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Student Research Report

Ecological Connectivity in Coastal British Columbia

How can we enhance habitat connectivity on the UBC campus and its adjacent ecosystems for the improvement of urban biodiversity ?

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How can we enhance habitat connectivity on the UBC campus and its adjacent ecosystems for the improvement of urban biodiversity ?

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Abstract

Habitat fragmentation has become an increasing threat to biodiversity , as it can result in isolation of species populations and the loss of genetic diversity. To address this problem, landscape connectivity modeling has become a popular method for identifying key areas for conservation efforts. The present study assessed habitat connectivity of two species , coyotes (Canis latrans) and brown creepers (Certhia americana), on the University of British Columbia campus using Conefor 2.6 and Conefor Inputs Tool. The study sought to identify key and hub patches for each species, to compare the connectivity of the two species and to identify important areas of connectivity for each species. The two species were selected based on their habitat requirements, proximity to greenspaces and dispersal distances. The land cover and Metro Vancouver data were used to identify habitat types and patch sizes needed by each species. Key and hub patches for each species were identified using spatial prioritization and evaluated their connectivity using the probability of connectivity (PC) values. The results showed that both species shared some important areas of connectivity, but brown creepers had a more connected network, while coyotes had higher key and hub patches. Areas of high and low connectivity for each species were also identified and found that connectivity was affected by factors such as buildings and proximity to greenspaces. The study highlights the importance of considering specific habitat requirements of different species in conservation efforts and emphasizes the need to prioritize the conservation of key and hub patches for maintaining habitat connectivity and ensuring the survival of multiple species. Future studies should focus on how factors such as landscape heterogeneity, human disturbance and habitat quality affect the connectivity of the two species.

Keywords: Habitat connectivity; Key-hub patches; Species dispersal; Landscape ecology; Conservation planning

Introduction

Urbanization is one of the leading causes of habitat fragmentation and loss, leading to significant declines in biodiversity worldwide. Urban environments can be challenging for many species, including coyotes and brown creepers, which are both known to be sensitive to habitat fragmentation (Lee-Wardell et al., 2019). Understanding the extent of habitat connectivity in urban environments is therefore critical for conserving these species and maintaining biodiversity. According to Ceballos et al. (2015), the sixth mass extinction on Earth is currently happening. If the current trend is allowed to continue, people would soon lose access to the benefits of biodiversity, including ecosystem goods and services, or cultural benefits. The International Convention on Biological Diversity outlines that ecosystem provide ecosystem services that support social, economic, and ecological well-being (Lee-Wardell et al., 2019). The biggest threat to biodiversity is altering the way resources are utilized by humans due to urbanization. Currently, the loss of biodiversity necessitates the challenge humanity is facing in leveraging the capacity of urban environments to replenish biodiversity (Rennalls et al., 2017). An essential element of ecosystem function, flexibility, and resilience is connectivity. Understanding the locations of significant habitat patches and how they are linked to one another becomes more crucial as urban areas get dense. Most often, urban greenspace is found as a patchwork of development, roads, utilities, and other land uses (Cen et al., 2015). The ability of plants and animals to disperse, the long-term flow of genes, and the sustainability of metapopulations can all be significantly impacted by habitat fragmentation, which can also have an adverse effect on ecosystem services (Dixo et al., 2009). The understanding of the landscape's capacity to meet habitat requirements is improved by quantifying the connectivity of urban greenspaces.

According to Rennalls et al. (2017) annual report, in line with the United Nations 17 Sustainable Development Goals released in 2015, there is a global concern to support biodiversity beyond government level through City Biodiversity

Indexes. Internationally, universities are aligning with regional priorities to conserve and develop wildlife habitat to support biodiversity. For instance, universities such as University College London in U.K, and Cornell in USA have demonstrated a need for ecological restoration on their campuses. This has resulted in increased ecosystem services ranging from climate resistant plants to supporting native populations. At the local and global scales, paradigms for the whole systems strategies to the conservation and improvement of biodiversity are being established. As a leading nation in science and sustainability, the University of British Columbia (UBC's) commitment in the worldwide movement toward bio - diversity preservation and improvement are crucial. This calls for attention to enhance biodiversity in urban environments inclusive of the UBC campus surrounded by numerous ecosystems that could increase ecosystem services and the social wellbeing of people around campus (Rennalls et al., 2017).

The University of British Columbia is a large and diverse urban environment that provides an ideal case study for assessing habitat connectivity. The UBC Vancouver campus offers or houses numerous ecosystem services and biological resources (Mantegna, 2018). This is evident by the fact that the university is a home to the UBC Botanical Garden (a living museum of native and foreign plant species) and is situated along the Pacific Flyway (an important migratory route for birds) and is close to Pacific Spirit Park (approximated 800 hectares of second growth forest) (Mantegna, 2018). Despite having these resources around the campus, few studies have investigated habitat connectivity on the UBC campus, and its adjacent ecosystems to facilitate the movement of flora and fauna to enhance ecological connectivity (Chu et al., 2022). Habitat connectivity refers to the degree to which habitats are connected or linked to each other (Hodgson et al., 2017). It describes the ability of wildlife and plant species to move through and use different habitats, which is important for maintaining healthy populations and ecosystems (Griswold et al., 2020). This study assessed habitat connectivity of coyotes and brown creepers on the UBC campus. Coyotes and brown creepers are two important species that can act as indicators of the overall health and connectivity of the UBC ecosystem (Hodgson et al., 2017). Coyotes are apex predators that play a critical role in regulating prey populations and maintaining ecosystem balance, while brown creepers are insectivorous birds that play a vital role in controlling insect populations and dispersing seeds (Dyson et al., 2019; Griswold et al., 2020).Assessing and comparing connectivity between these species can provide important insights into the overall health and connectivity of the UBC ecosystem (Griswold et al., 2020). Furthermore, identifying key and hub patches that are important for the connectivity of these species can inform conservation efforts and management strategies to restore biodiversity in urban environments (Hodgson et al., 2017).

This study sought to narrow the gap that exist between UBC campus and its adjacent ecosystems to promote ecological connectivity. The objectives of the study were to ;

- To determine habitat types that favor the connectivity coyotes and brown creepers on the UBC campus.
- To assess and compare habitat connectivity of coyotes and brown creepers on the UBC campus .
- To determine key-hub patches important for habitat connectivity of coyotes and brown creepers the UBC campus.

Therefore, this study sought to answer the broad research question : how we can enhance habitat connectivity on the UBC campus and its adjacent ecosystems for the improvement of urban biodiversity ?

Study area and data summary

Study area description

The study will be undertaken at the University of British Columbia Vancouver campus. The University is located at 49.2606° N and 123.2460° W, on the westernmost point of the Point Grey Peninsula in British Columbia, Canada (Figure 1) (Liang, 2021). The university is approximately 9.5 kilometers from downtown Vancouver and is largely encompassed by the Pacific Spirit Regional Park, was first established in a clearing of conifer forest (Sutherland, 2017). Since the campus' founding in 1908, it has increased the amount of urban space it covers with buildings, roadways, and open vegetation (UBC Campus & Community Planning, 2015). Currently 4.020 km2 in size, it includes a range of academic and natural land use types (Liang, 2021). On campus, the tree canopy has decreased by more than 24% in recent decades due to the growth of neighborhood housing complexes, with conifer cover reductions accounting for the majority of the decline (Sutherland, 2012). Furthermore, about half (2.044 km2) of the total campus land now consists of vegetative characteristics including grass, gardening beds, and trees, including the UBC Botanical Gardens and UBC Farm (Burton & Wiersma, 2016; Liang, 2021).

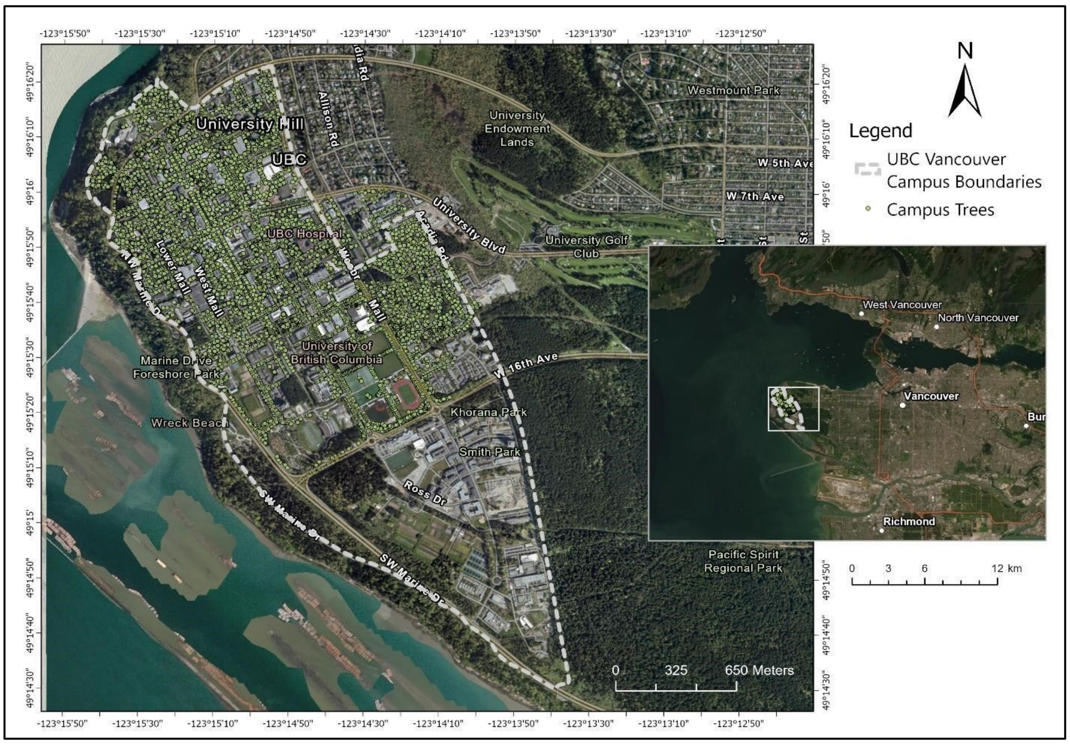

Figure 1 :The University of British Columbia encompassed by numerous trees species denoted by point grey, British Columbia, Canada. Trees within the boundary are well protected to avoid further loss due to urbanization. Burton & Wiersma (2016) provided a tree inventory data on the upper campus area sandwiched by academic land use. The Base imagery was projected in NAD 1983 UTM Zone 10N and sourced from ESRI, OpenStreetMap contributors and the GIS User Community (Liang, 2021).

Since 1925, the university has maintained and replanted approximately 10,000 native trees in its urban forest (UBC Campus & Community Planning, 2015). More so, the area provides numerous ecological services and biological resources as it is a home to the UBC Botanical Garden, a living museum of native and exotic plant species, that it is near Pacific Spirit Park, a second growth forest covering about 800 hectares, and that it is situated along the Pacific Flyway, a critical bird migration route (Mantegna, 2018). Other species within the study area include squirrels and coyotes. The study site has a constant climate, a flat landscape, and an average elevation of 87 meters (Liang, 2021). The area is characterized by warm, dry summers and mild, and wet winters because it is in the rain shadow of Vancouver Island and the Olympic Mountains

(Green & Klinka, 1994). The average high temperature in July and August is 22.2 °C, with temperatures of 30.6 °C and 34.4 °C, respectively. This season of year also has the lowest average precipitation, with 35.6 mm and 36.7 mm, respectively. The area has Canada's mildest climate, with droughts happening in drier areas and increasing yearly average temperatures recently (Environment and Climate Change Canada, 2020).

Data summary and descriptions

This section provides a description of the data summaries of the relevant dataset or sources I employed for this study. These datasets include the UBC Vancouver Campus Landscapes and Buildings , UBC Greenspaces, Metro Vancouver Landcover types, Campus wildlife, Campus landscape Metrics and connectivity and UBC Trees

Table 1: Data sets used in the study to assess habitat connectivity of coyotes and brown creepers on the UBC campus. The most important data set I used for my analysis was the raster layer depicting different landcover types in Metro Vancouver.

Data	Description	Importance for the study
UBC Vancouver Campus Landscapes and Buildings	Map depicting the boundaries of Pacific Spirit Park (PSP), the UBC campus, as well as the locations of the university's buildings, streets, and green areas.	Creating polygons for study interest (UBC Botanical Garden, Wreck beach and PSP) as well as calculating landscape metrics connectivity in these ecosystems.
UBC Vancouver Campus Greenspaces	Dataset containing shapefiles of the location soft landscapes or greenspaces on the UBC Vancouver campus.	Determining ecological connectivity and facilitating species movement.
UBC Vancouver Campus Wildlife	Open-source data of citizen science observations of campus wildlife, collected using programmes like iNaturalist and EBird and made available by the Global Biodiversity Information Facility (GBIF).	Identifying potential areas for increasing greenspaces to facilitate species movement within and outside ecosystems such as UBC Pacific Spirit Park, Wreck beach and Botanical Garden.
UBC Vancouver Campus Landscape Metrics Identification and Connectivity	Data from Metro Vancouver on ecological connectivity report, evaluating regional ecosystem connectivity in Metro Vancouver and providing a clear methodology to measure ecological connectivity employing the software Conefor.	Designing methodology and evaluating or identifying habitat patches for indicator species on the UBC campus using Conefor software tool. Employing landscape metrics such as number of links (NL), degree of Probability of Connectivity (dPC), and dPC connector.
Landcover types in Metro Vancouver	This data contained all the landcover types in Metro Vancouver designed from the Sensitive Inventory	This was used to extract the different land cover types that exist on the UBC campus

Methods

The chief geospatial inputs for my analysis were high-resolution land cover (LC_v4 and Metro Vancouver data), the greenspaces and buildings layers, and UBC boundary polygons. My analysis was facilitated by the utilization of Conefor 2.6 (Saura & Torné, 2009) and the Conefor Inputs Tool for ArcGIS 10.x 1.0.218 (Jenness, 2016), which allowed for a comprehensive and rigorous examination of the data.

The analytical process was divided into four distinct stages, commencing with the characterization of greenspaces and the identification of appropriate species, followed by the parameterization of the model, creation of habitat patches and links, generation of the Key and hub patches (quality layer, and the calculation of area-weighted quality) . The careful selection of Conefor metrics, which were tailored to the specific needs of the analysis, further ensured the scientific validity and accuracy of the findings.

Selection of species and model parameterization

To select species for connectivity modelling, each species was selected based on habitat type, dispersal distance, sightings, patch size (Lee & Rudd, 2003). Habitat types were determined based on land cover types, composition of landscapes, as well as proximity to greenspaces (Saura et al., 2017; Metro Vancouver Report, 2018). Dispersal distances for each species were calculated by finding the mean and median to determine patch sizes for species survivor. Modelling parameters required for this analysis included the median and maximum dispersal and minimum patch size required for survival. Factors that limit dispersal were also identified such as buildings. All the above elements were assessed by evaluating various primary and secondary sources from literature.

Two species were selected for connectivity modelling: the coyotes (Canis latrans), and the brown creeper (Certhia americana). The two species require mature forest as habitat; however, each species has unique habitat and dispersal characteristics. Each species chosen can be considered an umbrella species for conserving particular habitat types: coniferous or mixed or urban areas or grasslands for coyotes; and larger patches of mature forest, either deciduous, coniferous, or mixed for the brown creeper.

Conefor requires three types of information to model landscape connectivity for a species. These are minimum patch size and a species' minimum and maximum dispersal distances. To create realistic connectivity models, habitat patches with landcovers corresponding to each species habitat needs were selected (Table 2).

Table 2. Species parameters used for patch selection and connectivity modelling in Conefor.

Species	Median Dispersal (m)	Max distance(m)	Min patch size (ha)	Land Cover types	**Disp. roads & buildings**
Coyotes	100	1000	0.02	Coniferous or mixed, grassland, & wetlands	Yes
Brown creepers	88	2110	2.3	Mature Forest (Coniferous, Deciduous, Mixed)	No

Assessing habitat requirement & patches for the two species on the UBC campus

The brown creeper is a passerine bird species that is an indicator of mature forests (Poulin & Villard, 2011). C. americana has been shown to be sensitive to forest disturbances such as logging, and to have reduced fledgling survival within 100m of forest edges (Poulin & Villard, 2011). eBird Canada data shows multiple sightings for the brown creeper in Vancouver (eBird, 2012). I chose to model the brown creeper in as a species representative of larger, varied forest patches, as C. americana uses both coniferous and deciduous trees for foraging and nesting.

Coyotes are a common species in Vancouver and can be found in a variety of habitats, including urban and suburban areas, as well as parks and green spaces (City of Vancouver, 2021). They are highly adaptable and are known to thrive in human-altered environments. Coyotes are opportunistic and can utilize a wide range of habitats, including forests, grasslands, and wetlands (BC Ministry of Environment and Climate Change Strategy, 2021). Coyotes have been observed on the UBC campus, which is located in a forested area near the Pacific Spirit Regional Park and is surrounded by forested habitats that provide ideal cover and food sources for coyotes (Klinkenberg, 2019). However, human activity and development in the area may also contribute to the presence of coyotes on campus (BC Ministry of Environment and Climate Change Strategy, 2021)

To identify and determine habitat patches for the two species, I used the LC_v4 data to extract habitat types required on the UBC campus (Figure 2) and then extracted habitat types for each species using the Selection by Attributes function in ArcGIS Pro. I then created habitat patches for each species. Habitat patches for each species were created from the harmonized greenspace layer. Adjacent vegetation polygons sharing the landcover types relevant for each species were dissolved together. For example, for the brown creeper, polygons with coniferous, deciduous, and mixed forest labels were dissolved together into 'forest' patches. After the dissolve operation, the multi-part to single-part tool in ArcGIS Pro was used to ensure that resulting polygons had unique IDs. Habitat patches were then filtered by area to remove those which were less than the minimum patch size for a given species. For the coyotes, mature coniferous patches >= 0.02ha were selected. For the brown creeper, all mature forest was dissolved into polygons and those >= 2.3ha were selected. Each patch was assigned a quality value determined by overlaying patches with the UBC boundary quality layer and multiplying the resulting quality value by patch area. This area-weighted quality value is an important patch attribute, (a), for Conefor modelling (Saura et al., 2017; Williams et al., 2018).

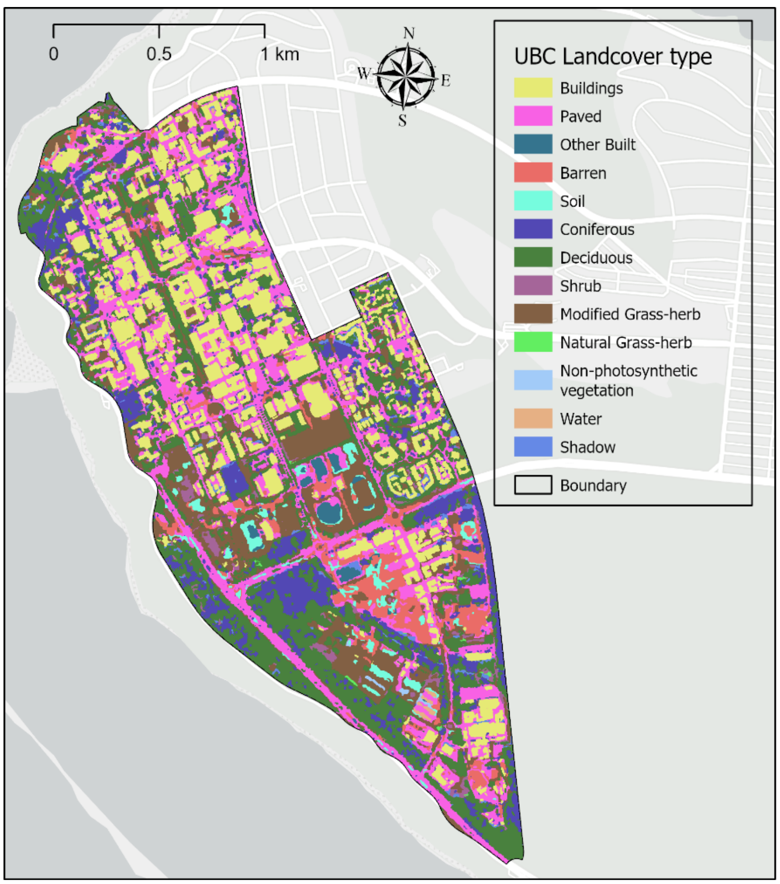

Figure 2: Different landcover types on the UBC campus extracted from Sensitive Ecosystem Inventory conducted in 2014 in Metro Vancouver, Canada.

Identifying key and hub patches for each species

To identify key and hub patches for the two species, I utilised habitat patches layer created and imported in Conefor 2.6. To evaluate key patches and assess the value for each species based on ecological connectivity, I conducted a spatial analysis by employing spatial prioritization (Metro Vancouver Report, 2018). The identified key patches were then overlayed to ascertain areas that provide the greatest collective value (Metro Vancouver, 2018). Further, to assess overall patch importance for each species, I employed an output metrics (degree probability of connectivity (dPC)), that binds within-patch and between- patch connectivity (Saura et al., 2017). Overall, key patches and hub patches for each species were determined contingent on the frequency distribution of dPC and dPCconnect (Saura & Pascual-Hortal, 2007). Any patches with a dNC (number of components) < 0 were, therefore, identified as hub patches whose removal would increase the number of components in the network, and therefore increase habitat fragmentation (Saura et al., 2017).

Identifying UBC important areas for connectivity for each species

To assess areas of most significance for connectivity on the UBC campus, I employed the two-output metrics (dPC and dPCconnect) through Conefor inputs software (removes all cells with low connectivity) (Saura et al., 2017; Metro Vancouver Report, 2018). I also used a related metric of dPC called PC, which quantifies the overall level of landscape connectivity of a given species network, and dPC measures the effect of node removal on overall network connectivity and identifies key patches in the network. dPC consists of: dPCintra, a measure of intrapatch connectivity, dPCconnect, the importance of a patch for connecting other patches together, and dPCflux, a measure of how connected a patch is to the network. These metrics values for each species were computed to determine areas of high connectivity and low connectivity on the UBC campus. I also used the Select by Location function in ArcGIS Pro to determine areas of high or low connectivity by assessing factors like buildings, roads, and proximity to greenspaces.

Below is a summary of the methodology employed for this project;

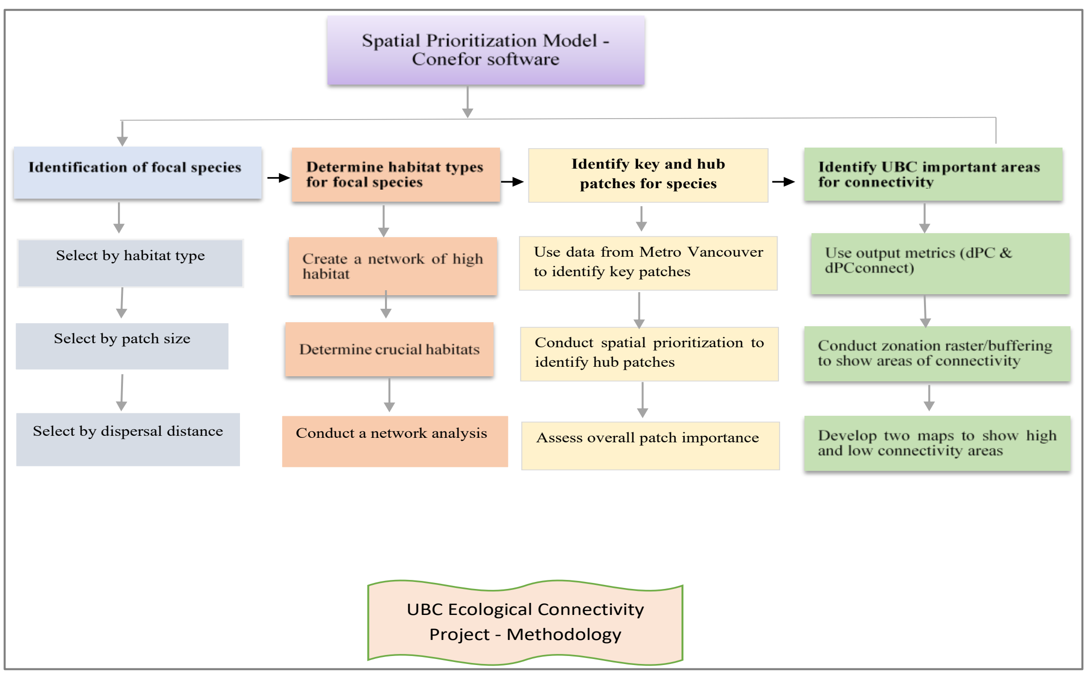

Figure 3: Spatial prioritization model using Conefor software (purple color) to assess ecological connectivity on the UBC Vancouver Campus and its adjacent ecosystems (Pacific Park Spirit, UBC Botanical Garden and Wreck Beach). The first step in the methodology involved identifying focal (indicator) species (denoted by light-grey), then determined habitat types for species (light-orange), identified key and hub patches for species (light-yellow) and ended with identifying important areas for connectivity on the UBC campus (light-green). The horizontal arrows signified the logical flow of the main methods while the arrows pointing down under each main step (method) signified the order in which activities occurred.

Results

Assess and compare habitat connectivity for the two species

The brown creepers had the most connected network, with PC value of 0.00625 than coyotes with connectivity value of 0.00321 (Figure 4,Table 3, Figure 5). The probability of connectivity (PC) indicates how connected the landscape is for that species, quantifying the amount of reachable habitat per species. Coyotes have a higher key and hub patches determined by dPC, dPCconnector & dNC than brown creepers (Table 2). Hub patches are the most important patches for each species for maintaining the connectivity of their respective networks. Hub patches were determined using dPCconnector, which is the measure of a patch's importance for connecting other patches together (i.e. stepping stone importance), and dNC, which is a measure of how important a patch is for maintaining component integrity. Counterintuitively, the more important a patch is for maintaining the number of components in the network, the more negative dNC becomes.

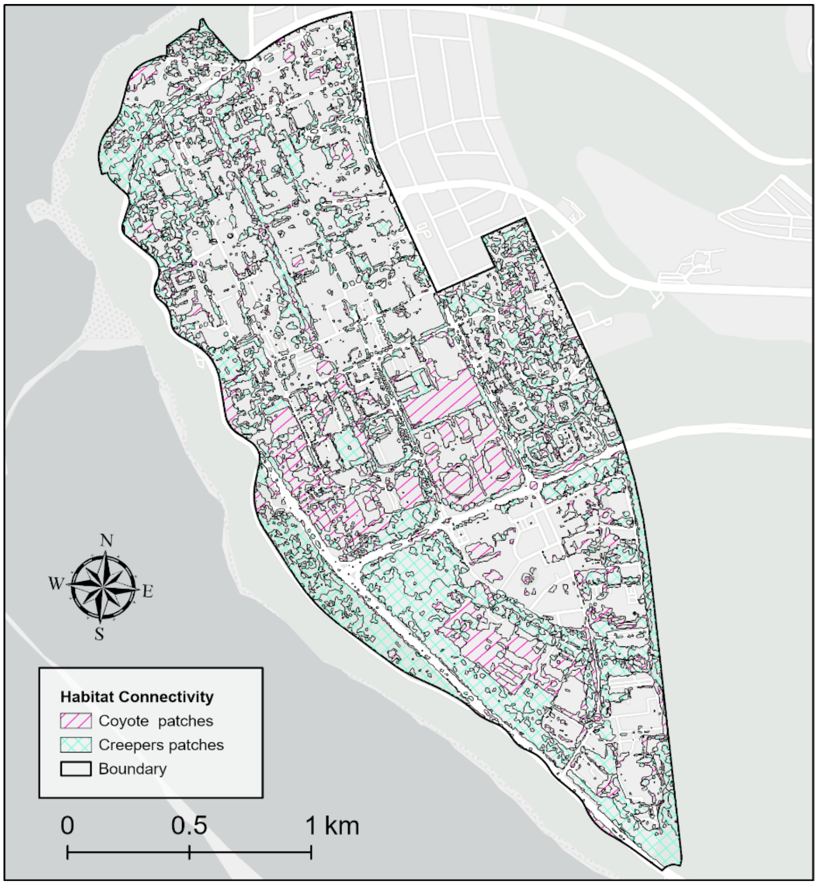

Figure 4; Brown creepers have a better-connected network than coyotes on the UBC campus. However, there is an overlap in the use of habitat types for the two species.

Overall, brown creepers had more links than coyotes especially between areas of low to high connectivity . There was a significant difference between low and high areas of connectivity for the two species (Figure 5).

Table 3: Habitat connectivity for brown creepers & coyotes on the UBC campus measuring PC, dPC & dNC .

Species	Probability of connectivity (PC Values)	Key patch percentile threshold (dPC)	Hub patch percentile threshold (dPCconnector and dNC)	Sum of dPCintra	Sum of dPCflux
Brown creepers	0.00625	0.6	0.8	12.23	111
Coyotes	0.00321	0.8	0.98	8.44	120

Figure 5: The degree of probability of connectivity (dPC) between brown creepers and coyotes indicate that brown creepers are well connected as observed by the number of links (red). However, coyotes have bigger patch sizes important for connectivity.

Identifying UBC important areas of connectivity (Key-hub patches) for each species

Coyote species networks contained good examples of hub patches that, although they may be smaller, with more edge and lower area-weighted quality, play an integral role in maintaining the connectivity of a network (Figure 6) .Coyotes prefer areas located in the southern part of campus where there are less buildings. The differences in hub patches for the two species was significantly minimal (Figure 4, Table 3). The different habitat types and landcover combinations, the key-hub patches for the two species provided an overview of areas important for habitat connectivity on the UBC campus. Because dPC can be considered as the sum of dPCintra, dPCflux and dPCconnector, key patches represented all elements of connectivity. Nonetheless, because both dPCintra and dPCflux use area-weighted quality in their calculation, dPC tends to be driven by area-weighted patch quality. Key patches that were better connected to the rest of the network showed added importance, but large, high-quality patches still qualified as a key patch even if they were isolated (Figure 6).

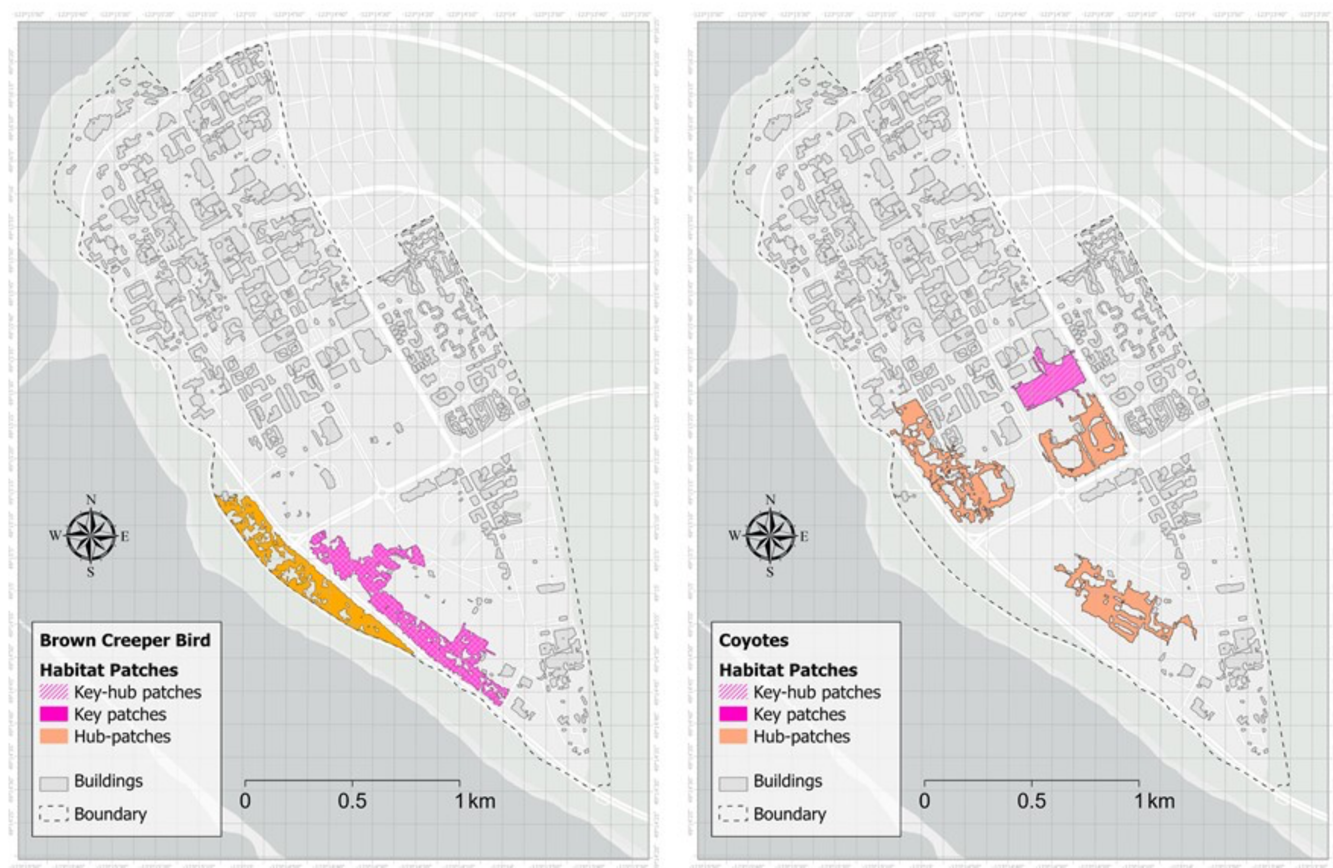

Figure 6: Key-hub patches determine important areas for connectivity on the UBC campus. There is an overlap in key-hub patches between brown creepers and coyotes.

Discussion

Assessing and comparing habitat connectivity for the two species

In this study, I applied spatial prioritization model method in Conefor and ArcGIS Pro software, using the high-resolution land cover data (LC_v4 and Metro Vancouver data), to assess and compare habitat connectivity of two species, brown creepers, and coyotes . Habitat connectivity provides the need to understand and maintain the interconnectedness of natural habitats, which is essential for the survival and persistence of species in the face of increasing habitat fragmentation and loss (Dyson et al., 2019), as observed on the UBC campus. My analysis revealed that brown creepers had a more connected network, with a higher probability of connectivity (PC) value of 0.00625 compared to coyotes with a connectivity value of 0.003 (Table 3, Figure 4).These findings differ from what Griswold et al. (2020) found, who reported that urban brown creepers have lower connectivity in Vancouver than in suburban landscapes. However, coyotes had higher key and hub patches, which play an important role in maintaining network connectivity. Similar findings were reported by Dyson et al. (2019) that key-hub patches for carnivore species are higher in Metro Vancouver. Hub patches were determined using dPCconnector, which measures a patch's importance for connecting other patches, and dNC, which measures the importance of a patch in maintaining component integrity (Williams, 2019; Metro Vancouver 2020). Key-hub patches are the most important patches in the network as they provide critical habitat on their own while also linking the network (Smith et al., 2016; Ban et al. 2017; Williams, 2019).

My findings suggest that there are significant differences in the connectivity of the two species on the UBC campus (Figure 4 & 5). Brown creepers were found to be more widely distributed and have a higher probability of connectivity (Table 3) (Williams, 2019). This could be explained by the fact that birds have an ability to fly and are not impacted by factors such as road, buildings or rivers (Ban et al. 2017). In contrast, coyotes tend to prefer areas in the southern part of the campus, where there are fewer buildings (Figure 5). This could be explained by the findings of Williams (2019) , who reported that coyotes are highly impacted by the presence of humans. Similarly, this preference by coyotes could be due to a variety of factors, such as food availability, water sources, or shelter (Dyson et al., 2019). Nonetheless, Smith et al. (2016) argued that coyotes prefer urban areas such as buildings and are highly adaptable to various environments. Understanding the preferences of different species in terms of their habitat requirements is important for developing effective conservation strategies (Nagorsen et al., 2016).

Overall, assessing and comparing habitat connectivity between species provides insights into the ecological requirements and preferences of each species, which can inform habitat management and conservation strategies (Ban et al., 2017). For example, brown creepers had higher connectivity values, it may indicate that they are more adaptable to fragmented landscapes and has a higher likelihood of persisting in the long term. Moreover, comparing habitat connectivity between species can help to identify areas of overlap and potential conflicts, such as competition for resources or habitat fragmentation (Smith et al., 2016). This information can be used to develop more targeted conservation and management efforts that consider the needs and requirements of multiple species. Finally, assessing and comparing habitat connectivity can help to identify important areas for conservation, such as key-hub patches, that can support the persistence of multiple species and maintain ecosystem functioning (Dyson et al., 2019).

Identifying Key-hub patches and UBC important areas of connectivity for each species

The second objective of my study was to identify key areas of connectivity for two different species, coyotes, and brown creepers. The results of the study revealed the presence of hub patches that play a critical role in maintaining the connectivity of the network (Figure 6). These findings are consistent with the findings of Hodgson et al. (2017), who reported that hub patches may be smaller in size and have lower area-weighted quality, but they are integral to the overall connectivity of the network. Similarly, Haeussler et al. (2017) highlighted the importance of considering even smaller patches of land in conservation efforts, as they can have a significant impact on maintaining habitat connectivity (Haeussler et al., 2017).

The study found that coyotes have large key-hub patches than brown creepers, but overall creepers have a better habitat connectivity (Figure 6). This is explained by Nagorsen et al. (2016), who reported that coyotes are large, wide-ranging predators that require large home ranges to find sufficient prey and maintain viable populations. As a result, they tend to use larger patches of habitat and have larger core areas than smaller, more specialized species like brown creepers. Similar suggestions were reported by Williams (2019) that coyotes have a more flexible diet and can use a range of habitats, which may allow them to persist in areas with lower connectivity . Furthermore, the results revealed that the differences in hub patches for the two species were minimal, indicating that the two species share some important areas of connectivity (Figure 5 & 6) . Similar results were reported by Ban et al. (2017), that animals tend to have areas (hub patches) they share for survivor and such areas include water points and location of food resources (Griswold et al., 2020). The identification of key-hub patches for each species provides an overview of areas important for habitat connectivity (Williams, 2019) on the UBC campus. The minimal differences in hub patches for the two species suggest that certain areas of the UBC campus are important for maintaining habitat connectivity for multiple species (Table 3, Figure 6) (Thompson et al., 2019). This finding is particularly significant as it highlights the importance of preserving and protecting these areas to ensure the survival of multiple species (MacLeod et al., 2019).

Overall, identifying key-hub patches and important areas of connectivity between species, such as coyotes and brown creepers on the UBC campus, is important for several reasons. First, it provides critical information for conservation planning and management efforts, enabling the development of more targeted and effective strategies to protect and maintain these species and their habitats (Zhu et al., 2020). By identifying the most important patches and areas for connectivity, conservationists can prioritize these areas for habitat restoration, land acquisition, or other conservation measures to ensure that they remain functional and connected (Moore et al., 2017). Also, identifying key-hub patches and important areas of connectivity can help to identify potential conflicts between species and inform the development of management strategies to reduce these conflicts (Sun et al., 2015; Dickson et al., 2018). For example, if coyotes and brown creepers are competing for the same key-hub patch, conservationists may need to manage the patch to ensure that both species can use it effectively without causing harm to one another (Dickson et al., 2018).

Application of the study in a broader context

This study on habitat connectivity of coyotes and brown creepers on the UBC campus has important implications for conservation and management efforts not only in the local context but also in a broader context. It highlights the importance of assessing and comparing habitat connectivity for different species, which can provide critical information for conservation planning and management. Also, identifying key-hub patches and important areas of connectivity can help to inform landscape-level conservation efforts, enabling conservationists to prioritize their efforts and maximize the benefits of conservation actions (Metro Vancouver , 2020). Moreover, the study provides a valuable contribution to the broader understanding of the importance of habitat connectivity in maintaining biodiversity and ecosystem functioning. Habitat fragmentation and loss of connectivity are major threats to biodiversity worldwide (Olson et al., 2017), and identifying key-hub patches and important areas of connectivity can help to address these threats. By focusing on connectivity, conservationists can help to maintain species interactions, gene flow, and ecosystem processes that are essential for the long-term persistence of ecosystems and the services they provide.

Overall, the study highlights the importance of assessing and comparing habitat connectivity for different species and identifying key-hub patches and important areas of connectivity in broader landscape-level conservation efforts. These approaches can help to maintain biodiversity, ecosystem functioning, and the benefits that these provide to humans and other species.

Limitations and improvement of the study

One of the limitations of this study was that it only examined two species, and thus, these findings may not be representative of other species on the UBC campus. Moreover, the study did not take into consideration of factors such as number of trees for the brown creepers and roads for coyotes. Additionally, the analysis focused on the physical connectivity of patches and did not consider other factors that could affect species connectivity, such as landscape heterogeneity, human disturbance, and habitat quality. Nonetheless, the study could be improved by increasing the number of species and taking into consideration factors affecting the maximum dispersal distance of the two species . Also, the study could be improved by exploring the impacts of landscape heterogeneity and human disturbance on species connectivity and network dynamics.

Conclusion and recommendations

Habitat connectivity on the UBC campus is an important issue that requires attention and action. Habitat connectivity plays a critical role in maintaining the health and sustainability of ecosystems. The results of this study highlight the importance of identifying key and hub patches for different species, as they provide important areas for habitat connectivity. The study found that brown creepers had a more connected network compared to coyotes, but both species shared some important areas of connectivity. It is crucial to prioritize the conservation of these key and hub patches in any conservation efforts, considering the specific habitat requirements of different species. The fragmentation of habitats due to human activities has negative impacts on the survival and well-being of wildlife populations. The UBC campus has a diverse range of habitats, including forests, wetlands, and water bodies, which provide a habitat for a variety of wildlife species. However, the lack of connectivity between these habitats limits the ability of species to move and access resources, which can lead to isolation and reduced genetic diversity.

The current efforts to increase habitat connectivity on the UBC campus are commendable. The construction of wildlife crossings, green roofs, and habitat corridors are all measures that can help to restore connectivity and improve the overall health of the ecosystem. However, there is still much work to be done to ensure that these measures are effective in promoting habitat connectivity and supporting the needs of wildlife populations.

Recommendations:

1. Conduct a comprehensive survey of the UBC campus to identify areas where habitat fragmentation is the most severe and prioritize these areas for habitat connectivity initiatives.
2. Prioritise and conserve different landcover or habitat types that exist on the UBC campus such as coniferous and deciduous forests which favour brown creepers and coytotes.
3. Increase public awareness of the importance of habitat connectivity and encourage individuals to take actions that can help to support habitat connectivity, such as reducing the use of cars and planting native plants.
4. Engage in ongoing monitoring and evaluation of the effectiveness of habitat connectivity initiatives, to ensure that they are having the desired impact on wildlife populations.
5. Collaborate with researchers and conservation organizations to identify best practices and innovative solutions for promoting habitat connectivity on the UBC campus.
6. Explore the potential for incorporating habitat connectivity into the campus design process, to ensure that new buildings and infrastructure do not further fragment habitats and impede connectivity.
7. Consider incorporating green roofs and walls on existing buildings and new developments to create new habitats and corridors for wildlife.
8. Engage in ongoing communication and collaboration with stakeholders, including faculty, staff, students, and the surrounding community, to ensure that habitat connectivity initiatives are well-supported and successful in achieving their goals.

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