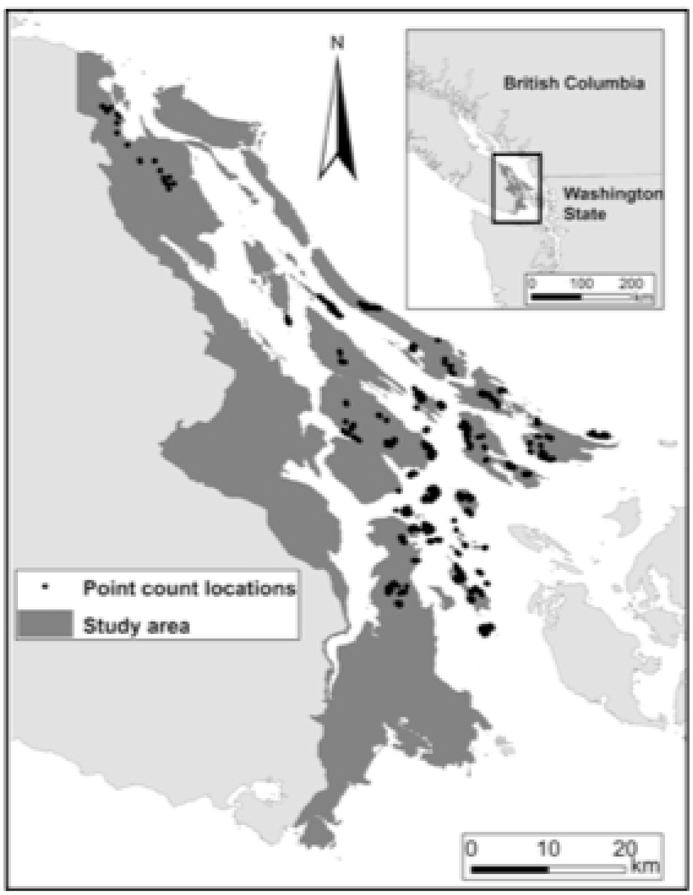

Figure 1: A map of the study area provided by Schuster and Arcese (2012)

Most of the forests found in this zone have experienced some form of disturbance; however, there are also old, and mature forest stands present (Meidinger and Pojar 1991). The diverse structure in the forests of the CDF allow for a variety of species to inhabit them (Meidinger and Pojar 1991). With an expanding urban area, the CDF ecosystem is now threatened (Meidinger and Pojar 1991).

Data

Forty-seven bird species distribution maps using detection and non-detection data were used to predict the occurrence of these species in the Georgia Basin. The data were collected and provided by Schuster and Arcese from their 2012 study. These maps were generated from point count data collected from April 30th to July 11 from 2005, 2007-2010 on 45 different islands (Schuster and Arcese 2012). The data obtained was based on the entire Coastal Douglas Fir zone (Schuster and Arcese 2012). 712 sample locations that were recorded with a GPS (GPS 60, Garmin, KS, USA) were used (Schuster and Arcese 2012). For 10 minutes at each location, trained observers took note of all birds that were within a 50 metre radius between the hours of 5:00 and 12:00 (Schuster and Arcese 2012). The degree to which each species associate with existing habitat types in the Coastal Douglas Fir zone was estimated using expert rankings, from professional Ornithologists with 5 or more years of local experience (Schuster and Arcese 2012). Occupancy predictions were used for each bird species.

Five spatial and twenty-nine predictor covariates that incorporated information about the condition of the site and the landscape were created (Schuster and Arcese 2012). To reflect habitat features at fine (100 metres) and coarse scales (1 kilometre), data were obtained from Terrain Resource Information Management, Sensitive Ecosystem Inventory: East Vancouver Island and the Gulf Islands, Earth Observation for Sustainable Development Landcover, aerial photographs, and Madrone Environmental Services (2008) Terrestrial Ecosystem Mapping of the CDF (Schuster and Arcese 2012).

Life History Traits

Based on Croci *et al.* (2008), certain traits were selected to help determine whether a species would be present in human dominated and non-human dominated land cover types. The traits selected were body size (based on wingspan), nesting substrate, migratory pattern, degree of sociability, and diet. This information was obtained from the Birds of North America database, and the Cornell Lab of Ornithology (Appendix B).

Based on the criteria of Croci *et al.* (2008), the size of species was determined using wingspan: where small species had a wingspan less than 20 centimetres (cm), large species had wingspans greater than 30 cm, and medium sized species had wingspans greater than 20 and less than 30 cm. Somewhat similar to the classification of Croci *et al.* (2008), ground nesting was ground nesting unless otherwise specified, below 2 metres to ground was considered shrub nesting unless otherwise specified, and nesting substrate above two metres was considered tree nesting unless otherwise specified. Migratory pattern was determined by the presence of the species during the winter months. Sociability was defined as the interaction the species has with individuals other than its mate and offspring during the mating season. Diet was defined as what mainly composed the species regular food intake. In the case of mixed feeders, this category was a combination of species whose regular intake consisted of seeds and insects. The information used, if available, was that which applied to British Columbia. Species were then organized in their respective guilds based on the trait that they possessed. For example, within the trait 'Diet' there were the following guilds: predatory, granivorous, insectivorous, and omnivorous. Traits were analyzed individually. Predictions were formulated regarding the probability of the occurrence of species in human dominated landscapes based on the traits suggested by Croci *et al.* (2008).

Analysis

Non-human dominated and human dominated habitats were created by combining the TEM layers, provided by Schuster and Arcese (2012), FOR 1, FOR 2, SHR, HRB, SAV, WET and the TEM layers RUR and URB respectively. These represented respectively young forest, mature forest, shrub, herbaceous, savannah, wetland, rural and urban habitat types. This served to simplify the number of habitat features and provide a comparison between what was considered a human and non-human dominated habitat. An index of association, the degree to which each species associates to human or non-human habitat features, was created by running a general linear model in Minitab 16 Statistical Software (Minitab Inc.). The simplified TEM, human and non-human dominated habitats, was included as a variable in the model, and the polygon area was included as a co-variate.

A separate trial was also run without ‘polygon area’ as a co-variate to determine whether or not polygon area influenced a species’ association to a particular habitat type. For every species, the index was calculated by taking the mean probability of occurrence in non-human dominated habitats and subtracting the mean probability of occurrence in human dominated habitats (Appendix A). If the value was more negative, the species associates more with human dominated habitats, but if more positive, the species associates more with non-human dominated habitats. One-way analyses of variance, using the index of association and the traits, were run to determine where, based on the traits, bird species would most likely be found. An α value of 0.05 was used to test for significance of traits and Tukey’s Post-hoc test was run to determine if guilds were significantly different from one another.

In the trial that was run without ‘polygon area’, only one species, the Song Sparrow, was found to have a significant preference for the non-human dominated habitat while in the trial with the co-variate, this association was not significant (Appendix A). For the most part there were very small differences in index of association means for most species, but all yielded the same result; if all species were significantly associated to their particular habitats with the co-variate, they were significantly associated to their particular habitats without the co-variate (Appendix A). Under the trial without ‘polygon area’, the variable TEM, which represented the different habitat types, was significant in all species but the Swainson’s Thrush and the Yellow Warbler (Appendix A).

When running the analysis for the trait ‘Diet’ the Bald Eagle was excluded, as it was the only species that was considered predatory and could not have been combined with any other category. This was also the case for the Rufous hummingbird, as its diet mainly consists of nectar and does not match any other species diet. Furthermore, when running for the trait ‘Nesting substrate’, the Brown-headed Cowbird was excluded from the analysis as it was the only species that was a brood parasite.

Results

Individual Species

Of the 47 species included, 17 showed significant preference for human dominated habitats (Appendix A). Twenty-seven species significantly preferred non-human dominated habitats and 3 species showed no preference (Appendix A). The co-variate ‘polygon area’ in the analysis was significant in 36 species while the variable TEM, which included human dominated and non-human dominated habitats, was significant in 44 species (Appendix A). Only one species, the Swainson’s Thrush, was found in which neither ‘polygon area’ or TEM was significant (Appendix A).

Species that were strongly and significantly associated with human dominated habitats included: the Barn Swallow, European Starling, Northwestern Crow, Savannah Sparrow, and Violet-Green Swallow (Appendix A). Species that were strongly and significantly associated with non-human dominated habitats included: the American Goldfinch, Bewick's Wren, Brown Creeper, Chestnut-backed Chickadee, Golden-crowned Kinglet, Pileated Woodpecker, Pacific-slope Flycatcher, Purple Finch, Red-breasted Nuthatch, Townsend's Warbler, Tree Swallow, Winter Wren, and Yellow-rumped Warbler (Appendix A). Finally, only the Song Sparrow, Swainson's Thrush, and Yellow Warbler did not show a preference for either habitat type (Appendix A). Note that although the 25 other species significantly associated with their respective habitat types, they did not do so as strongly as the above-mentioned species.

Guilds

Body size predicted association patterns with smaller birds being more often associated with non-human dominated habitats and medium-sized birds not associating with a particular habitat (Figure 2). For larger birds, however, the association was not as strong for non-human dominated habitats as it was for smaller birds (Figure 2). Small and Medium birds were found to be significantly different, while large birds were not found to be significantly different from either small or medium sized birds (Appendix A). The trait 'size' was found to be significant (p=0.018) as all three means are not equal as medium and small sized birds have a different preference (Table 1).

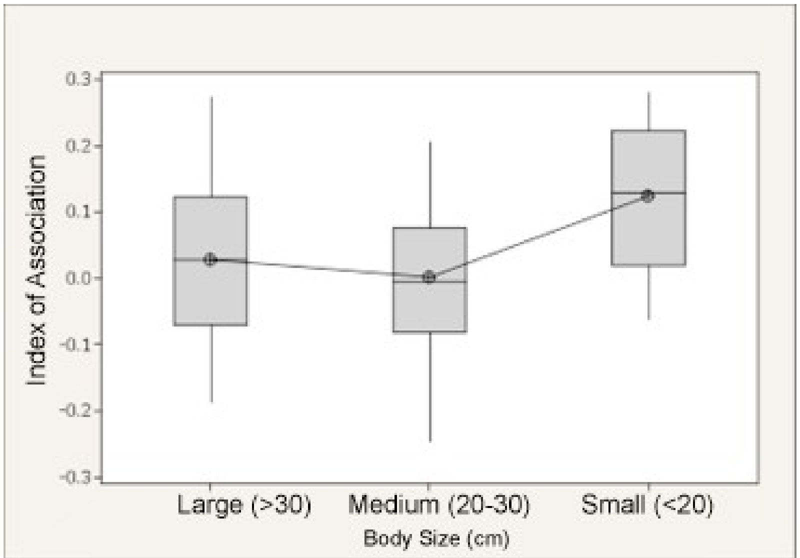

Figure 2: The box plot of the means, and median between the 25th and 75th percentile of the index of association for the guilds that were part of the trait 'Size'

Level	N	Mean	Standard Deviation
Large	12	0.0281	0.1349
Medium	22	0.0024	0.1155
Small	13	0.1252	0.1128

Table 1: Summary of the trait 'Size' displaying the sample size, means and standard deviation for each level

Cavity nesting and tree nesting birds preferred non-human dominated habitats while ground nesters and species favouring man-made structures preferred human dominated habitats (Figure 3). Shrub nesting species were found to not associate with a particular habitat (Figure 3). Cavity and tree nesters were found to be significantly different from species using man-made structures (Appendix A). Furthermore, cavity and tree nesters were not found to be significantly different from each other (Appendix A). While shrub and ground nesters were not found to be significantly different from cavity, tree nesters, or species using man-made structures (Appendix A). The nesting substrate was found to be significant (p=0.002) as all five means are not found to be equal as it looks like species that nest on man-made structure are different from all the other guilds (Figure 3; Table 2).

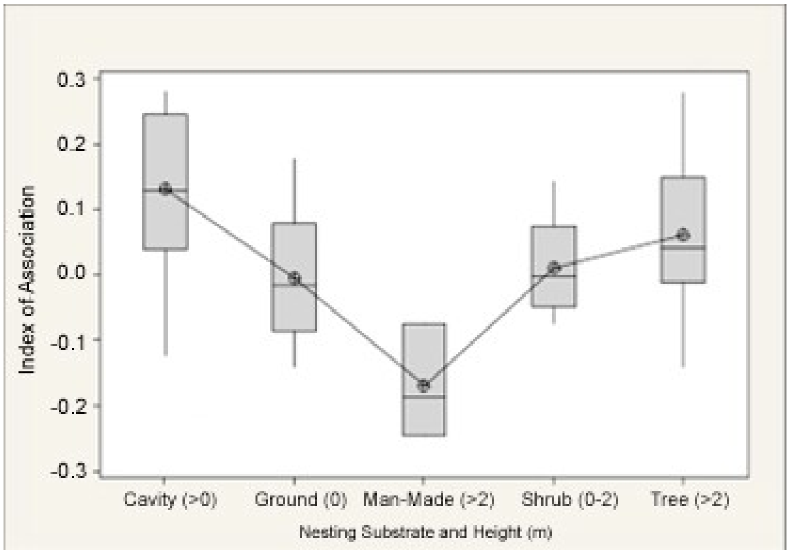

Figure 3: The box plot of the means, and median between the 25th and 75th percentile of the index of association for the guilds that were part of the trait 'Nesting Substrate'

Level	N	Mean	Standard Deviation
Cavity	11	0.1308	0.1253
Ground	8	-0.0051	0.1045
Man-made	3	-0.1698	0.0879
Shrub	5	0.0096	0.0804
Tree	19	0.0603	0.1114

Table 2: Summary of the trait 'Nesting Substrate' displaying the sample size, means and standard deviation for each level

Migratory and sedentary species do not prefer non-human dominated habitats over human dominated (Figure 4). Furthermore, migratory and sedentary species were not significantly different from each other (Appendix A). The migratory pattern was not found to be significant (p=0.499) the means between the two patterns are statistically the same (Figure 4; Table 3).

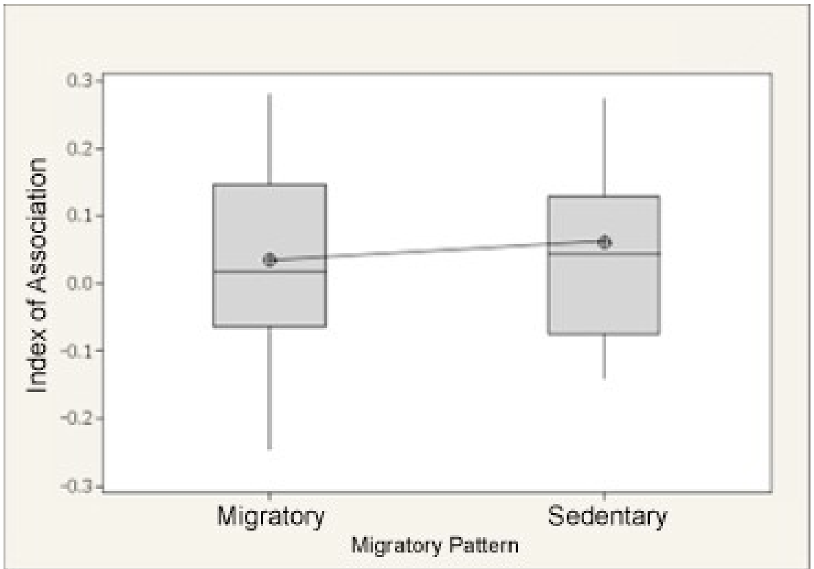

Figure 4: The box plot of the means, and median between the 25th and 75th percentile of the index of association for the guilds that were part of the trait 'Migratory Pattern'

Level	N	Mean	Standard Deviation
Sedentary	15	0.0617	0.1254
Migratory	32	0.0342	0.1310

Table 3: Summary of the trait 'Migratory Pattern' displaying the sample size, means and standard deviation for each level

Social and non-social species, during their breeding season, were not found to prefer human dominated habitats over non-human dominated habitats (Figure 5). Social species and non-social species were not found to be significantly different (Appendix A). Furthermore, sociability was not found to be significant (p=0.135) meaning that the means of social and non-social are not statistically different (Figure 5; Table 4).

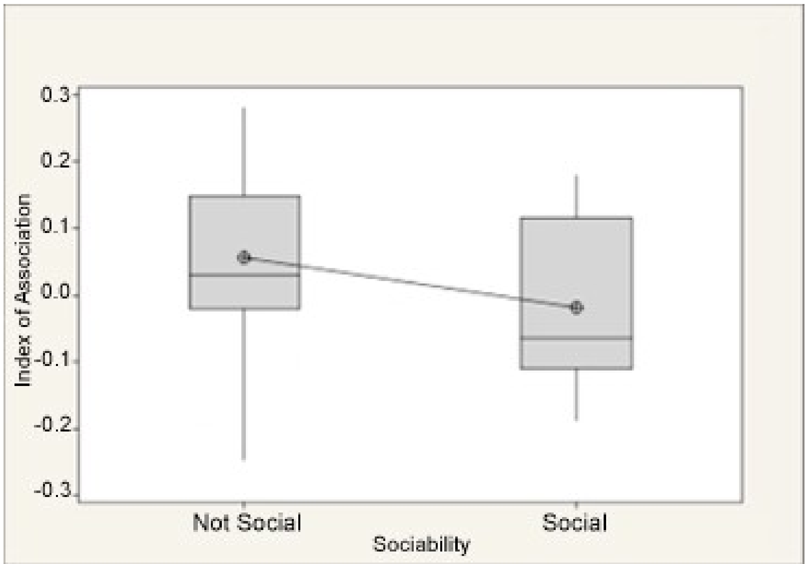

Figure 5: The box plot of the means, and median between the 25th and 75th percentile of the index of association for the guilds that were part of the trait 'Sociability'

Level	N	Mean	Standard Deviation
Not Social	39	0.0557	0.1265
Social	8	-0.0191	0.1281

Table 4: Summary of the trait 'Sociability' displaying the sample size, means and standard deviation for each level

Omnivorous species appear to be most associated with human dominated habitats, followed by granivorous species (Figure 6). Mixed feeders and insectivorous species appear to be more associated with non-human dominated habitats (Figure 6). Diet was not found to be significant (0.165) as all the means of the different guilds were found to be statistically the same (Figure 6; Table 5). None of the guilds were found to be significantly different from each other (Appendix A).

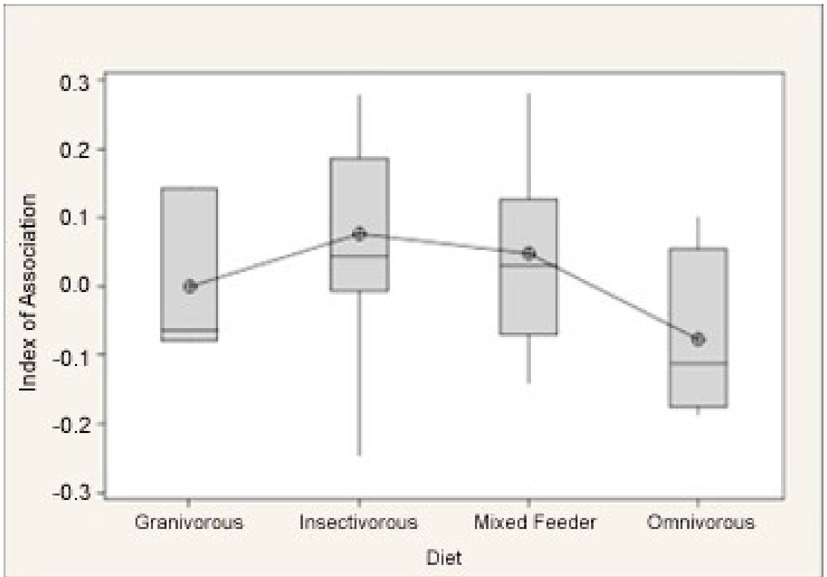

Figure 6: The box plot of the means, and median between the 25th and 75th percentile of the index of association for the guilds that were part of the trait 'Diet'

Level	N	Mean	Standard Deviation
Granivorous	3	-0.0009	0.1239
Insectivorous	21	0.0751	0.1318
Mixed feeder	17	0.0466	0.1214
Omnivorous	4	-0.0787	0.1259

Table 5: Table 4: Summary of the trait 'Diet' displaying the sample size, means and standard deviation for each level

Discussion

Thirteen bird species were found to be strongly associated with non-human dominated habitats, while only five species were found to strongly association with human dominated habitats. Which traits were determined to allow a species to better associate with humans?

Size

Contrary to what Croci *et al.* (2008) obtained, large bird species were not found to associate with human dominated habitats, while medium sized birds were not found to associate with any habitat in particular (Figure 2). Although body size may not directly predict abundance, it is thought to play a role in resources requirements in species (Blackburn *et al.* 1996). Large species are believed to require more food and space for body maintenance relative to smaller species (Blackburn *et al.* 1996). Potentially due to this relatively lower cost of maintenance, medium sized species may have been better able to utilize food sources in human dominated habitats, while larger species prefer non-human dominated landscapes where they can meet their metabolic needs as food sources are greater. Although having lower maintenance requirements, smaller species may put more energy towards reproduction, and so still require abundant food sources so as to be able to maintain themselves and produce many offspring. This may partly explain the preference of non-human dominated habitats in small species.

Nesting Substrate

Species that preferred nesting on man-made substrate such as lampposts, or structures with overhangs were found to be more associated with humans (Figure 3). What was surprising, however, was that ground nesters somewhat preferred human dominated habitats (Appendix A). This result is contrary to what Croci *et al.* (2008) found as they suggested that species that would nest at or above two metres would be more successful in urban areas. The availability of nesting substrate would explain the preference for human dominated habitats for species that nest on man-made substrate, as there are plenty of roofs with overhangs and lampposts to nest on in such a habitat. Ground nesters may be taking advantage of the fact that grassier areas are being created, for parks and recreation by humans, and generating more potential nesting areas for these species. However, this is contrary to what was suggested by Clergeau *et al.* (2006) as ground nesting species appear to prefer areas with less human influence. Shrubs nesters appear to not have a preference for either human or non-human dominated habitats (Figure 3), but the park-type habitats may serve as good nesting areas for these species along with the shrub areas in non-human dominated habitats.

Typically, cavity nesters are associated with non-human dominated habitats (Figure 3). However, with the growing numbers of bird houses in human dominated areas, it may be plausible that cavity nesters may begin utilizing these resources to establish in human dominated habitats as the addition of bird houses increased the abundance and diversity of cavity nesters in forests and may even increase the abundance of non-cavity nesters (Sánchez *et al.* 2007). Tree nesting species are typically found in areas that are not human dominated most likely due to a greater number of trees in those areas. However, this association to non-human dominated habitats is not as strong as in cavity nesters (Figure 3) and may be due to the fact that in managed forests, such as in urban or rural areas, trees are typically younger (Keller *et al.* 2003) and not always suitable for the cavity nesters. However, although trees may be found in urban areas, a suitable tree to nest in may not be extremely abundant.

Migratory Pattern

The trend observed for the trait ‘Migratory pattern’, although not significant, was unexpected (Appendix A). Croci *et al.* (2008) suggested that sedentary species would be more associated with humans relative to migratory species. This would be assumed because a species that remains in the area year-round, would have better knowledge of the area in ways such as resource location, as well as better temporal awareness with regards to what is available when. Furthermore, species that do not migrate are said to be more at ease with fragmentation of habitats (Bender *et al.* 1998). In this case, however, migratory and sedentary species did not associate with one habitat more than another (Appendix A). It may be possible that migratory species are not more or less affected by non-human or human dominated habitats as they do not have to tolerate them for as long and so are indifferent just as sedentary species may be accustomed to these habitats too. This result should be further investigated.

Sociability

Sociability was not found to be significant (Appendix A), however, the trend observed reflects the results obtained by Croci *et al.* (2008). Social species appeared to have a greater association with human dominated habitats (Figure 5). Social species may be involved in the sharing of information within their groups about food sources whether new, familiar, or short-lived such as in short-tailed fruit bats (Ratcliffe and ter Hofstede 2005). Due to this information sharing, species are better able to navigate the human dominated areas and are more efficiently searching for food.

Diet

Diet was not significant, but, the trend observed was, as suggested by Croci *et al.* (2008), that omnivorous species had a greater association with human dominated habitats (Figure 6). Granivorous species were also more associated with humans (Figure 6). An ability to use a wide variety of food resources and being able to utilize sources of food provided by humans will play an influential role (Laube *et al.* 2013) in associating with human dominated landscapes and is best displayed by omnivorous species. The higher association of granivorous species with human dominated habitats may be due to the large amount of bird feeders being put up in urban and rural areas, as mentioned by Lepczyk *et al.* (2004). Granivores having a greater association with human dominated habitats was also found by Lim and Sodhi (2004). Insectivorous species and mixed feeders weakly associated with non-human dominated habitats (Appendix A). In mixed feeders this may be because, similar to omnivorous species, mixed feeders can rely on multiple food sources and so are not as constrained to a particular habitat. As for the insectivorous species, the resource being utilized is quite abundant in non-human dominated habitat and so would explain of association to non-human dominated habitats. This is similar to what Lim and Sodhi (2004) have found, and this has been attributed to a lower availability of insects (Sekercioglu *et al.* 2002) in human dominated habitats.

Conclusion

Looking at the individual traits, medium sized, migratory, social, omnivorous species, as well as species that nest on man-made structures, are expected to be more associated with human dominated habitats, and as a result are predicted to occur more frequently in these areas. Guilds that showed indifference or that were very weakly associated with one habitat over the other included large, ground and shrub nesting, and granivorous species. Finally, guilds that tended to associate with non-human dominated habitats included cavity and tree nesters, small, not social, mixed feeders, and insectivorous species.

In contrast to Croci *et al.* (2008), this study did not find that grouping species based on their respective life history traits prove effective in differentiating among species that associated with human positively or negatively. Although Laube *et al.* (2013) note that species' traits play an important role in determining the range that a species can occupy, only two out of the five traits were significant, body size and nesting substrate (Appendix A). For example, in the case of diet and nesting substrate, the latter seems to be more influential in determining presence in a human dominated habitat than the former (Clergeau *et al.* 2006). In situations like this, it may explain why certain traits were significant, as one trait may be more influential than the other.

Despite this, the other traits did display trends that, for the most part, reflected the results of Croci *et al.* (2008) and may prove to be useful in terms of management.

When considering management, the use of the index of association will serve as the best predictor for each individual species. Although, human and non-human dominated habitats are conglomerates of several habitat types, this may still give predictive power as to where the specific species is most likely to be found. As 44 species were found to significantly associate with one habitat or another, this would then ideally allow to prioritize which species are likely to require special management or not. Species, in human dominated habitats, that are abundant and have strong associations with humans (Jeschke and Strayer 2006) and will not require special management include: the Barn Swallow, Brown-headed Cowbird, Dark-eyed Junco, European Starling, House Finch, House Sparrow, MacGillivray's Warbler, Northwestern Crow, Northern Rough-Winged Swallow, Pine Siskin, Rufous Hummingbird, Red-Winged Blackbird, Savannah Sparrow, Spotted Towhee, Violet-Green Swallow, White-Crowned Sparrow, Western Tanager. The Yellow Warbler and Swainson's Thrush do associate with human dominated habitats, however are not significantly associated with these and monitoring these species may be a good idea. In light of expanding cities and rural areas, management efforts should not be allocated towards the above-mentioned specie and focus on the 27 species that prefer non-human dominated habitats to be most efficient.

Analyzing traits individually and categorizing all the traits, even though some could have been treated as continuous variables, is an aspect of the study that if repeated, would be done differently. By only analyzing individual traits, one discovers which ones are more associated with human dominated habitats, however, no single trait will determine the occurrence of a species. Furthermore, using discrete categories for the traits may have been easier to organize the species into respective guilds but for some traits it may have been more effective to have them as continuous variables. Also, when categorizing the species there were some grey areas. For example, where species chooses to nest varies with height and substrate, and although the preferred combination was used in this study, species are not necessarily limited to one nesting height or substrate and may nest in areas other than the preferred ones. This was also the case with diet, where species are not necessarily limited to one type of food.

Areas of further research may include doing a similar study except as mentioned above, use a combination of continuous and categorical variables and also looking at more than one region in British Columbia, and even comparing between regions across the country. This study only looked into the effects of traits on the probability of occurrence, however, looking at climatic factors and the distribution of the species habitats may also be of interest.

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Appendices

Appendix A: Statistical Output

Table 6: Individual species response to non-human dominated habitats

Species	Difference of Means	Standard Error of Difference	│T-value│	Adjusted p-value	Polygon Area p-value	TEM p-value
American Goldfinch	0.1419	0.005847	24.27	0.0000	0.002	0.000
American Robin	0.04012	0.002965	13.53	0.0000	0.001	0.000
Bald Eagle	0.02978	0.003530	8.437	0.0000	0.000	0.000
Barn Swallow	-0.2478	0.005128	48.32	0.0000	0.0053	0.000
Bewick's Wren	0.1292	0.004756	27.16	0.0000	0.000	0.000
Brown-headed Cowbird	-0.06404	0.005818	11.01	0.0000	0.000	0.000
Brown Creeper	0.2451	0.004885	50.17	0.0000	0.973	0.000
Chestnut-backed Chickadee	0.1231	0.002995	41.11	0.0000	0.000	0.000
Chipping Sparrow	0.06501	0.003116	20.86	0.0000	0.000	0.000
Common Raven	0.09984	0.005748	17.37	0.0000	0.576	0.000

Species	Difference of Means	Standard Error of Difference	│T-value│	Adjusted p-value	Polygon Area p-value	TEM p-value
Dark-eyed Junco	-0.02124	0.005174	4.104	0.0000	0.000	0.000
European Starling	-0.1870	0.003361	55.64	0.0000	0.915	0.000
Fox Sparrow	0.03043	0.001826	16.67	0.0000	0.084	0.000
Golden-crowned Kinglet	0.1485	0.004180	35.53	0.0000	0.000	0.000
Hammond's Flycatcher	0.2067	0.004374	47.26	0.0000	0.002	0.000
Hairy Woodpecker	0.02653	0.000922	28.79	0.0000	0.832	0.000
House Finch	-0.08048	0.001308	61.52	0.0000	0.000	0.000
House Sparrow	-0.07448	0.001960	37.99	0.0000	0.000	0.000
House Wren	0.04332	0.004460	9.713	0.0000	0.000	0.000
MacGillivray's Warbler	-0.02382	0.005152	4.624	0.0000	0.000	0.000
Northwestern Crow	-0.1413	0.004594	30.76	0.0000	0.001	0.000
Northern Flicker	0.03862	0.005426	7.117	0.0000	0.000	0.000

Species	Difference of Means	Standard Error of Difference	│T-value│	Adjusted p-value	Polygon Area p-value	TEM p-value
Northern Rough-winged Swallow	-0.01029	0.002390	4.305	0.0000	0.719	0.000
Orange-crowned Warbler	0.1774	0.003566	49.75	0.0000	0.000	0.000
Olive-sided Flycatcher	0.006331	0.002959	2.140	0.0324	0.000	0.032
Pine Siskin	-0.06564	0.004577	14.34	0.0000	0.000	0.000
Pileated Woodpecker	0.2741	0.004768	57.49	0.0000	0.007	0.000
Pacific-slope Flycatcher	0.1791	0.005683	31.51	0.0000	0.000	0.000
Purple Finch	0.1097	0.006234	17.60	0.0000	0.000	0.000
Red-breasted Nuthatch	0.2794	0.004832	57.82	0.0000	0.000	0.000
Rufous Hummingbird	-0.06238	0.004040	15.44	0.0000	0.000	0.000
Red-winged Blackbird	-0.07481	0.005026	14.89	0.0000	0.210	0.000
Savannah Sparrow	-0.1417	0.006185	22.91	0.0000	0.019	0.000
Song Sparrow	0.006915	0.004303	1.607	0.1081	0.000	0.108

Species	Difference of Means	Standard Error of Difference	│T-value│	Adjusted p-value	Polygon Area p-value	TEM p-value
Spotted Towhee	-0.08628	0.004787	18.02	0.0000	0.000	0.000
Swainson’s Thrush	-0.002031	0.004601	0.4415	0.6589	0.058	0.659
Townsend’s Warbler	0.2775	0.004702	59.02	0.0000	0.000	0.000
Tree Swallow	0.2007	0.006464	31.04	0.0000	0.068	0.000
Varied Thrush	0.1290	0.004888	26.39	0.0000	0.000	0.000
Violet-green Swallow	-0.1228	0.005637	21.78	0.0000	0.000	0.000
Warbling Vireo	0.02868	0.003266	8.781	0.0000	0.000	0.000
White-crowned Sparrow	-0.08439	0.004118	20.49	0.0000	0.000	0.000
Western Tanager	-0.01179	0.001096	10.76	0.0000	0.000	0.000
Wilson’s Warbler	0.09518	0.004615	20.62	0.0000	0.000	0.000
Winter Wren	0.2018	0.003973	50.78	0.0000	0.439	0.000
Yellow-rumped Warbler	0.1935	0.004394	44.04	0.0000	0.000	0.000
Yellow Warbler	-0.006108	0.003341	1.828	0.0675	0.000	0.068

Table 7: Individual species response to non-human dominated habitats without ‘Polygon Area’ as a covariate

Species	Difference of Means	Standard Error of Difference	│T-value│	Adjusted p-value	TEM p-value
American Goldfinch	0.1427	0.005843	24.42	0.0000	0.000
American Robin	0.04052	0.002963	13.68	0.0000	0.000
Bald Eagle	0.03081	0.003530	8.729	0.0000	0.000
Barn Swallow	-0.2474	0.005124	48.28	0.0000	0.000
Bewick’s Wren	0.1282	0.004754	26.97	0.0000	0.000
Brown-headed Cowbird	-0.06186	0.005821	10.63	0.0000	0.000
Brown Creeper	0.2451	0.004881	50.21	0.0000	0.000
Chestnut-backed Chickadee	0.1240	0.002995	41.41	0.0000	0.000
Chipping Sparrow	0.06557	0.003114	21.05	0.0000	0.000
Common Raven	0.09970	0.005743	17.36	0.0000	0.000
Dark-eyed Junco	-0.02009	0.005172	3.883	0.0001	0.000
European Starling	-0.1870	0.003358	55.69	0.0000	0.000
Fox Sparrow	0.03056	0.001824	16.75	0.0000	0.000

Species	Difference of Means	Standard Error of Difference	∣T-value∣	Adjusted p-value	TEM p-value
Golden-crowned Kinglet	0.1497	0.004180	35.81	0.0000	0.000
Hammond's Flycatcher	0.2073	0.004371	47.42	0.0000	0.000
Hairy Woodpecker	0.02652	0.000921	28.80	0.0000	0.000
House Finch	-0.08077	0.001308	61.76	0.0000	0.000
House Sparrow	-0.07533	0.001963	38.38	0.0000	0.000
House Wren	0.04472	0.004461	10.02	0.0000	0.000
MacGillivray's Warbler	-0.02195	0.005155	4.259	0.0000	0.000
Northwestern Crow	-0.1407	0.004591	30.64	0.0000	0.000
Northern Flicker	0.03967	0.005423	7.314	0.0000	0.000
Northern Rough-winged Swallow	-0.01033	0.002388	4.324	0.0000	0.000
Orange-crowned Warbler	0.1787	0.003568	50.09	0.0000	0.000
Olive-sided Flycatcher	0.007348	0.002960	2.483	0.0130	0.013
Pine Siskin	-0.06463	0.004576	14.13	0.0000	0.000
Pileated Woodpecker	0.2746	0.004764	57.64	0.0000	0.000

Species	Difference of Means	Standard Error of Difference	∣T-value∣	Adjusted p-value	TEM p-value
Pacific-slope Flycatcher	0.1808	0.005684	31.82	0.0000	0.000
Purple Finch	0.1109	0.006231	17.79	0.0000	0.000
Red-breasted Nuthatch	0.2807	0.004831	58.10	0.0000	0.000
Rufous Hummingbird	-0.06117	0.004040	15.14	0.0000	0.000
Red-winged Blackbird	-0.07508	0.005021	14.95	0.0000	0.000
Savannah Sparrow	-0.1423	0.006180	23.02	0.0000	0.000
Song Sparrow	0.009076	0.004311	2.105	0.0353	0.035
Spotted Towhee	-0.08540	0.004785	17.85	0.0000	0.000
Swainson's Thrush	-0.002397	0.004597	0.5214	0.6021	0.602
Townsend's Warbler	0.2791	0.004704	59.34	0.0000	0.000
Tree Swallow	0.2002	0.006459	30.99	0.0000	0.000
Varied Thrush	0.1280	0.004886	26.19	0.0000	0.000
Violet-green Swallow	-0.1198	0.005649	21.21	0.0000	0.000
Warbling Vireo	0.02941	0.003265	9.009	0.0000	0.000
White-crowned Sparrow	-0.08247	0.004124	20.00	0.0000	0.000

Species	Difference of Means	Standard Error of Difference	│T-value│	Adjusted p-value	TEM p-value
Western Tanager	-0.01132	0.001098	10.31	0.0000	0.000
Wilson's Warbler	0.09595	0.004612	20.80	0.0000	0.000
Winter Wren	0.2016	0.003970	50.79	0.0000	0.000
Yellow-rumped Warbler	0.1951	0.004397	44.39	0.0000	0.000
Yellow Warbler	-0.005200	0.003340	1.557	0.1195	0.120

Table 8: Trait and guild responses based on the Index of association and grouping after Tukey's Post Hoc test

Trait	p-value	Guild	Sample Size	Mean Index of Association	Standard Deviation	Grouping
Size	0.018	Large	12	0.0281	0.1349	AB
		Medium	22	0.0024	0.1155	B
		Small	13	0.1252	0.1128	A
Nesting Substrate	0.002	Cavity	11	0.1308	0.1253	A
		Ground	8	-0.0051	0.1045	AB
		Man-made	3	-0.1698	0.0879	B
		Shrub	5	0.0096	0.0804	AB
		Tree	19	0.0603	0.1114	A
Migratory Pattern	0.499	Migratory	32	0.0342	0.1310	A
		Sedentary	15	0.0617	0.1254	A

Trait	p-value	Guild	Sample Size	Mean Index of Association	Standard Deviation	Grouping
Sociability	0.135	Not Social	39	0.0557	0.1265	A
		Social	8	-0.0191	0.1281	A
Diet	0.165	Granivorous	3	-0.0009	0.1239	A
		Insectivorous	21	0.0751	0.1318	A
		Mixed Feeder	17	0.0466	0.1214	A
		Omnivorous	4	-0.0787	0.1259	A

Appendix B: Bird Species Summary

Table 9: Summary of the traits of the bird species

Common Name	Latin Name	Nesting Substrate	Feeding guild	Social interaction with other birds in same species	Migratory or Sedentary	Size (wingspan)
Chesnut-backed Chickadee	*Poecile rufescens*	Tree cavity nester, also use nest boxes	Mixed feeder (insectivore, granivore)	Not known	Sedentary	Small
American Robin	*Turdus migratorius*	Tree nester (preference), will nest from ground to tree tops	Insectivore/Frugivore	Social	Migratory	Medium
acific-slope Flycatcher	*Empidonax difficilis*	Tree nester (preference)/shrub nester	Insectivore	Social	Migratory	Small

Common Name	Latin Name	Nesting Substrate	Feeding guild	Social interaction with other birds in same species	Migratory or Sedentary	Size (wingspan)
Song Sparrow	*Melospiza melodia*	Shrub nester (preference), ground nester, also in trees	Omnivore	Not social	Migratory or Sedentary	Medium
Orange-crowned warbler	Oreothlypis celata	Shrub/ground nester (preference)	Insectivore/Frugivore	Not social	Migratory	Small
ownsend's Warbler	*Setophaga townsendi*	Tree nester	Insectivore	Not social	Migratory	Small
Rufous ummingbird	*Selasphorus rufus*	Tree nester	Nectarivore/Insectivore	Not social	Migratory	Small
Spotted Towhee	*Pipilo maculatus*	Ground nester	Omnivore	Not social	Sedentary, some migrate	Medium
Dark-eyed Junco	*Junco hyemalis*	Ground nester	Mixed feeder (Granivore/Insectivore)	Not Social	Migratory	Medium
Red-breasted Nuthatch	*Sitta canadensis*	Cavity nester	Mixed feeder (Insectivore/Granivore)	Not social	Partial Migrant	Small
Brown-headed Cowbird	*Molothrus ater*	Brood parasite	Mixed feeder (Granivore/Insectivore)	Social	Short distance migrant (within North America)	Medium
Pine Siskin	*Spinus pinus*	Tree nester (preference)/shrub nester	Mixed feeder (Granivore/Insectivore)	Social	Migratory	Small

Common Name	Latin Name	Nesting Substrate	Feeding guild	Social interaction with other birds in same species	Migratory or Sedentary	Size (wingspan)
Brown Creeper	*Certhia americana*	Cavity nester	Mixed feeder (Insectivore/Granivore)	Not social	Sedentary, some migrate	Small
inter Wren	*Troglodytes hiemalis*	Variable (cavity,ground, tree)	Insectivore	Not social	Sedentary	Small
urple Finch	*Carpodacus purpureus*	Tree nester (preference), shrub nester, sometimes ground	Mixed feeder (Granivore/Insectivore)	Not Social	Migratory	Medium
White-crowned Sparrow	*Zonotrichia leucophrys*	Shrub nester/ground nester (preference)	Mixed feeder (Granivore/Insectivore)	Not social	Migratory	Medium
Yellow-rumped Warbler	*Setophaga coronata*	Tree nester	Insectivore/Frugivore	Not Social	Migratory	Medium
iolet-green Swallow	*Tachycineta thalassina*	Cavity nester (tree or boxes)	Insectivore	Social	Migratory	Medium
Golden-crowned Kinglet	*Regulus satrapa*	Tree nester	Insectivore	Not social	Migratory	Small
ouse Wren	*Troglodytes aedon*	Tree cavities (prefer closer to ground)	Insectivore	Not social	Migratory	Small
ammond's Flycatcher	*Empidonax hammondii*	Tree nester	Insectivore	Not social	Migratory	Medium

Common Name	Latin Name	Nesting Substrate	Feeding guild	Social interaction with other birds in same species	Migratory or Sedentary	Size (wingspan)
American Goldfinch	*Spinus tristis*	Shrub nester	Granivore	Social	Migratory	Small
European Starling	*Sturnus vulgaris*	Cavity nester (trees, cliffs, nest-boxes)	Omnivore	Social	Migratory	Medium
Wilson's Warbler	*Cardellina pusilla*	Ground nester	Insectivore	Not social	Migratory	Small
orthwestern Crow	*Corvus caurinus*	Tree (most nest in trees in Vancouver BC), ground, shrub nester	Omnivore	Not Social	Sedentary	Large
Northern Flicker	*Colaptes auratus*	Cavity nester	Mixed feeder (Insectivore/Granivore/Frugivore)	Not social	Migratory	Large
Warbling Vireo	*Vireo gilvus*	Tree nester (preference)/shrub nester	Insectivore/Frugivore	Not social	Partial Migrant	Medium
ox Sparrow	*Passerella iliaca*	Ground nester (preference)/shrub nester	Mixed feeder (Insectivore/Granivore/Frugivore)	Not Social	Migratory	Medium
Yellow Warbler	*Setophaga petechia*	Tree nester (preference)/shrub nester	Insectivore/Frugivore	Not social	Migratory	Small

Common Name	Latin Name	Nesting Substrate	Feeding guild	Social interaction with other birds in same species	Migratory or Sedentary	Size (wingspan)
Bald Eagle	*Haliaeetus leucocephalus*	Tree nester	Carnivore (predatory)	Not Social	Migration depends on food, severity of climate of breeding site	Large
Common Raven	*Corvus corax*	Tree nester	Omnivore	Not social	Sedentary	Large
Swainson's Thrush	*Catharus ustulatus*	Shrub nester	Frugivore/Insectivore	Not social	Migratory	Medium
Barn Swallow	*Hirundo rustica*	Nests on any wall with an overhang (man made structures)	Insectivore	Not social	Migratory	Medium
Olive-sided Flycatcher	*Contopus cooperi*	Tree nester	Insectivore	Not social	Migratory	Medium
Red-winged Blackbird	*Agelaius phoeniceus*	marsh emergent vegetation nester/Tree nester	Mixed feeder (Granivore/Insectivore)	Not Social	Migratory	Medium
Savannah Sparrow	*Passerculus sandwichensis*	Ground nester	Mixed feeder (Insectivore/Granivore/Frugivore)	Not Social	Migratory	Small
Bewick's Wren	*Thryomanes bewickii*	Cavity nester (trees, cliffs, nest-boxes)	Insectivore	Not Social	Sedentary	Small

Common Name	**Latin Name**	**Nesting Substrate**	**Feeding guild**	**Social interactio n with other birds in same species**	**Migratory or Sedentary**	**Size (wingspan)**
Chipping Sparrow	*Spizella passerina*	Tree nester/shrub nester	Mixed feeder (Insectivore/Granivore/Frugivore)	Not Social	Migratory	Medium
Pileated oodpecker	*Dryocopus pileatus*	Cavity nester	Insectivore/Frugivore	Not Social	Sedentary	Large
acGillivray's Warbler	*Geothlypis tolmiei*	Ground nester/shrub nester (preference)	Insectivore	Not social	Migratory	Small
House Sparrow	*Passer domesticus*	Hole type nest/tree nester	Mixed feeder (Granivore/Insectivore)	Social	Sedentary	Medium
Tree Swallow	*Tachycineta bicolor*	Cavity nester (trees, nest-boxes)	Mixed feeder (Insectivore/Granivore)	Not Social	Migratory	Medium
Varied Thrush	*Ixoreus naevius*	Tree nester (preference), shrub nester, sometimes ground	Mixed feeder (Insectivore/Frugivore/Granivore)	Not social	Unclear on coast	Medium
Western Tanager	*Piranga ludoviciana*	Tree nester	Insectivore/Frugivore	Not social	Migratory	Medium
Hairy oodpecker	*Picoides villosus*	Cavity nester	Mixed feeder (Insectivore/Frugivore/Granivore)	Not social	Sedentary	Medium

Common Name	**Latin Name**	**Nesting Substrate**	**Feeding guild**	**Social interaction with other birds in same species**	**Migratory or Sedentary**	**Size (wingspan)**
ouse Finch	*Carpodacus mexicanus*	Tree nester, but will use variety of substrate like street lamps	Granivore/Frugivore/	Not Social	Seasonal movement, after 5-10 years permanent resident	Medium
Northern Rough-winged Swallow	*Stelgidopteryx serripennis*	Ground nester, but will accept cavity in vertical surface	Insectivore	Not Social	Migratory	Medium