SEEDS KNOWLEDGE EXCHANGE:

Ecological Connectivity Toolkit

Toolkit Guide

Acknowledgements

Report Compiled By:

Ben Scheufler
Urban Biodiversity Coordinator
SEEDS Sustainability Program

Nicholas Mantegna
Senior Bachelor of Urban Forestry Student
UBC Faculty of Urban Forestry

Finn Köpf
Senior Bachelor of Urban Forestry Student
UBC Faculty of Forestry

Laura Arango
Climate Crisis in Urban Biodiversity (CCUB) Coordinator
SEEDS Sustainability Program

Zachary Johnston
Urban Biodiversity Coordinator
SEEDS Sustainability Program

Report Contributers

SEEDS Sustainability Program* student researchers**, Climate Crisis in Urban Biodiversity (CCUB) Initiative Steering Committee***

1. *The UBC SEEDS Sustainability Program is an internationally recognized Campus as Living Laboratory initiative, that advances UBC's sustainability and wellbeing commitments through applied student-led research and interdisciplinary partnerships between students, faculty, staff and community partners.

2. ***Climate Crisis in Urban Biodiversity (CCUB) is an initiative aimed towards co-creating interdisciplinary, demand-driven, diverse, and inclusive student-led research that informs urban solutions to the climate and biodiversity crises simultaneously. CCUB was launched as a PURE (Program for Undergraduate Research Experiences) funded pilot as part of the SEEDS Sustainability Program in partnership with the Faculties of Arts, Forestry, Science, and others.

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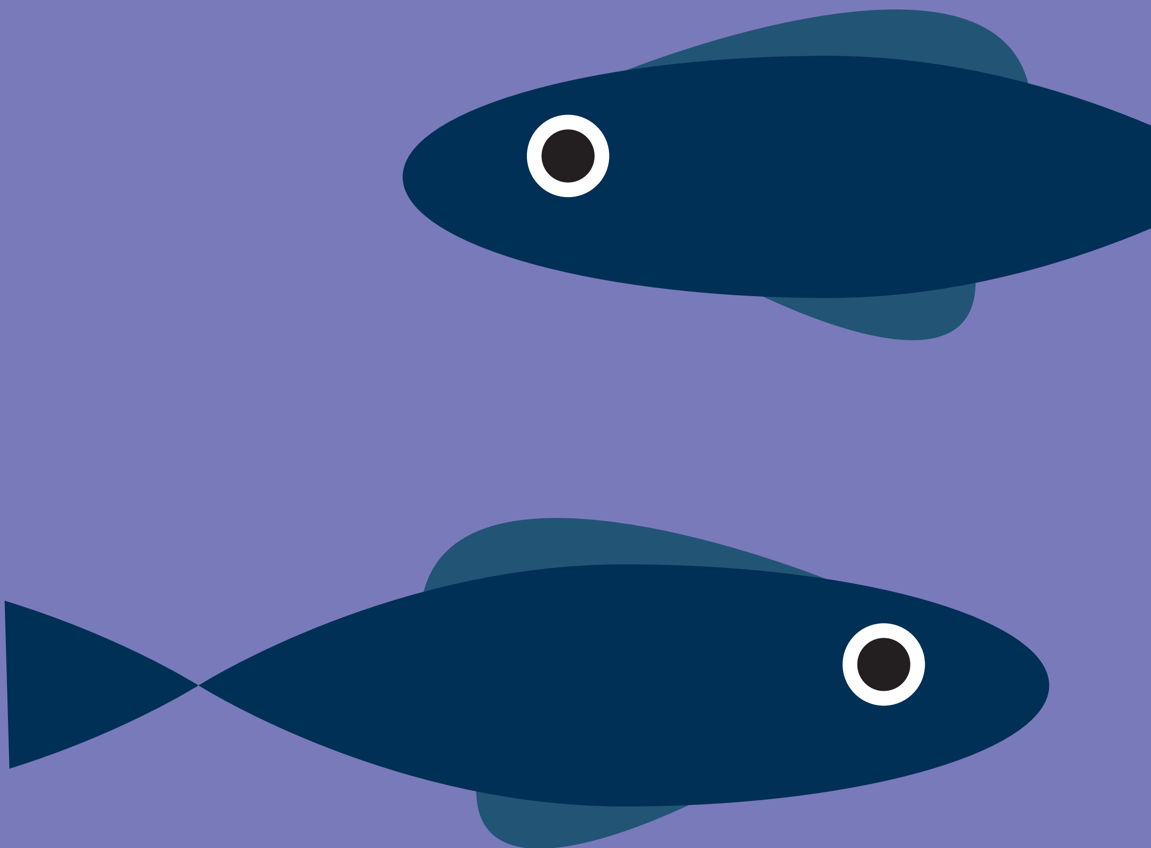


Toolkit Purpose:

Each Toolkit in the **Urban Biodiversity in a Changing Climate ToolTree** aims to support applied student-led research projects in partnership with UBC faculty and staff in ways that can help advance UBC's sustainability and wellbeing commitments. This Toolkit is designed to share learnings from the student-led Campus Tree Inventory on the UBC Vancouver Campus (2018-present), which has been identified as an important part of supporting healthy urban ecosystems, and interdisciplinary and applied research to advance UBC's sustainability commitments. This Toolkit describes the general process of conducting a tree inventory, and uses the ongoing UBC student-led Campus Tree Inventory as a case study to show how this practice can be implemented.

Who is this Toolkit for?:

UBC STUDENTS:
Tools can be used to support student applied research to inform UBC's guiding sustainability policies and commitments, and professional skills development related to the complex challenges connected to climate change and its impacts on biodiversity.

UBC OPERATIONAL STAFF:
Serve as a collection of summarised knowledge and lessons learned from student-led research, to continue and inform UBC's guiding sustainability policies and commitments and the areas of work which have inspired and guided the direction of SEEDS research.

UBC FACULTY:
Serve as a resource to integrate biodiversity and climate topics into curriculum, and support student research and professional skills development.

UBC COMMUNITY:
Promote community engagement and collaboration on biodiversity and climate change challenges and opportunities at UBC and beyond.

What will you Learn?

This toolkit covers a number of topics related to ecological connectivity. Learning outcomes include:

1

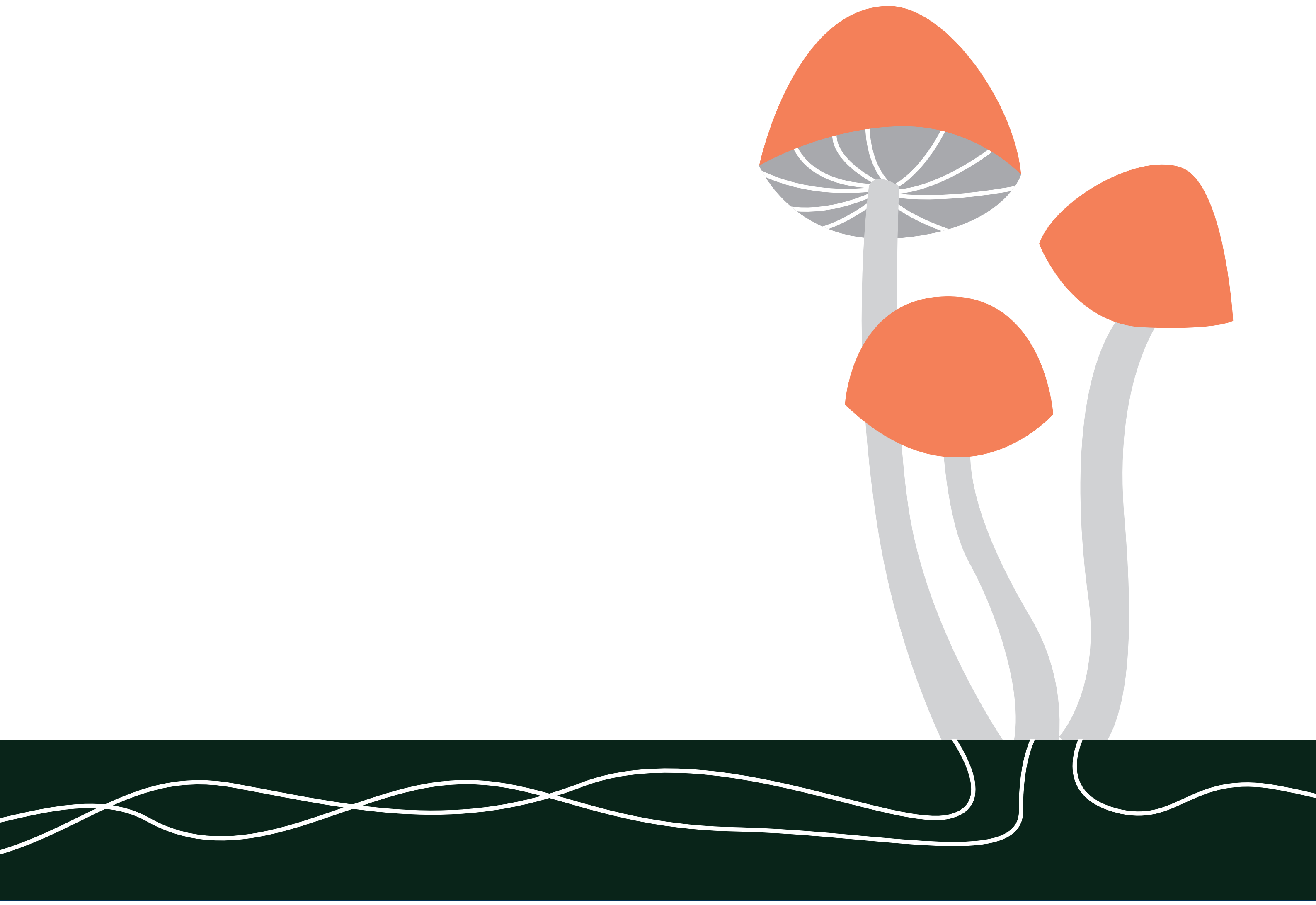
Learn about ecological connectivity, including structural and functional components, why they are important, and how they relate to urban biodiversity in a changing climate

2

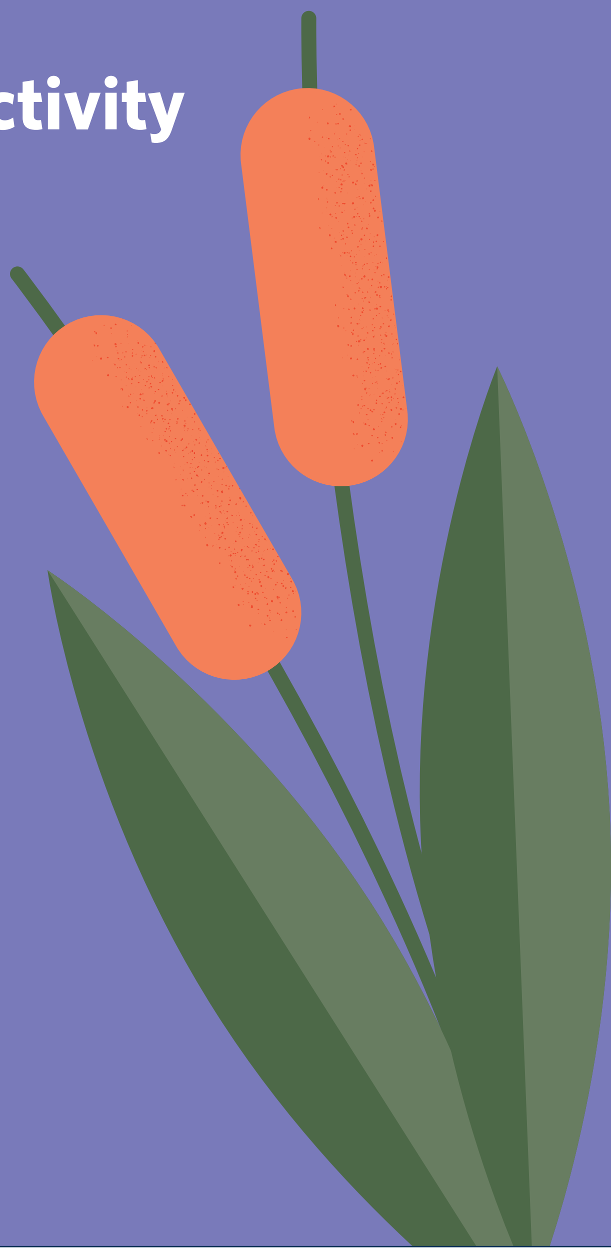
Learn about **key takeaways from applied student-led research on ecological connectivity** at UBC, and how it can apply to landscape planning and design.

3

Learn about how you can analyse urban landscapes to **determine how habitats connect** to one another.



About Ecological Connectivity



What is Ecological Connectivity?

Have you ever watched bees passing between backyard gardens, disregarding fences and walls? Have you ever seen a little seedling growing in a planter or soil without another individual of its species anywhere nearby? These are examples of the ways that urban habitats allow species to connect and travel through cities.

Ecological connectivity consists of 2 components. It is a measure of 1) how well connected habitats are to one another (Taylor et al. 1993), and 2) how easy it is for different species to move across the landscape (Vogt, et al. 2009). These two components are known as structural and functional connectivity:

Structural connectivity: Refers to "the degree to which the landscape facilitates or impedes movement along resource patches" (Taylor et al. 1993). Structural connectivity is determined by the spatial distribution of habitats, and it affects how possible it is for species to move between green spaces.

Functional connectivity: Refers to measures of how different species are likely to move across the landscape, given their specific habitat needs and how they interact with other organisms (Vogt, et al. 2009). Functional connectivity is determined by the structural connectivity of the landscape, as well as which specific plant and animal species live in the ecosystem.

Why is Ecological Connectivity Important?

Ecological connectivity is an important part of ecosystems that determines how well they can function and adapt, especially in urban areas. Ecological connectivity is important for biodiversity and many ecosystem services that benefit humans, including adaptation to climate change.

ECOLOGICAL CONNECTIVITY INCREASES, BIODIVERSITY INCREASES.

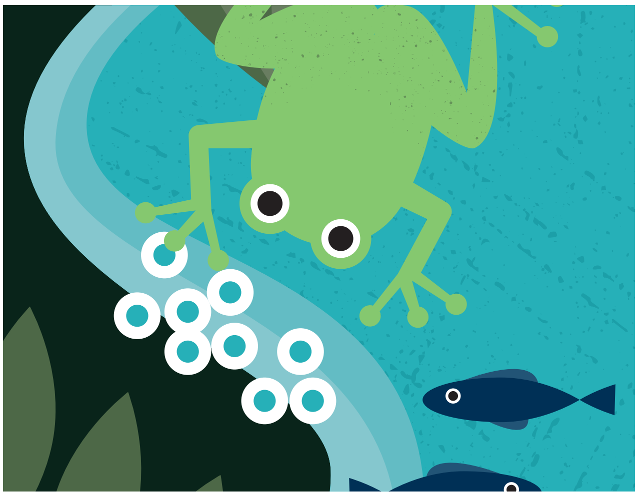
In 2017 researchers Melliger, Rusterholz & Baur looked at habitat factors that affected the behaviour and diversity among grasshoppers, butterflies and vascular plants in Basel, Switzerland. They found that although habitat size played a large role in biodiversity, a better indicator of butterfly and grasshopper diversity was the presence and accessibility of adjacent greenspaces.

BIODIVERSITY INCREASES, ECOSYSTEM FUNCTION INCREASES.

In turn, ecological functions are also generally enhanced by biodiversity (Tilman et al., 2014). Because some species are "more functional" than others (they have different traits that allow them to perform better), having more unique species (higher species richness) in the same ecosystem increases the probability that species which are more functional will be present — meaning more carbon is sequestered, more flowers are pollinated, etc.

ECOSYSTEM FUNCTION INCREASES, CLIMATE RESILIENCE INCREASES.

Biodiversity and ecosystem function both help ecosystems to adapt to climate change (Munang et al., 2013). One way to illustrate this is using the analogy of an airplane, with rivets holding the wing together — the plane may lose a few rivets after a shock (in the same way species could be lost in an ecosystem as the climate changes), however it will still be able to fly, as there are redundant rivets (in the same way other species may have also performed the same functions).



Urban Ecology

Even though many of the types of habitats and organisms found in cities are also found in natural areas, urbanisation gives cities a very unique combination of changing temperatures, hydrology and disturbances that make it harder to apply the same ecological “rules” that work in other ecosystems.

The field of urban ecology looks at these differences found in cities, to try and learn more about how cities work as ecosystems. One of the most important defining features of cities is the grid of impervious surfaces formed by streets and the built environment. Urban habitats exist inside of this “matrix” of non-habitat, and that means they are almost always very separated and fragmented compared to the natural landscape.

Caption: This view of the UBC Main Mall fountain shows the “matrix” of hard surfaces that surround the greenspaces on campus.

The Urban Forest

Although the practice of urban forestry has been defined in many research papers, the exact definition can be difficult to articulate. Often it is described as all trees and plants, both public and private, within and around cities and rural areas.

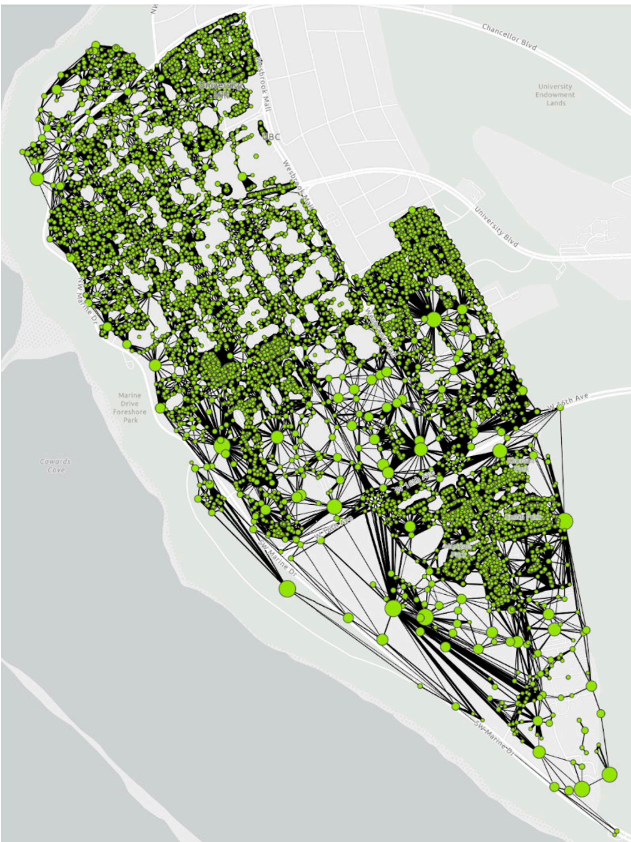
The Canadian Urban Forest Strategy defines the urban forest as **“trees, forests, greenspace and related abiotic, biotic and cultural components in areas extending from the urban core to the urban-rural fringe.”** (Tree Canada, n.d.)

This definition tries to capture a holistic view of urban forests, taking into account the important components of the ecological systems that help to sustain them.

Connectivity Research

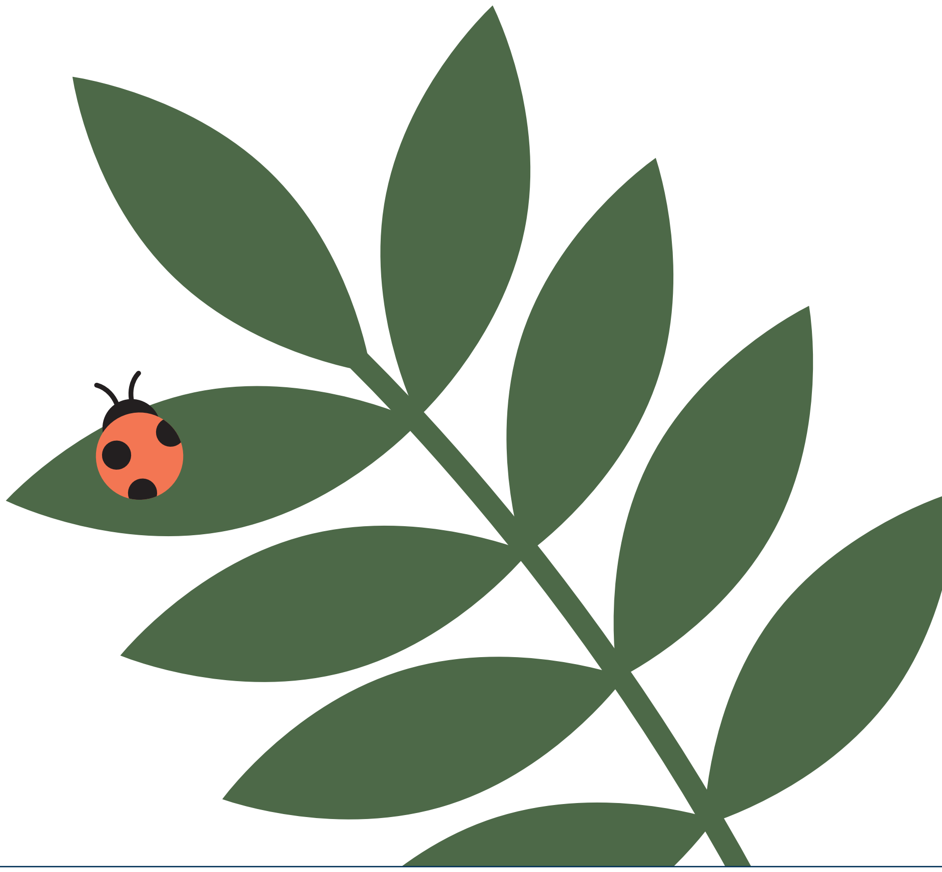
What can Ecological Connectivity Research Teach Us?

Research developed by Nick Mantegna, a senior undergraduate student in the Bachelor of Urban Forestry Program, in UBC's Faculty of Forestry. Read his full report here.



By taking what we know about the urban forest, and transforming it into this type of network model, we gain access to some powerful new ways of learning about how these urban habitats interact with one another. They can also offer clues on how we can mimic the design of nature for resilience. The field of network analysis has led to many great discoveries about the relationships in networks. "Betweenness centrality" and "Modularity" represent two key types of network relationships: they can each be calculated for other analyses using free online tools like Kumu.io, which allows users to develop their own network models!

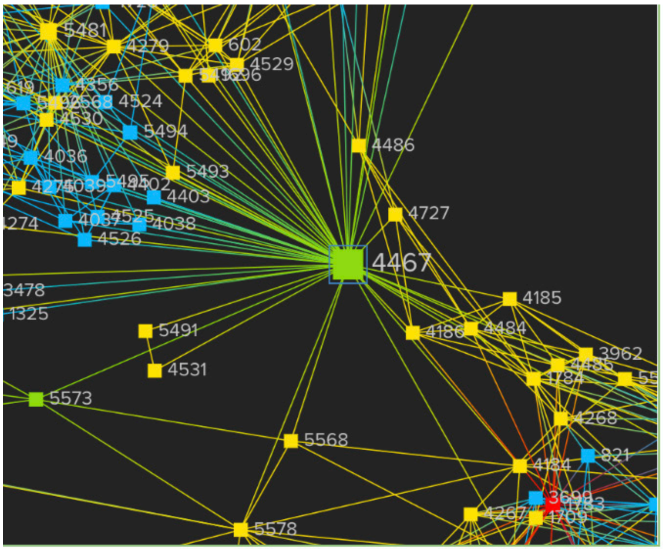
Caption: Student-led research developed this ecological connectivity network map of the University of British Columbia Vancouver campus, which shows the ways in which different vegetated areas are connected to one another, using nodes and links.



BETWEENNESS CENTRALITY

Betweenness centrality measures how many times an element lies on the shortest path between two other elements. For a small mammal, for example, the betweenness of a greenspace can be used to measure the likelihood that it will need to cross that greenspace on its journey, from one random point on campus to another. In a network, nodes with high betweenness centrality act as key bridges, and they can also be potential single points of failure.

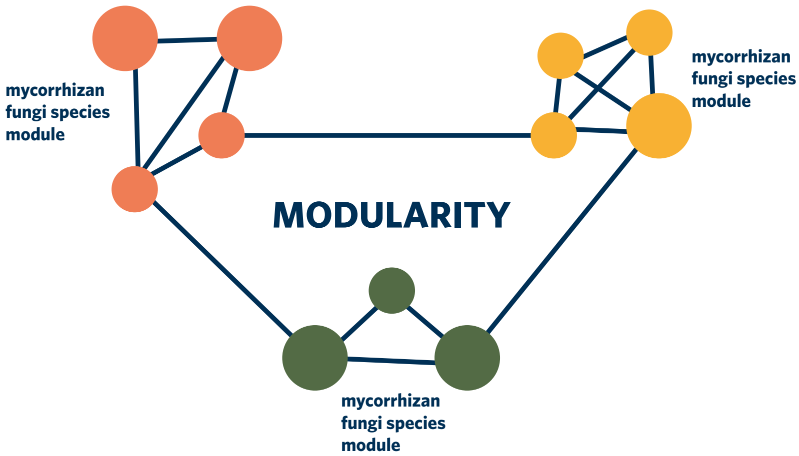
Example: The large green square below, labelled 4467 has the highest "betweenness" in the UBC Vancouver Campus' network of habitats. This means that it lies on the shortest path between the most other greenspaces in the network. This is understandable, as this point represents the forest at the UBC Farm, a large greenspace in a central place on campus. However, this also means that the farm forest represents an important strategic location in maintaining ecosystem health, as it has a strong influence on the movement of species through the ecosystem.



Caption: The image on the left shows the betweenness centrality of the UBC Farm (#4467). On the right, you can see this location in person!

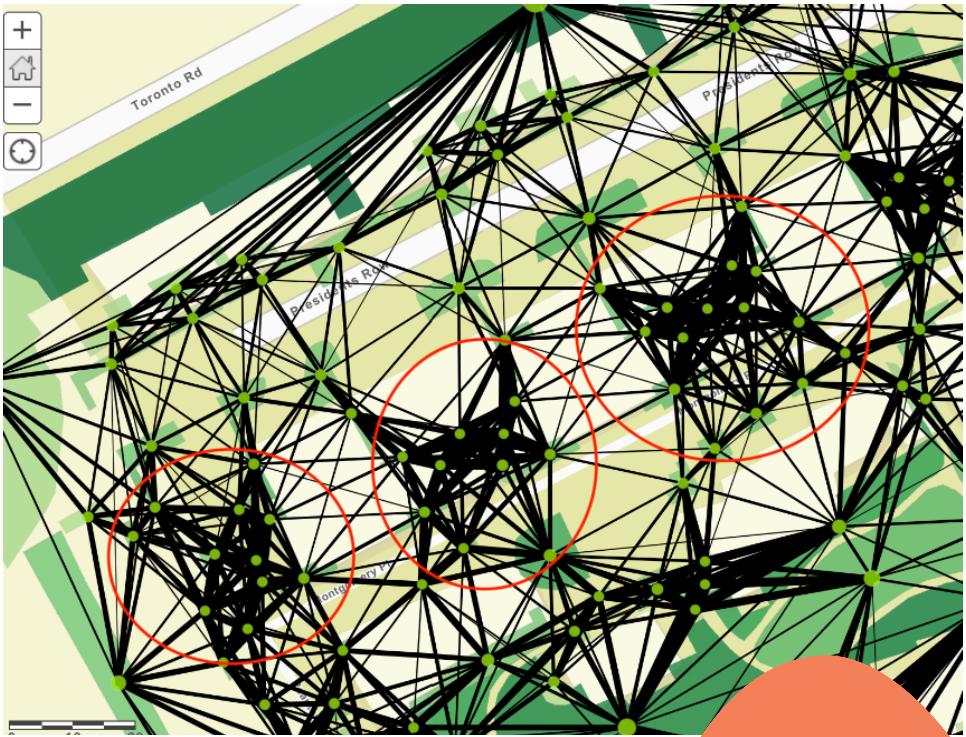
Modularity

A network with a high degree of modularity is
self-assembled into interconnected communities in which the number of connections within a group is maximised and the number of connections between groups is minimised. You can see an illustration of this concept on the right!

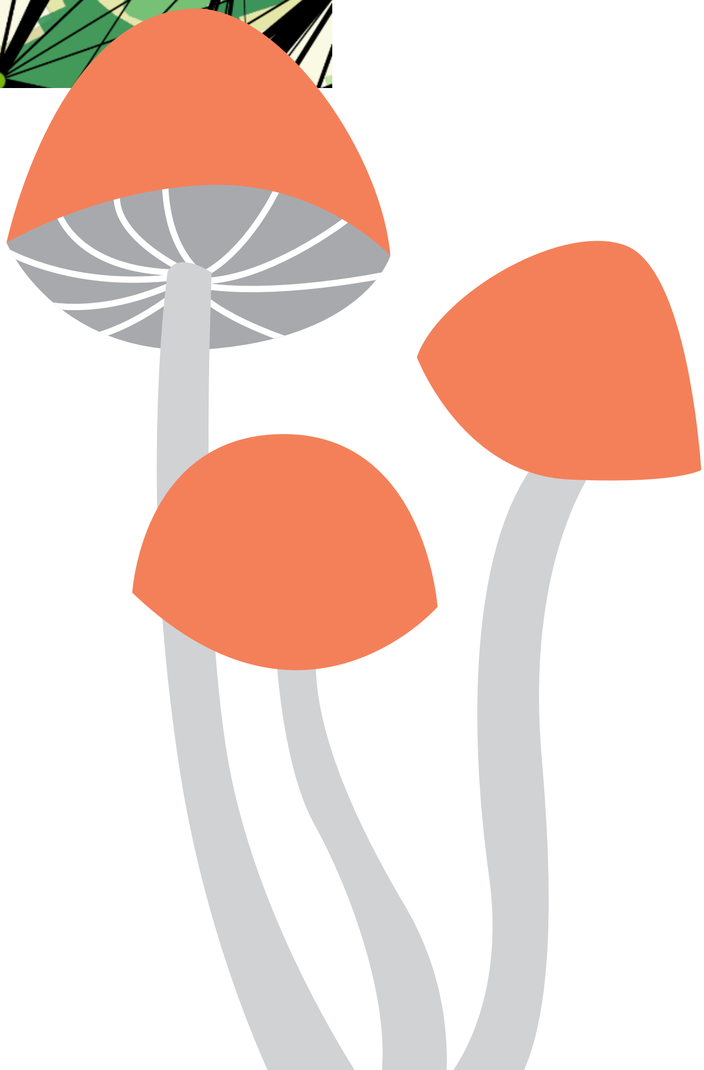


Caption: The image above provides a visual description of modularity. Within it, you can observe three distinct communities interacting between each other and within themselves. A similar structure can be observed in ecological connectivity maps provided in this toolkit (Mantegna, N. 2021).

Modularity is a key contributor to the resilience of greenspaces. When there is high modularity, animals can travel easily between habitat patches within the network, and it can be harder for pathogens or invasive species to infiltrate the area. By building modularity in landscapes, we can mimic the design of mycorrhizal networks, which have shown a high degree of modularity when they grow naturally. You can see an example of this type of connectivity below, in the Acadia Park neighbourhood on UBC's Campus.



Caption: The Acadia neighbourhood in the East campus of UBC Vancouver shows a high degree of modularity. Within the red circles, the communities of greenspaces are closely connected to one another, but they are less closely connected to the surrounding landscape.



How can you Increase Ecological Connectivity?

"By implementing this soft landscape communities design strategy at the UBC Vancouver campus, it is more likely that urban forests of UBC will be equipped to withstand local climate change impacts such as rising temperatures, extreme weather events and biodiversity loss."

— Mantegna, 2021

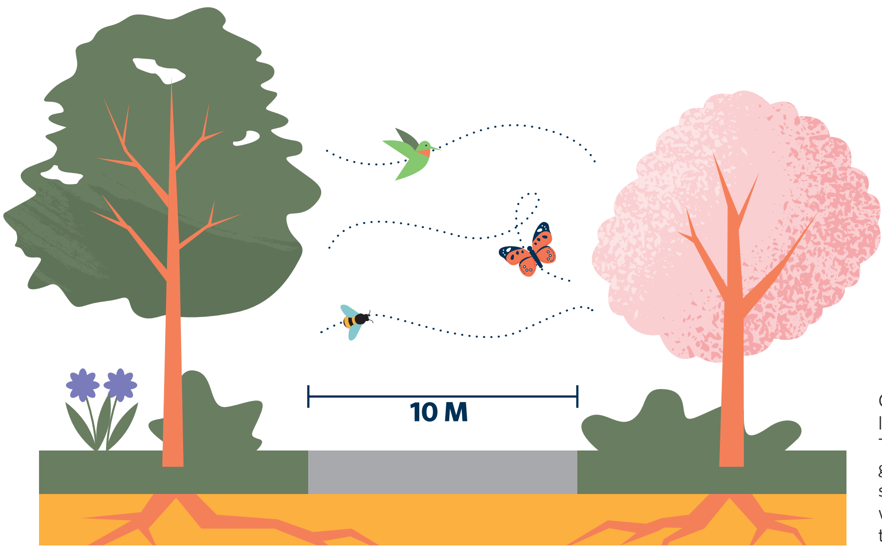
Ecological connectivity research has led to a number of conclusions for how landscape designers and planners can work to increase ecological connectivity in soft landscapes, for increased climate resilience and biodiversity. In this context, soft landscapes are defined as vegetated areas with soil within the built urban environment. See the key strategies listed below to see how connectivity can be enhanced:

DEVELOP MODULARITY

Given that biomimicry teaches us that mycorrhizal networks express a high degree of modularity, we can apply that knowledge to soft landscapes designs. Modular communities of soft landscapes can help enhance ecological connectivity. The soft landscape communities would mimic the modular design of a mycorrhizal network.

BUILD GREEN CORRIDORS FOR WILDLIFE

Green corridors (thin strips of greenspace that can facilitate movement of wildlife) can help to connect isolated green spaces to the larger green infrastructure network.



Caption: Physically linking two soft landscapes is not always possible. This diagram shows how nearby greenspaces could act as stepping stones to increase connectivity without being physically connected throughout.

IMPLEMENT GREEN ROOFS

Green roofs (building roofs that are covered with vegetation and a layer of soil) can fill a similar role to green corridors, because they can also act as stepping stones — especially for birds and other species that can easily reach them! This can help to lower the dead zone area, where there are many buildings on the landscape.

IMPLEMENT GREEN WALLS

Green walls (walls that support vertical vegetation) can provide a direct pathway between soft landscapes on the ground and a green roof that can facilitate movement of small organisms, thus improving the landscape connectivity.

Case Study: **Ecological Connectivity on the UBC Vancouver Campus**

About the Case Study

This case study highlights an applied, student-led research project that produced the first visual baseline of ecological connectivity on the UBC Vancouver campus.

By showcasing this case study, we hope you learn more about the processes, learning and tools used to create this ecological connectivity analysis, and that by doing so, you can apply concepts and tools to build upon this work. Below you will find a summary of this research, including the methods used, key learnings and resources:

Case Study - Adapted SEEDS Sustainability Program Research Project:

Author: Mantegna, N. (2021). UBC In A Changing Climate: Soft Landscape Communities Design Strategy. Retrieved from: https://sustain.ubc.ca/sites/default/files/seedslibrary/FRST_248_201_Soft%20Landscape%20Communities%20Design%20Strategy_FinalReport.pdf

Web Map Retrieved from: https://www.arcgis.com/home/item.html?id=7ce9a40969094e0b9cd8a55de6068c1b

Faculty of Forestry Staff Partners: Campus + Community Planning, UBC Botanical Garden

SCOPE

The project aimed to identify opportunities to enhance connectivity and biomimicry that could be used to inform decision making processes and practices at UBC, in order to to accelerate climate action and maintain and enhance campus biodiversity.

METHODS

The process used to develop the ecological connectivity network map included 6 mains steps:

Supporting Video Resource: Mantegna also created a video of himself walking through the web map and web scene tool. You can view the video through this youtube link.

Step 1: Greenspaces in Geographic Information Systems (GIS)

Any greenspace on campus can be geographically represented as a polygon in a Geographic Information System (GIS). UBC maintains a github repository that includes GIS data for a variety of features on campus. Within that repository is a dataset that contains polygon data for all of the “soft landscapes” on campus (vegetated areas with soil), and attributes like their type of greenspace — from patches of lawn, to wild areas like Pacific Spirit Park!

Step 2: Finding the Connections

To start the analysis, a "buffer" was created around each of the polygons. In GIS, a buffer is an area that is added on to the outside of a shape. Buffers were used to determine which greenspaces were "connected" to other greenspaces. Buffer size needed to be determined, and it was identified that a 10 metre buffer would be the best distance to determine connectivity.

Why use a 10 metre buffer size? Research found that soft landscapes closer than 10 metres apart were more likely to have these types of ecological connections. This distance was chosen as a rough estimate for the minimum dispersal range for many smaller organisms, fungal hyphae and animal-dispersed seeds from street trees. Additionally, a two lane road at UBC, with bicycle lanes on either side is approximately 10 metres wide. Therefore, any soft landscapes that are not directly across the street from one another would not have buffers that overlap.

Step 3: Recording the Connections and Strength of Connections

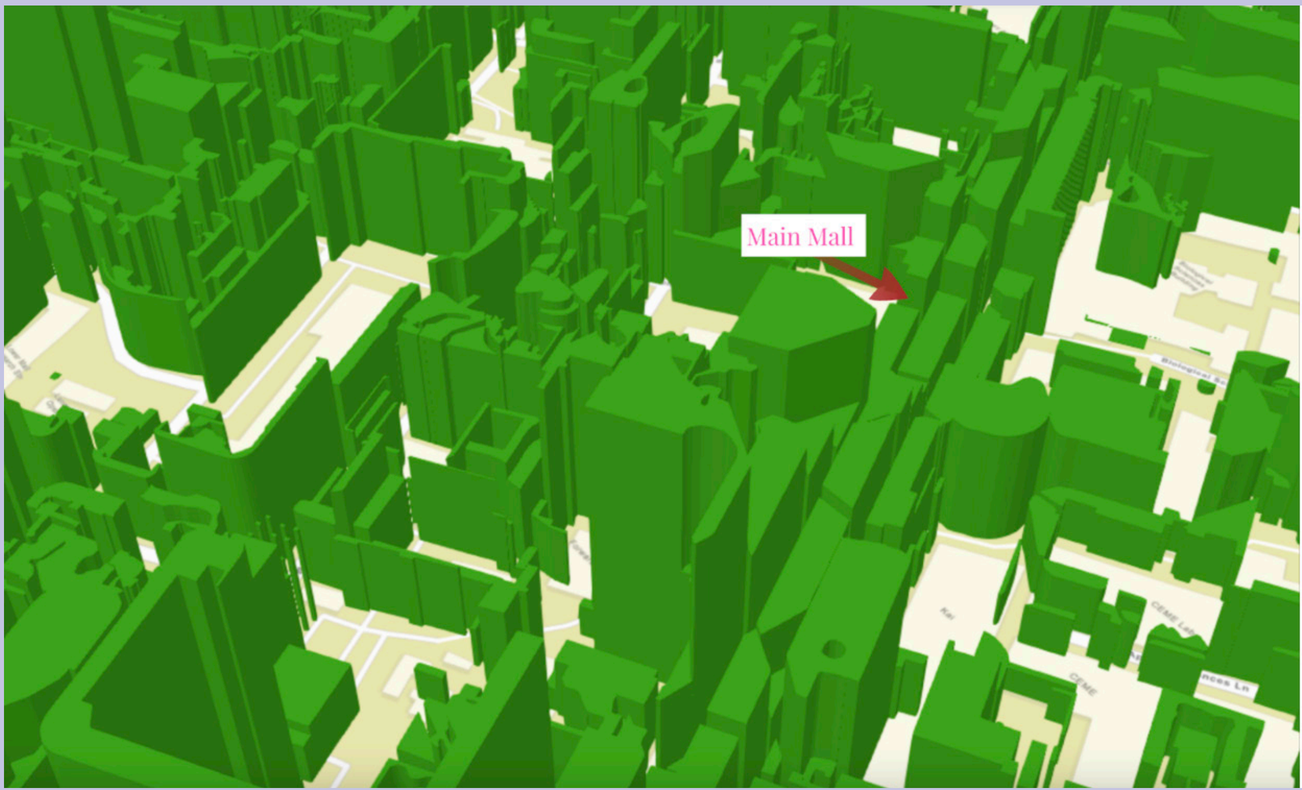
Next, the "polygon neighbours" tool in ArcGIS Pro was used which counted all of the intersecting buffers for each polygon. To calculate how connected each polygon was to its neighbours, 3 key metrics were used:

The number of different greenspaces that each polygon was connected to. Greenspaces that are connected to more other greenspaces on the surrounding landscape are more likely to help animals to move across the landscape.

The total area that was overlapped for each connection. Soft landscapes with a high area measurement (m2) are likely to have higher ecological connectivity than soft landscapes with a low area measurement.

Tree count on each soft landscape. A soft landscape with trees is likely to have higher ecological connectivity than a soft landscape without trees, because they provide important shade and nutrients to their neighbouring organisms.

With these three metrics, the metrics were exported to a spreadsheet and each of them were scaled from 0 to 1, to create a relative "index" for each metric. The average of the three scaled metrics (frequency, tree density, area) was calculated, then applied back to the soft landscapes, to create an "importance" value that was then added to each polygon. In the example below each polygon is extruded in 3D by their importance metric, meaning that taller polygons represent areas with higher levels of connectivity to other greenspaces.



Caption: A view of Main Mall on UBC's Vancouver campus, where the shape of each polygon has been extruded depending on how connected it was found to be." Taller" greenspaces are more connected!

Step 4: Finding the "Dead Zones"

The areas of the UBC Vancouver campus that are 10 or more metres away from any soft landscape were referred to as "dead zones" in this project, because these areas were characterised by extensive grey infrastructure development which can make it harder for animals or plant seeds to disperse from them. Deadzone areas also contribute to habitat fragmentation, which decreases the flow of genes from one population to another.

Caption: This aerial view of UBC's Main Mall shows some of the "dead zones" that were found on the UBC Vancouver campus — highlighted in red, in between the buffers surrounding each green space.

Step 5: Building the Node and Link Network

In order to visualise the data in different ways, a map of the entire campus was made, including the "nodes" or "hubs" as individual greenspaces, and the "links" showing which greenspaces were connected to one another.

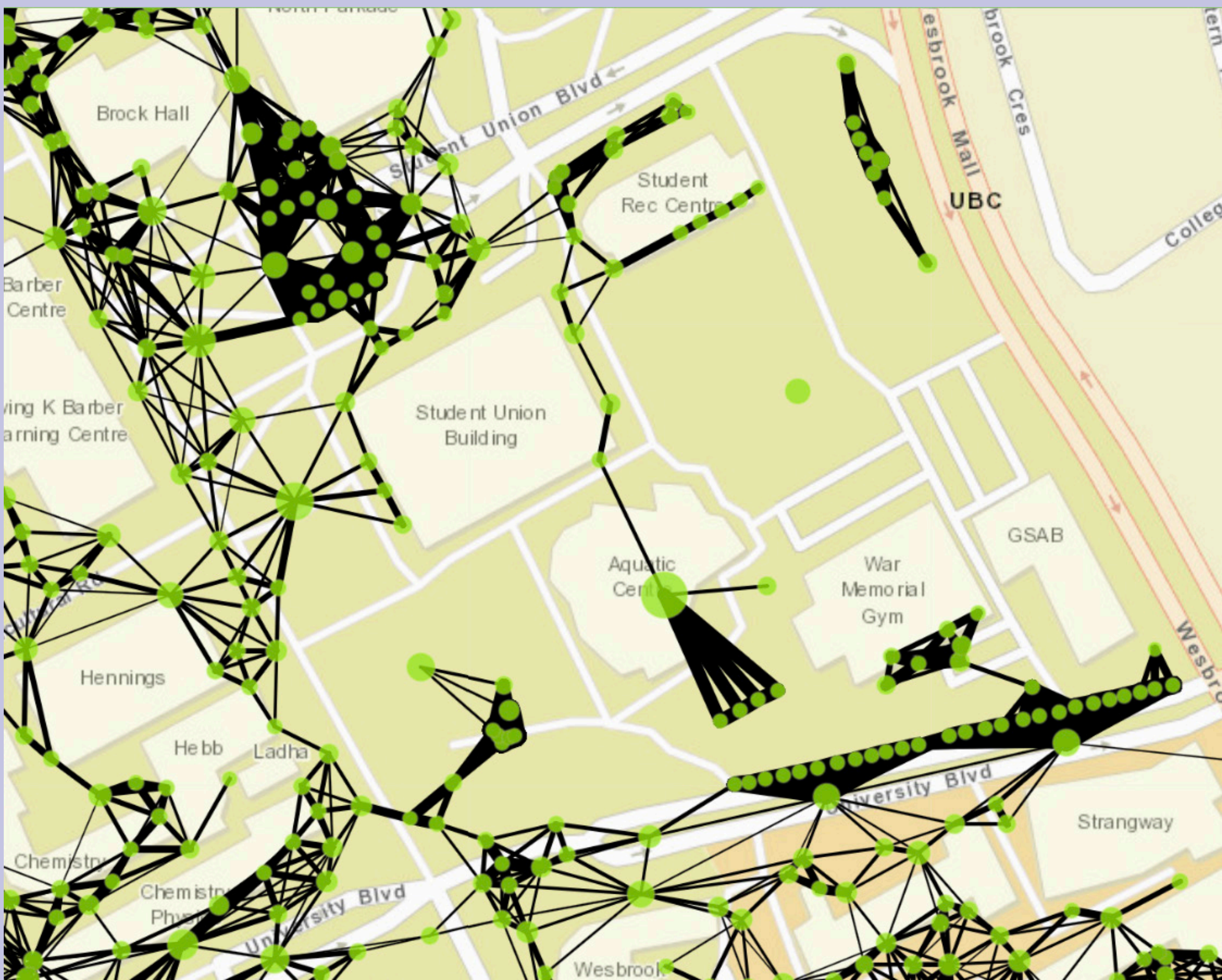
The following three parts of the first analysis were used to make this map:

Which greenspaces were connected to which other greenspaces

How "strong" this connection was for each relationship

The location of the nodes of the network (the start and end points for each link)

A point was placed in the centroid (the geometric center) of each polygon to create the "nodes", and the difference in coordinates was then worked out between the two points that made up a connection to create the linking lines between them. These lines were made thicker or thinner based on the relative "strength" of the connection.



Caption: This image of the campus area surrounding the UBC Alma Mater Society Student Union Building (AMS Nest) displays a small part of the node and link network you saw earlier. Notice how some nodes are not connected to the rest of the network!

Step 6: Finding the "Dead Points"

Some areas (like the nodes on the right side of the map above) were found to be "disconnected" from the larger network. To determine which greenspaces were "accessible" within the network, a "network analysis" was performed using ArcGIS Pro. This works similarly to google maps on a phone — you select a starting location, and it looks at all the possible places that can be reached within a given distance. The process entails starting from a well-connected point, running the ArcGIS Pro tool, and extracting all the points that were possible to reach using only the connected pathways. You can see here, these disconnected "dead points" are marked in red.

Caption: Here you can see the "dead points" (highlighted in red), disconnected from the larger network and marked in red on the UBC Vancouver campus.

LEARNINGS:

Key learnings from this ecological connectivity on the UBC Vancouver Campus case study include:

Greenspaces on campus are full of diverse and interacting species that benefit from being managed at a systems level

Increasing overall greenspace cover helps to increase ecological connectivity

Biologically diverse greenspaces that are connected as a green infrastructure network can help UBC adapt to a changing climate

Learning from the modular design of mycorrhizal fungi species diversity, and applying a modular design to the green infrastructure network at UBC, can result in a climate resilient campus that is more equipped to adapt to climate change if urban forest cover is preserved and increased

You can read Mantegna's (2021) full report here and watch a walk through video explaining the SEEDS Ecological Connectivity Tool here.

Helpful Resources

Additional Resources:

Listed below are additional tools to help further your knowledge and applications of ecological connectivity network analysis on the UBC Vancouver campus:

ECOLOGICAL CONNECTIVITY TOOL: PROJECTED AS A NODE AND LINK NETWORK (WEB MAP)

Web map displaying the results of the research above. Use the different layers to display different parts of the connectivity analysis, from the soft landscape polygons to the node and link network!

ENHANCING GREEN NETWORKS AND FABRIC

Students of LARC 553 in the School of Architecture and Landscape Architecture (SALA) have developed a number of individual assessments of the green networks and Fabric on UBC's Vancouver campus, with accompanying recommendations for each of their respective study areas.

KUMU NETWORK MAP: ECOLOGICAL CONNECTIVITY ON CAMPUS

Use this map to visualise the nodes and links of the above research in another way. In this view, the map has been re-organized in a force-directed layout, so that the network is in its optimal shape (created by treating each connection as an elastic, and allowing it to "spring" into place). Here, you can also play around with different metrics of the network.

UBC VANCOUVER'S OPEN ACCESS SPATIAL DATA

To begin developing your own connectivity analysis of UBC Vancouver campus, use this resource containing helpful datasets and shapefiles. This Github page contains locations (buildings, addresses, campus services, food outlets, etc.) and landscape data (trees, water features, lawn areas, etc.).

GEOMATICS FOR ENVIRONMENTAL MANAGEMENT: AN OPEN TEXTBOOK FOR STUDENTS AND PRACTITIONERS CHAPTER 8: NETWORK ANALYSIS

To learn more about network analysis in GIS, the Master of Geomatics Program in the Faculty of Forestry at UBC has an open textbook with a chapter on network analysis. It provides an overview of key terms and concepts, as well as review and study materials, and extra readings to improve and inform analysis.

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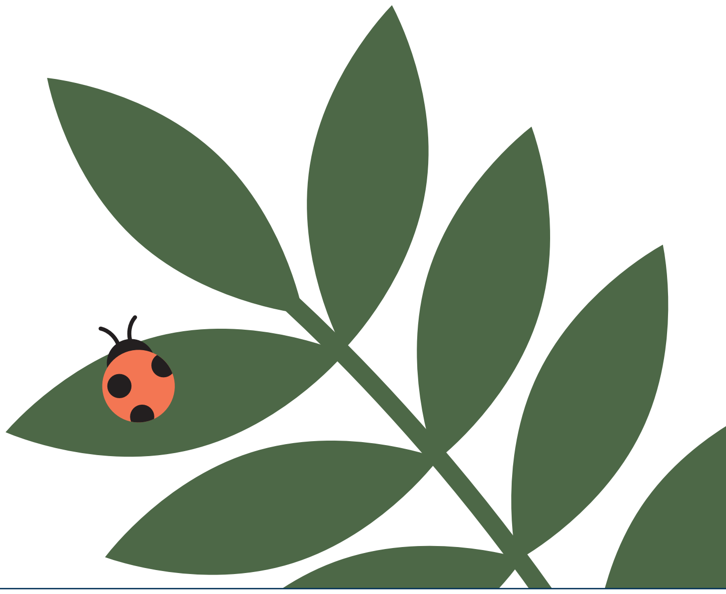

Thank you for reading! We hope you found the research summarized in this Toolkit useful.

Please email seeds.info@ubc.ca for any questions or comments.