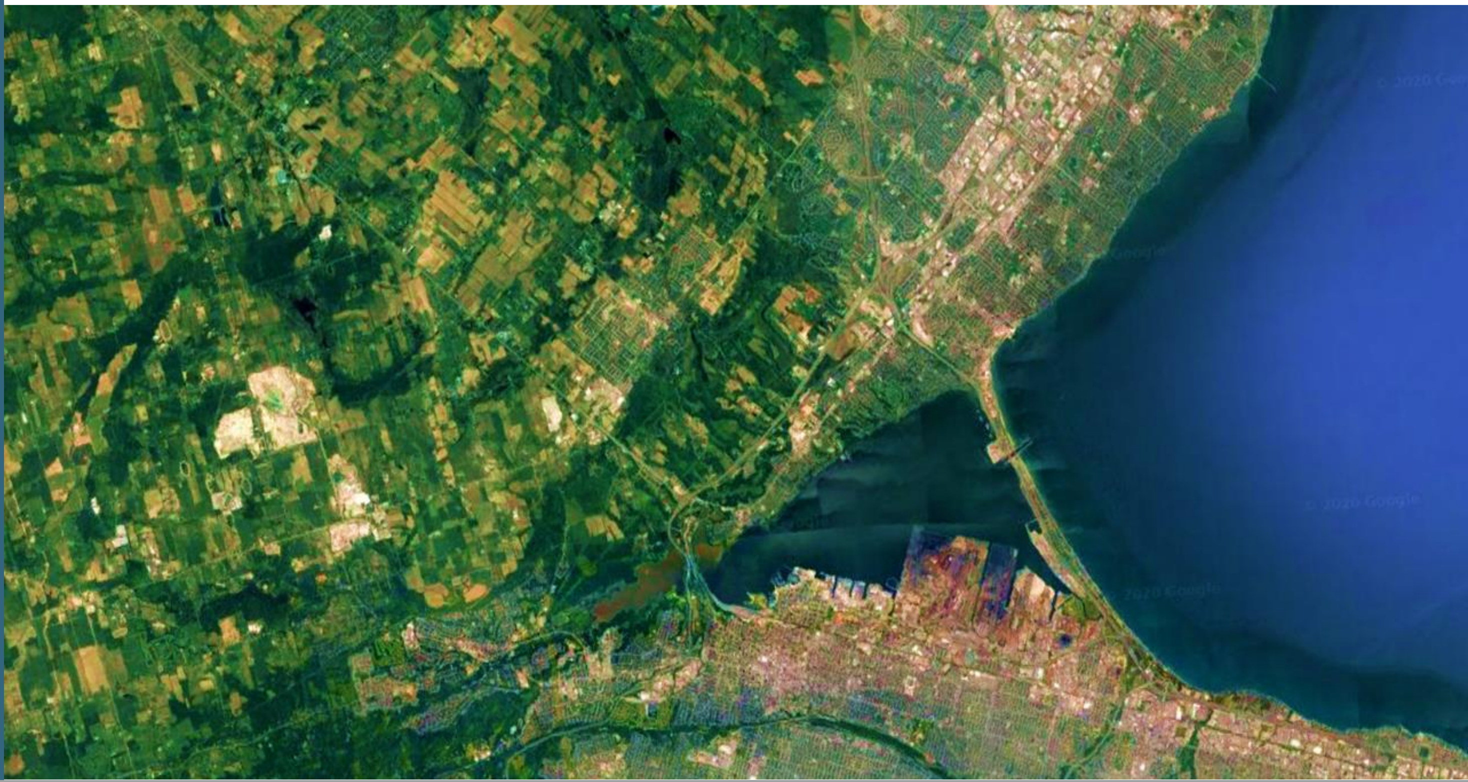

Full Report
Wildlife Corridor Mapping in the Cootes To Escarpment EcoPark System

Prepared by: Apex Resource Management Solutions, C. Talbot & Associates, and the Cootes to Escarpment EcoPark System

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Cootes to Escarpment EcoPark System

Cootes to Escarpment EcoPark System Partners

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Possibility grows here.

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Cover Photograph: Google Map of Cootes Paradise Marsh in Hamilton, Ontario, Canada

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1.0 Executive Summary

The Cootes to Escarpment EcoPark System area is one of Canada's biodiversity hotspots, a complex landscape of protected lands, open space, urban development, and other uses at the western end of Lake Ontario, centred around Cootes Paradise Marsh in Hamilton and Burlington, Ontario. The natural areas in this landscape are under threat because of habitat fragmentation, invasive species, climate change, water quality impairment, and other anthropogenic effects.

Protecting and restoring habitat connectivity is a widespread strategy for achieving biodiversity conservation. Connected landscapes enable wildlife to move between suitable habitat and gain access to the best available mates, nesting sites, and food resources. Landscape connectivity also maintains genetic diversity within wildlife populations and facilitates seasonal and climate-driven migrations across the landscape.

The goal of this Wildlife Corridor Mapping Study is to support biodiversity conservation and management activities in the Cootes to Escarpment EcoPark System by identifying habitat patches and movement corridors that promote landscape connectivity. Two complementary analyses were used:

1. A *generalized analysis* which identified probable movement corridors for forest- and wetland-dwelling wildlife across the Cootes to Escarpment EcoPark System. We mapped the permeability (or 'resistance') of the landscape for animals that avoid unnatural landscape features such as roads and developed land and applied circuit connectivity methods to account for all potential paths across and within the landscape to identify probable movement corridors.
2. *Focal-species analyses* identifying components of connectivity at the species-level (habitat suitability and habitat patch importance for landscape connectivity). Blanding's turtle, northern short-tailed shrew, and white-tailed deer were selected to reflect the local diversity in terrestrial habitat and connectivity needs.

This analysis predicts many corridors of movement within the Cootes to Escarpment EcoPark System and a few corridors - to the south-west and to the north - connect the EcoPark System to the broader landscape. The habitat suitability values, summarized across species, confirms that much of the EcoPark System is either highly suitable for a specific species, or broadly suitable for multiple species. However, not all areas of high habitat suitability have high connectivity value and vice versa. Patches of particular importance for maintaining local connectivity are generally large and centrally located, allowing for wildlife movement within their boundaries and providing connectivity among neighbouring patches. Many, but not all, of the high value areas fall within existing EcoPark System partner lands and defined management areas.

These findings were shared with EcoPark System partner agencies and in a series of five inter-active virtual workshops. What emerged from this engagement process was a

i. greater awareness of the unique landscape characteristics, barriers and opportunities
ii. deeper understanding of the impacts associated with land fragmentation, aging and poorly designed infrastructure, urban development pressures, increased recreational trail use on wildlife movement and well-being within the EcoPark System , and
iii. commitment to continue to work collaboratively, advocating for an integrated system approach to decision-making, policy, planning, design, funding, public education and stewardship to preserve and protect this unique and critical eco-system.

2.0 Introduction

Protecting and restoring habitat connectivity is a widespread strategy for achieving biodiversity conservation targets. Connected landscapes can promote biodiversity persistence in a multitude of ways: by sustaining gene flow to prevent local extinctions; by facilitating recolonizations after local extinctions; and by promoting annual and climate-driven migrations. Habitat networks can be managed for biodiversity conservation by promoting multiple scales and types of movement. The contribution of individual habitat patches and corridors within networks can be assessed in terms of their importance to network connectivity. Conservation priority should be given to those habitat patches and linkages that are important for multiple species at multiple spatial scales. Conserving connected habitat networks is particularly important in highly fragmented and rapidly changing landscapes such as landscape surrounding the Cootes to Escarpment EcoPark System.

The Cootes to Escarpment EcoPark System is an alliance of land-owning agencies within Hamilton and Burlington, Ontario collaborating to permanently protect a connected landscape between Lake Ontario wetlands (Cootes Paradise Marsh) and the Niagara Escarpment. This landscape has been fragmented due to economic growth and urban development, resulting in a patchwork of protected areas of varying sizes, owned by a diversity of agencies. Retaining the biological diversity within this landscape requires protection and restoration of areas that maintain its ecological connectivity.

The goal of the Cootes to Escarpment EcoPark System Wildlife Corridor Mapping project was to support biodiversity conservation within the EcoPark System by identifying landscape elements that promote functional connectivity. Our approach combined a generalized connectivity analysis to provide a broad scale picture of connectivity across the landscape that surrounds the EcoPark System and focal-species analyses to provide a detailed view of functional connectivity within the EcoPark System. We combined the results of these two analyses to prioritize landscape patches in relation to their contributions to functional connectivity. This study extends an existing methodology which had mapped ecological connectivity across Ontario at 1km resolution (Bowman and Cordes, 2015) in order to map ecological connectivity in the EcoPark System in high resolution (15m).

3.0 Methods

Overview of Approach

We combine complementary connectivity analyses to identify priority areas of the landscape for multispecies connectivity conservation: a generalized analysis that identified probable movement paths for generic forest- and wetland-dwelling wildlife; and focal species analyses that identified species-specific habitat patches and their contributions to functional connectivity. Our approach involves four steps (Figure 1):

1) *Land use and land cover mapping*: Gather appropriate data to develop a land use and land cover map for the study area.
2) *Generalized connectivity analysis*: Develop a generic description of dispersal resistance across the landscape for forest- and wetland-dwelling wildlife. Use of circuit connectivity analyses to identify probable paths of movement within and across the landscape.
3) *Focal species connectivity analyses*: Select focal wildlife species that represent the regional diversity of species needs in terms of habitat preference and dispersal ability. Gather data on species-specific habitat and dispersal. Model habitat suitability and dispersal resistance for each focal species. Quantify the importance of habitat patches towards maintaining connectivity across the landscape.
4) *Identification of priority areas for connectivity conservation*: Combine results from the generalized and species-specific connectivity analyses to identify important habitat patches and corridors supporting connectivity on the landscape.

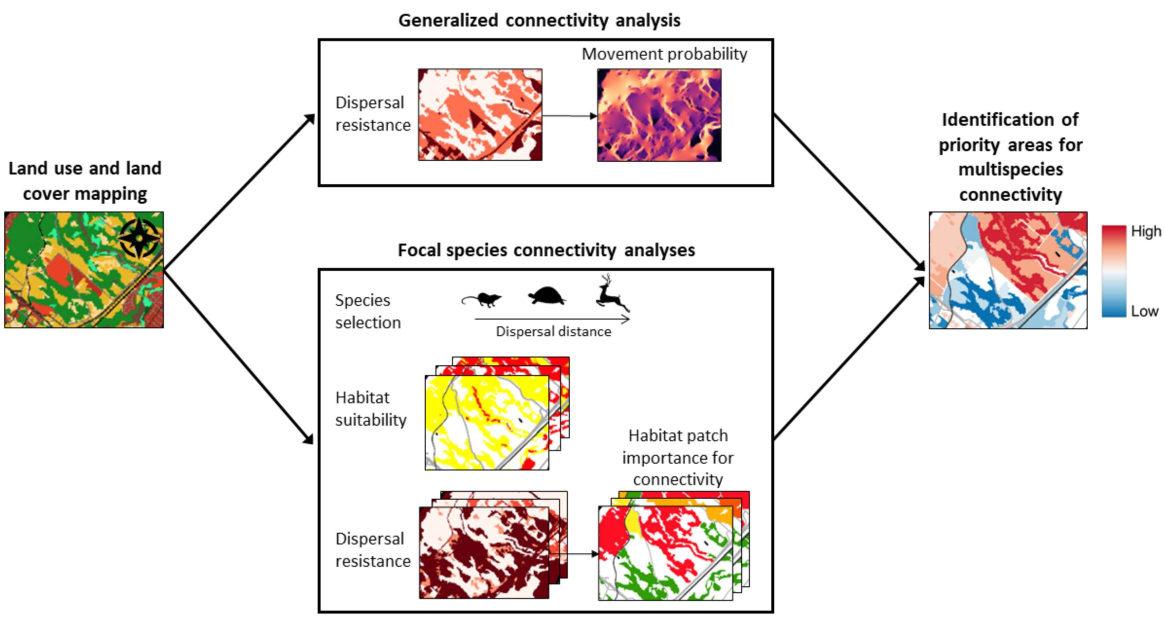

Figure 1. Overview of approach for identifying priority areas for multispecies connectivity conservation. The generalized connectivity analysis uses the land use and land cover map to identify movement probability across the landscape for forest- and wetland-dependent wildlife. The focal species connectivity analyses combine the land use and land cover map with species-specific habitat preferences and dispersal abilities to identify the most important habitat patches for maintaining connectivity across the landscape. Priority areas for connectivity are identified by summing the resulting generalized and focal-species connectivity maps.

Study Area

The study was centered on the Cootes to Escarpment EcoPark System, in the Burlington-Hamilton area at the western end of Lake Ontario (Figure 2). The EcoPark System is home to nearly a fifth of Canada's wild plants and more than 60 species at risk, making it a national biodiversity hotspot. Within the EcoPark System, partner agencies consisting of local government and non-profit organizations are working together to protect and restore their natural lands, secure additional lands to create buffers and ecological corridors, and deliver sustainable education and recreation opportunities.

We focussed on an area of approximately 50 km^2 encompassing lands owned by the EcoPark System partner organizations. This focal area comprised a mix of land use and land cover classes dominated by forests, agriculture, urban, open water, and wetlands (Figure 2). Currently, 39.2% of the focal area is owned by EcoPark System partner organizations. We created a 20km buffer around this focal area to assess the connectivity between partner owned properties, privately owned properties within the EcoPark System, and the surrounding landscape (Figure 2).

Land use and Land Cover Data

We assembled a comprehensive land use and land cover (LULC) map with 23 classes by combining multiple remotely sensed land cover datasets and other relevant GIS data (Appendix Table A1), following the method of Bowman and Cordes (2015). All spatial data were converted into a common grid of 15m x 15m resolution based on the Southern Ontario Land Resource Information System.

To maximize the spatial and temporal accuracy of the LULC map, the following rank hierarchy was used when overlaying GIS data:

1. Built-Up Areas (2012)
2. Ontario Railway Network (2020)
3. Ontario Road Network: Major Roads (2020; see road classification in Table A2)
4. Ontario Road Network: Minor Roads (2020; see road classification in Table A2)
5. Ontario Hydro Network - Waterbody (2020)
6. Expert-based land use land cover classifications (2020)
7. Southern Ontario Land Resource Information System (2000 – 2015)
8. Ontario Land Cover Data Base (1998)

This hierarchy was adapted from Bowman and Cordes (2015) because their analysis covered all of Ontario at a much coarser resolution (100 m^2). The main differences were as follows: We gave major roads a higher rank order than minor roads in the overlay process and buffered them both by 12m to ensure contiguity; We added railways and expert-based land use

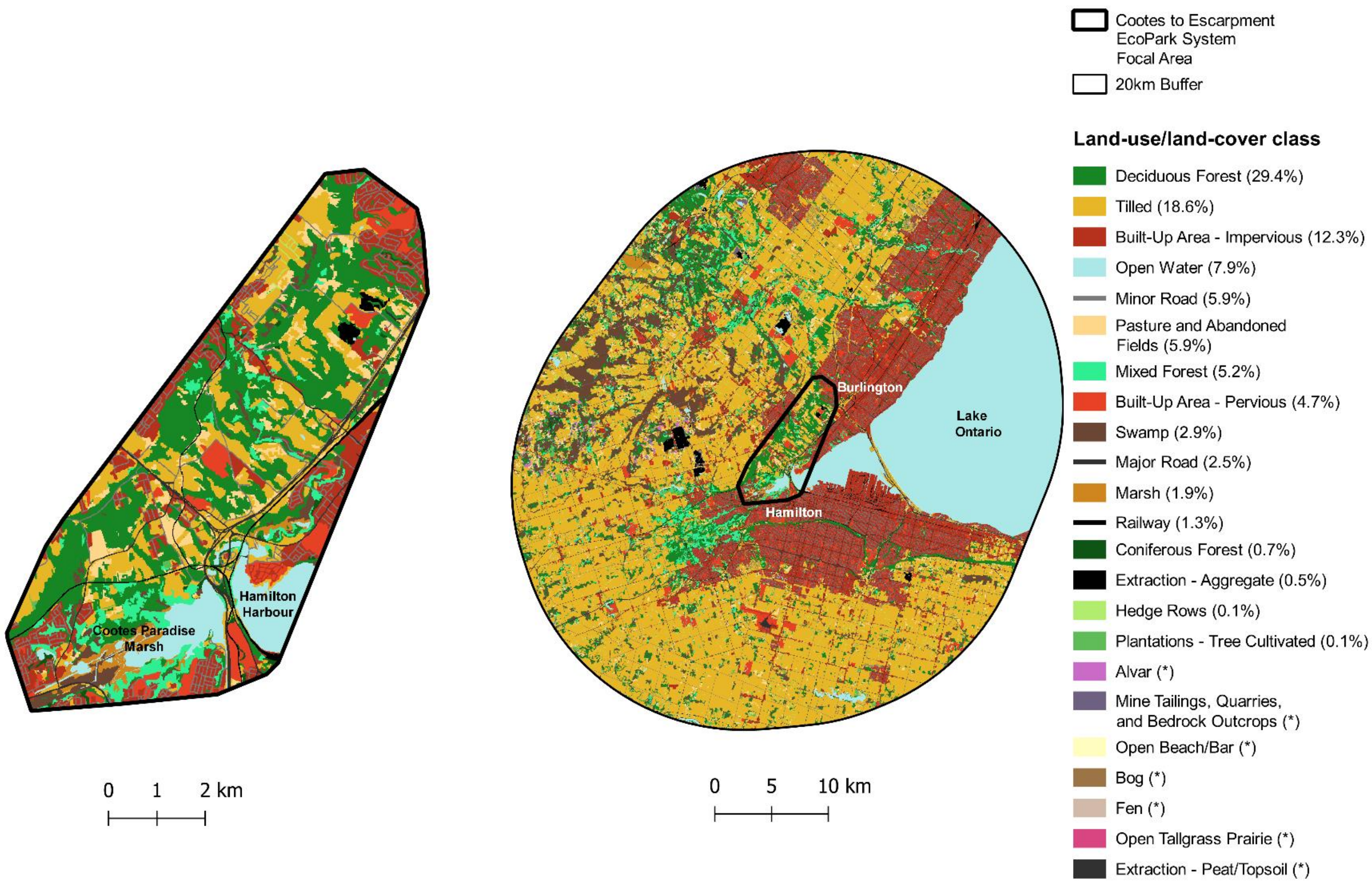

Figure 2. Land use and land cover (LULC) classes in the Cootes to Escarpment EcoPark System focal area and in a 20km buffer. This visualization does not include the Built-Up Areas data (Appendix Table A1) so that roads and railways are easier to see. The percentage of the focal area that is covered by each LULC class is provided in the legend. LULC classes that occur only in the buffer are indicated by (*).

and land cover classifications; We assigned a higher rank to built-up areas and roads than waterbodies. The expert-based classifications were based on consultation with the EcoPark System partners. Feedback on preliminary LULC mapping from EcoPark System partners resulted in a reclassification of two EcoPark System partner properties (Hopkins Tract and Berry Tract II) from "Tilled" (based on the Southern Ontario Land Resource Information System 3.0) to "Pasture and Abandoned Fields". A common feature between Bowman and Cordes (2015) and our overlay schema is that minor roads within built-up areas retain a high cost resistance relative to those in the periphery. A visualization of the final LULC map is shown in Figure 2. This LULC map was reclassified 1) into a generic resistance grid for the generalized connectivity analysis and 2) into species-specific habitat suitability grids and species-specific resistance grids for the focal species connectivity analyses (see Section 3.4 Connectivity analyses).

Available culvert and bridge underpass data within the focal area were also included in the generalized connectivity analysis (Appendix Table A1). Culverts and bridge underpasses can allow wildlife to crossroads safely, thereby decreasing the resistance of roads at their locations. Culvert data included length and diameter at each end to assess the potential for wildlife to use the culvert as a crossing structure.

Data on lands currently owned by the Cootes to Escarpment EcoPark System partners were obtained to overlay them with the priority areas for multispecies connectivity conservation. These data included the name and owner of each of the EcoPark System partner lands (Appendix Table A1).

4.0 Connectivity analyses

Generalized Connectivity Analysis

Dispersal resistance grid. Generalized resistance values were used to model the permeability of LULC classes for a generic forest- and wetland-dwelling species (Koen et al. 2014; Bowman and Cordes 2015). High resistance (1000) was assigned to highly modified, unnatural LULC classes such as major roads; medium resistance (100) was assigned to unnatural but somewhat permeable LULC classes such as agriculture; and low resistance (10) was assigned to natural LULC classes with high permeability to movement such as forests (Appendix Table A4). Railways were assumed to have the same resistance as major roads (value = 1000; Appendix Table A4).

Culverts and bridges were included in the generalized resistance grid to reduce the resistance at their locations. We calculated the Openness Ration (OR) of culverts – a measure of the amount of light available at the end of a culvert – which affects culvert utility for different species groups (Conservation Halton, 2018). We retained only those culverts with OR values greater than 0.05 m, the smallest size considered useful for connectivity (Conservation Halton, 2018). All bridges were retained in the analysis. Culverts and bridges were buffered to 12 m in all directions to align them with the similarly buffered roads before overlaying them on top of the generalized resistance grid. Culverts and bridges were assigned the lowest resistance value (10).

This generic resistance grid including suitable culverts and bridges was produced for the focal area encompassing the Cootes to the Escarpment EcoPark System and a 30km buffer zone. Results are reported for the focal area and a 20km buffer, the additional 10km buffer was included in the connectivity analysis to reduce edge effects (Bowman and Cordes, 2015, Koen et al., 2014).

Circuit-based connectivity analysis. We used electrical circuit theory to model connectivity following the method of Koen et al. (2014). Circuit-based connectivity analysis has been shown to be a useful model for both wildlife movement (Walpole et al., 2012) and gene flow (McRae & Beier, 2007). The resistance grid (reclassified from the LULC map) serves as a circuit board to direct current flow between pairs of circuit nodes placed randomly around the buffered grid boundary. We randomly distributed 50 nodes, 1225 node-pairs, around the buffered resistance grid to obtain a description of omnidirectional connectivity (Koen et al. 2014). When all pairwise connections are combined, a current density map is generated which is analogous to the movement probability of random walking animals (McRae et al. 2008). This movement probability map describes predicted functional connectivity of the landscape for generic forest- and wetland-dwelling wildlife. The current density map based on this resistance grid has been validated in eastern Ontario for use on diverse taxa such as fishers and herpetofauna (Koen et al. 2014). We used the software Circuitscape 5 (circuitscape.org) to conduct our circuit connectivity analysis (McRae and Shah 2009).

Focal species connectivity analyses

Choice of focal species. We selected a group of three focal species reflecting the local diversity in terrestrial habitat and connectivity needs (
Table 1): The Northern short-tailed shrew (*Blarina brevicauda*), the white-tailed deer (*Odocoileus virginianus*), and the Blanding's turtle (*Emydoidea blandingii*). Blanding's turtle was of particular interest as it is considered Endangered in Canada (COSEWIC 2016), Threatened in Ontario, and is a 'Specially Protected Reptile' under the Ontario Fish and Wildlife Conservation Act. To analyse functional connectivity in the Cootes to Escarpment EcoPark System, landscape maps describing habitat suitability, habitat patches, and resistance to movement were needed for each of the focal species. The focal species connectivity analysis was conducted at the scale of the EcoPark System focal area, however focal species habitat suitability, habitat patch and resistance maps for the for the 20km buffer zone are provided in Appendix Figures A1 to A9.

Habitat suitability. We modelled habitat suitability for each of the three focal species based on the LULC map. For each focal species, each LULC class was assigned a specific suitability value (Appendix Table A3). Habitat suitability is a unitless variable that scales arbitrarily between 0 and 100 and reflects the ability of a patch to meet an organism's requirements and/or preferences. Biologically, we define suitability values following the Corridor Design Project (http://corridordesign.org/) as 0 = no use at all, < 30 avoided, 30 - 60 = occasional use for non-breeding, 60 - 80 = consistent use for breeding, 80 - 100 = best habitat for survival and breeding. For both white-tailed deer and the Northern short-tailed shrew, habitat suitability data were obtained from previously published values (in Albert el al. 2017, based on an

Table 1. List of focal species for the Cootes to Escarpment EcoPark System Wildlife Corridor Mapping project. Focal species were selected to represent local diversity in habitat requirements and dispersal abilities.

Common name	Scientific name	Diet	Longevity (years)	Dispersal Distance* (m)	Habitat Preference	Minimum patch area (ha)	Status**	iNaturalist (count)***
 Northern short-tailed shrew	*Blarina brevicauda*	Insectivore	1.5	459	Dense, old forest	1	Common	54
 Blanding's turtle	*Emydoidea blandingii*	Omnivore	75	1390	Wetlands and forested areas	2	Endangered	12
 White-tailed deer	*Odocoileus virginianus*	Herbivore	20	20521	Medium dense forest and open areas	5	Common	429

*Median dispersal distance derived from literature estimates.
**Status for shrew and deer obtained from What's Alive in Hamilton 2013; status for turtle obtained from COSEWIC (2016).
***iNaturalist observations from the Biodiversity of the Hamilton Study Area project (January 1, 2015 to September 22, 2020).

exhaustive review of the scientific literature). For Blanding's turtle, we obtained habitat suitability values from the published literature (COSEWIC 2016, Species at Risk Public Registry, Millar et al. 2011, Mui et al. 2017) and local expert knowledge. Feedback on initial Blanding's turtle habitat suitability mapping with EcoPark System partners resulted in assigning all LULC classes within Hendrie Valley a habitat suitability value of 100 because a Blanding's turtle population is known to occur. Pixels with habitat values greater than or equal to 60 were considered potential habitat (Albert et al. 2017).

Habitat patches. Each habitat suitability map identifies individual pixels which are suitable for a focal species. Individual species also differ in the minimum area of suitable habitat needed for a patch to be useable for maintenance and reproductive activities. We identified the minimum patch sizes required by all species using data published in Albert et al. (2017) for white-tailed deer and the Northern short-tailed shrew, and from the COSEWIC Assessment and Status Report on the Blanding's Turtle (Table 1). For each focal species, we constructed maps identifying only those patches which contain suitable habitat (habitat suitability values > 60) and which are greater than the minimum required patch size. These maps are binary, containing values of either 0 (not suitable) or 1 (suitable).

Resistance. Species-specific resistance values were assigned to each LULC class, for each focal species, to model its permeability to that species' movement (Appendix Table A4). For a given species, areas of suitable habitat are considered most conducive for movement, and therefore given the lowest resistance value (1). Subsequent LULC classes received a resistance value derived from an exhaustive review of the scientific literature on the subject (see Albert et al. 2017 for details). These values double with each decrement in movement ability (i.e. 2, 4, 8, 16, 32) resulting in six resistance classes in total.

Habitat network connectivity analysis. To evaluate the importance of each habitat patch for connectivity among all patches, we used a network connectivity approach. This requires information on the number and size of habitat patches and the connections among all patches. Habitat patch number and size were derived from the habitat patch maps for each focal species. Connections among habitat patches were derived from the focal species' resistance maps as least-cost paths (Adriaensen et al. 2003). The strength of the connection between a pair of habitat patches was a function of the total resistance along the least-cost path and the dispersal ability of the species (Table 1). The resulting habitat network represents habitat patches and the likelihood of the focal species moving among them within the EcoPark System focal area.

Based on each focal species' habitat network, we assessed the importance of each habitat patch in terms of its role as: 1) a source of successful dispersers based on the size of the habitat patch and its distance to other patches in the network (Area-weighted flux); and 2) a stepping stone to facilitate movement among other patches in the network (Stepping stone connector). We calculated these measures (PCflux and PCconnector; Saura and Pascual-Hortal, 2007) for all focal species using the Makurhini R package (v. 1.0.0, https://github.com/connectscape/Makurhini).

5.0 Research Summary

We summarised the generalized and focal species connectivity analyses in 3 maps:

i. Movement Probability: We log-transformed and range-scaled the generalized movement probability map so that the values fall between 0-1.

ii. Overall Connectivity Importance of Habitat Patches: We calculated an aggregate measure of habitat patch importance across all focal species in the EcoPark System focal area. We range-scaled the area-weighted flux and stepping-stone connector connectivity measures, and then summed their values across the three focal species' habitat patch importance values for each pixel. The final measure was then range-scaled between 0-1 for comparability.

iii. Overall Habitat Suitability: We calculated an aggregate measure of habitat suitability across all focal species in the EcoPark System focal area. To create a map showing the combined habitat suitability for all species, we calculated the maximum value of three species' habitat suitability values in each pixel. As the species' layers have values between 0-100, the resulting aggregate measure had values between 0-100 as well. We then range-scaled the values to fall between 0-1 (where 0.6 represents the minimum value of suitable habitat for at least one species).

Finally, we created an overall summary map showing priority areas for multispecies connectivity conservation. This overall summary was calculated as the sum of the multispecies movement map, the overall connectivity importance of habitat patches map, and the overall habitat suitability map. The resulting map has values that can be used to identify areas which make important contributions to connectivity across multiple measures and/or species (overall range 0-3). We overlaid lands currently owned by EcoPark System partner organizations on top of this overall summary map to highlight areas of high priority that are not currently owned by EcoSystem partner organizations.

All analyses, except for the circuit analysis, were performed using the R statistical computing environment (R Core Team 2020), version 3.6.0. Analysis scripts are available from https://github.com/ApexRMS/Wildlife-Corridor-Mapping-Cootes-to-Escarpment-EcoPark-System.

6.0 Results

Generalized Connectivity Map

Generic resistance map. The generic resistance map describes the ease or difficulty with which a generic forest or wetland-dependent species can move across the landscape (Figure 3). Areas that are difficult to move through are generally open water or human modified areas: built-up areas, roads, tilled areas. Forests and wetland areas facilitate movement in this generic resistance map.

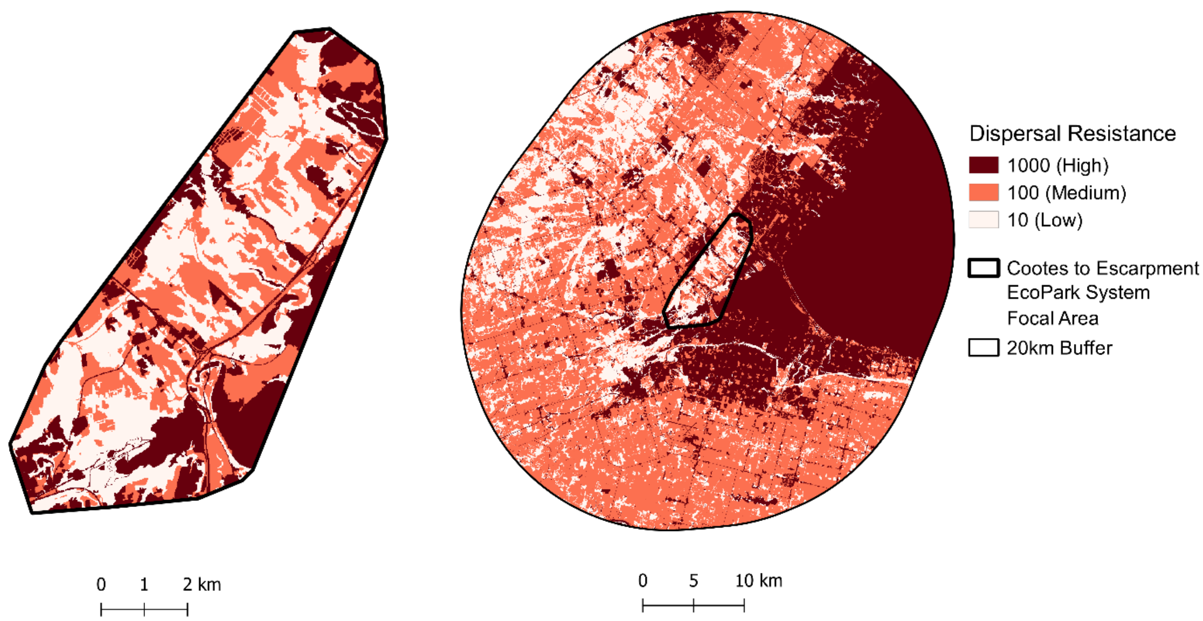

Figure 3. Generic resistance surface in the Cootes to Escarpment EcoPark System focal area (left hand panel) and in a 20km buffer around the focal area (right hand panel). Resistance reflects the effort required to move through different land use and land cover types for a generic wetland- and forest-dwelling species (values 10 to 1000).

Circuit-based connectivity analysis. The generic resistance map was used as the basis for the circuit connectivity analysis which produced a map of movement probability within the EcoPark System and in the surrounding 20km buffer (Figure 4). Areas with high movement probability correspond to pixels with high cumulative current density. Within the EcoPark System, the Niagara Escarpment provides an important movement corridor along the north-south axis. Cootes Paradise Marsh is also a general area of high connectivity in the south. Ravines extending perpendicular to the Niagara Escarpment provide probable movement corridors along the east-west axis. Many pinch points exist within the EcoPark

System where movement is constrained and becomes concentrated in a narrow area. These areas represent potential movement corridors with a high probability of movement and should be considered for connectivity conservation activities.

Connectivity between the EcoPark System and the broader landscape is limited by Lake Ontario to the east and built-up areas to the west. Two corridors of movement connect the EcoPark System to the north-west: one along Grindstone Creek and one along the Niagara Escarpment (Figure 4). Three corridors of movement connect the EcoPark System to the south-west: one the Niagara Escarpment and two just south of Cootes Paradise. Bridge underpasses under Cootes Drive play an important role in maintaining connectivity within the corridors south of Cootes Paradise (Figure 4). These five corridors provide a critical connection to the remaining natural areas and habitats that surround the EcoPark System.

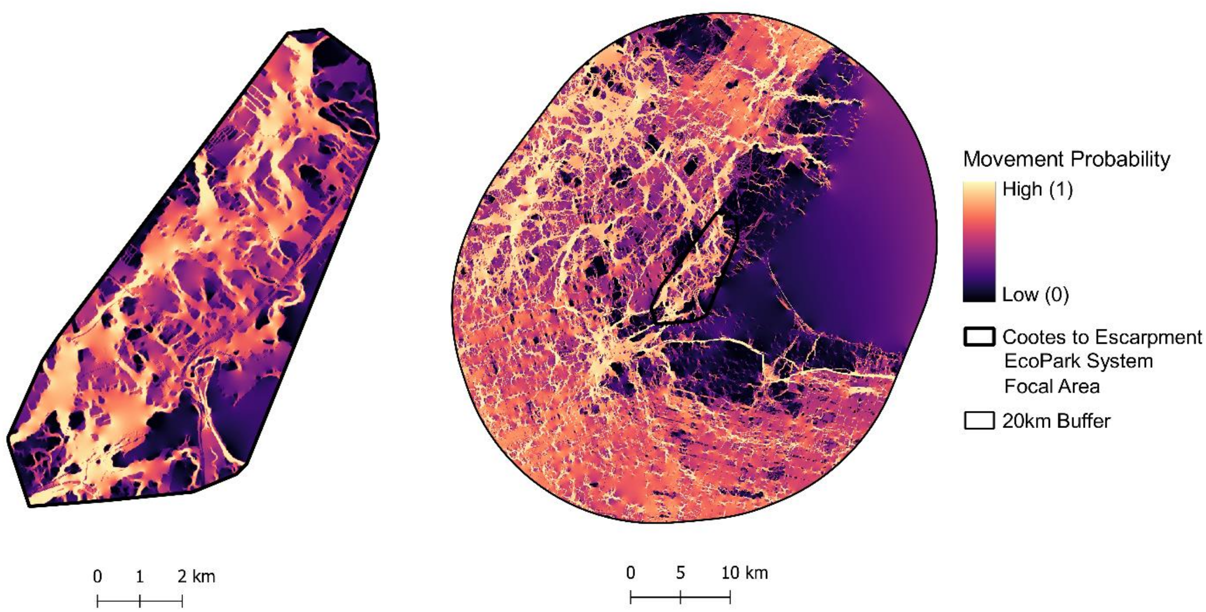

Figure 4. Generic connectivity map in the Cootes to Escarpment EcoPark System focal area (left hand panel) and in a 20km buffer around the focal area (right hand panel). Arrows on right hand panel indicate corridors that provide connectivity between natural areas within the EcoPark System and natural areas in the surrounding landscape.

Focal Species Connectivity Analysis

Habitat suitability. All species had suitable habitat available both within the EcoPark System focal area (Figure 5) and across the 20 km buffer area (Appendix Figures A1 – A3). Forested areas are highly suitable for both the White-tailed deer and the Northern short-tailed shrew. Both species have high suitability habitat across the EcoPark System focal area, in the deciduous forested areas. Additionally, White-tail deer can make use of pasture and abandoned fields and tilled land, extending their habitat outside of the forested areas. Blanding's turtle requires wetland habitats, including swamps, marshes, and bogs, with lower suitability for forested areas.

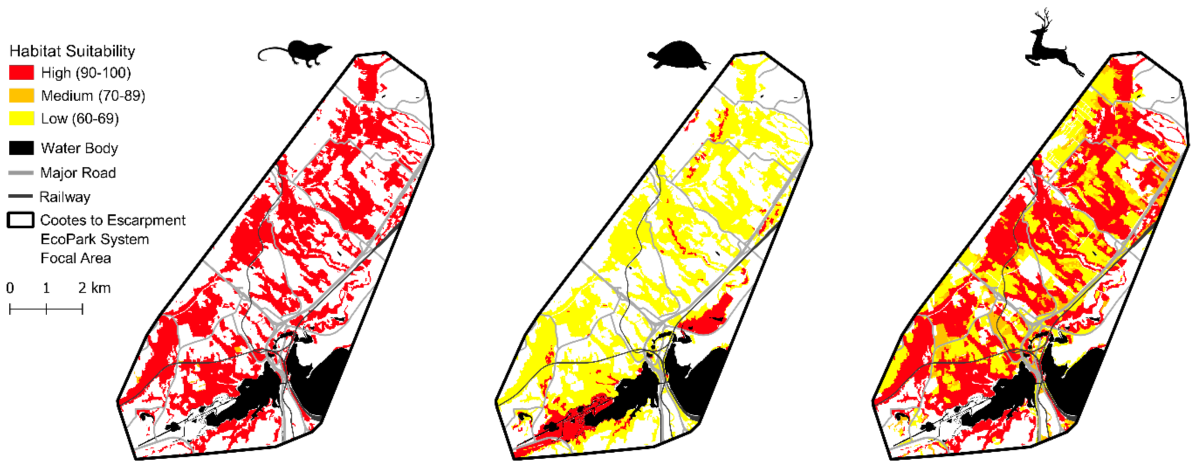

Figure 5. Focal species' habitat suitability in the Cootes to Escarpment EcoPark System focal area. Pixels with a value greater than or equal to 60 are considered potential habitat. Areas with habitat suitability lower than 60 are white.

Habitat patches. Based on the species habitat suitability maps, we localized patches of suitable habitat that were large enough to meet the needs of each focal species. All species had suitable habitat patches spanning the EcoPark System focal area (Figure 6) and present across the 20 km buffer area (Appendix Figures A4 – A6). The patches differed in size among the focal species. The White-tailed deer had expansive habitat patches covering many areas of the EcoPark System while the Northern short-tailed shrew and Blanding's turtle had smaller and more restricted habitat patches.

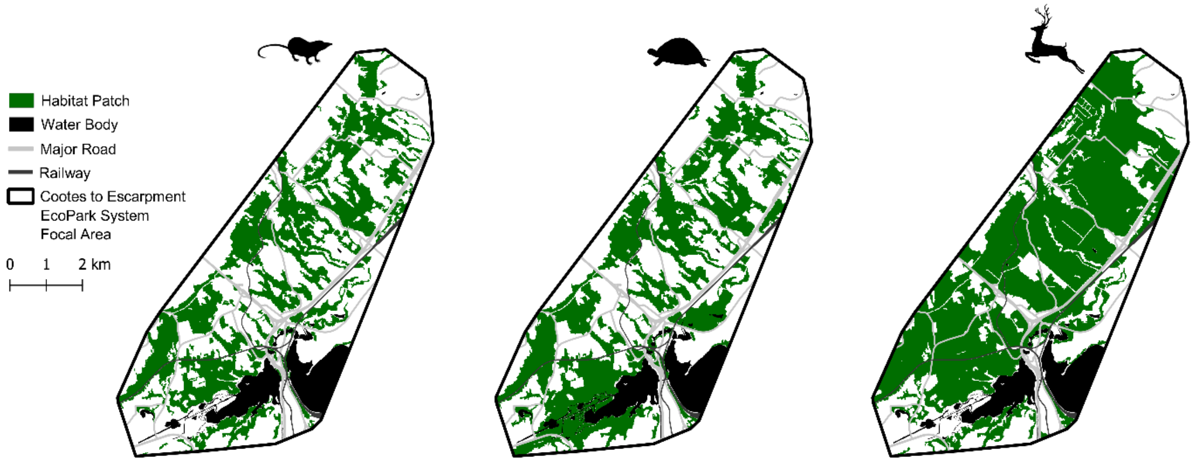

Figure 6. Focal species' habitat patches in the Cootes to Escarpment EcoPark System focal area. Habitat patches have habitat suitability >=60 and are larger than the minimum patch size required for each focal species (Table 2).

Habitat resistance. For each focal species we described the ease or difficulty in their movement across the landscape (Figure 7; Appendix Figures A6 – A9). All species were given the highest resistance values (i.e. the greatest difficulty of movement) in built up urban areas, railways, and major roads, as these features fragment suitable habitat patches in multiple places. Outside of roads and built up areas, the white-tailed deer had the lowest resistance across the EcoPark System landscape, moving easily though forests, tilled areas, and pastures. Blanding's turtle had the most constrained movement, moving easily in wetlands and forests but facing difficulties when moving through tilled and built-up areas. The Northern short-tailed shrew had intermediate movement resistance with moderate difficulty moving across minor roads, pervious urban areas, tilled areas and wetlands.

Figure 7. Focal species' dispersal resistance in the Cootes to Escarpment EcoPark System focal area. Resistance reflects the effort required to move through different land use and land cover types (values 2 to 32) relative to habitat patches (value of 1; Table A4).

Habitat network connectivity analysis. We measured the importance of habitat patches to maintaining functional connectivity for each of the focal species. We measured habitat patch importance with two complimentary metrics. Patch importance based on area-weighted flux identifies patches that are large and have lots of connections to other patches. There was variability across the focal species in terms of which patches were most important based on area-weighted flux, but a commonality was that for all species there was moderate to high importance for large forested patches in the middle of the EcoPark System focal area (Figure 8). The value of these patches comes from their relatively large size and from their central position in the focal area. Cootes Paradise is also identified as important for Blading's turtle because of its size.

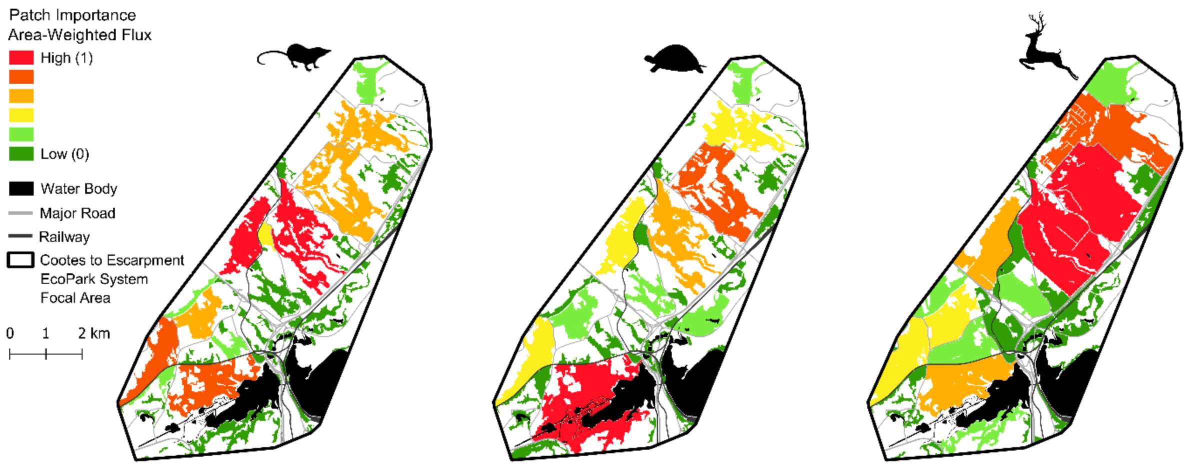

Figure 8. Focal species' habitat patch importance based on area-weighted flux in the Cootes to Escarpment EcoPark System focal area. Important habitat patches are large and highly connected to many other patches.

Stepping stone patch importance identifies habitat patches which are important for maintaining connections among distant parts of each focal species' habitat network. The extent to which habitat patches on the landscape act as stepping stones varied greatly among the focal species (Figure 9). The Northern short-tailed shrew and the White-tailed deer had relatively few patches that are high importance stepping stones. The short dispersal distance of the shrew meant that it was not able to move across the full focal area and therefore did not have many habitat patches that served as stepping stones. The long dispersal distance of the deer meant that it was able to move about the full focal area with ease and was not dependent on any given patch to act as a stepping stone. The role of individual patches to act as stepping stones was most important for Blanding's turtle which is a moderate disperser relative to the size of the focal area. Maintaining connectivity across the Blanding's turtle habitat network requires a series of stepping stone movements and as a results many of the habitat patches are important.

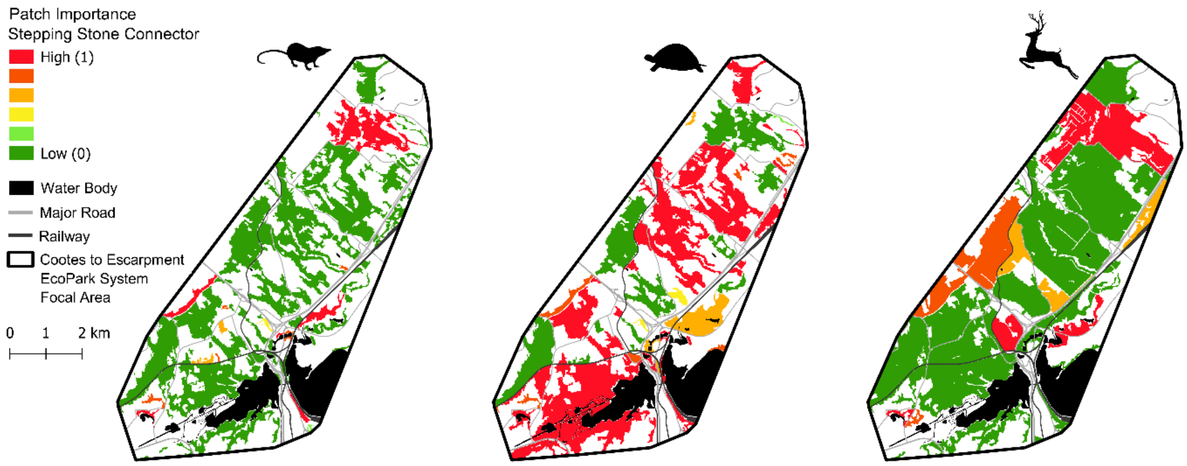

Figure 9. Focal species' habitat patch importance based on stepping stone movements in the Cootes to Escarpment EcoPark System focal area. Important habitat patches provide connectivity among all other habitat patches in the network. Blanding's turtle is most dependent on stepping stone movements due to its moderate dispersal distance relative to the size of the focal area.

The results of the generalised and focal species connectivity analyses are summarized in Figure 10. The movement probability map shows areas where we expect corridors of movement across the landscape for a generic wetland or forest-dependent species. The focal species overall connectivity importance of habitat patches identifies areas of agreement across the area-weighted flux and stepping stone patch importance measure for all focal species. The large, central forested patches in the north as well as Cootes Paradise Marsh were important for multiple connectivity metrics and multiple focal species. Overall, habitat suitability in the EcoPark system was high, suggesting that there were large amounts of either highly suitable habitat for a single species, or suitable habitat for multiple species.

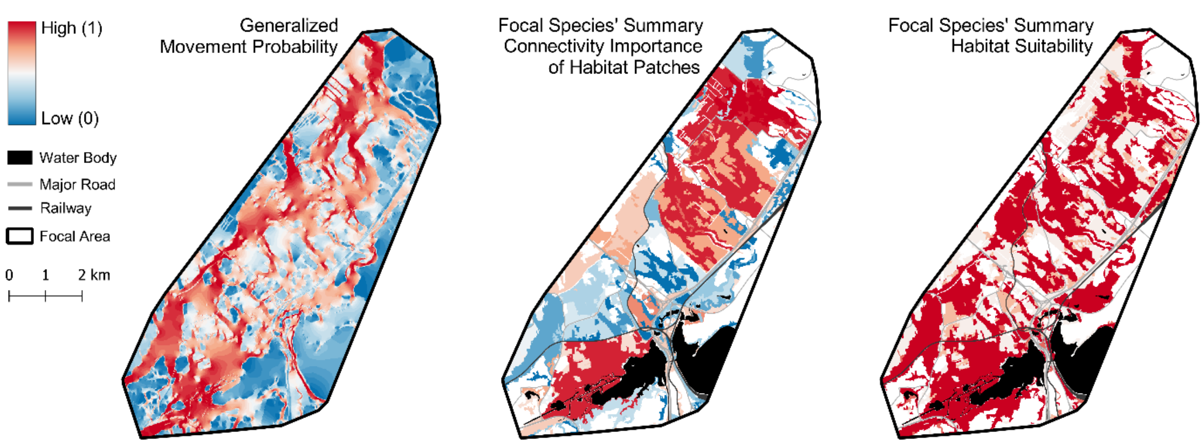

Figure 10. Summary of generalized and focal species connectivity analyses within the Cootes to Escarpment EcoPark System focal area. Movement probability (panel 1) highlights probable movement corridors; connectivity importance of habitat patches (panel 2) shows areas that are important for multiple types of connectivity and for multiple focal species. Habitat suitability summary (panel 3) indicates areas of suitable habitat for at least one or more focal species.

Overall Summary

The overall summary map shows priority areas for multispecies connectivity conservation (Figure 11). This summary map integrates all analyses across all focal species by summing the three maps shown in Figure 10. There were high value connectivity areas across the EcoPark System. Some of these high value areas were already protected by EcoPark System partner organizations (shown in grey); however, high value connectivity areas also fell outside of EcoPark System partner lands and these areas represent key opportunities for connectivity management and conservation activities.

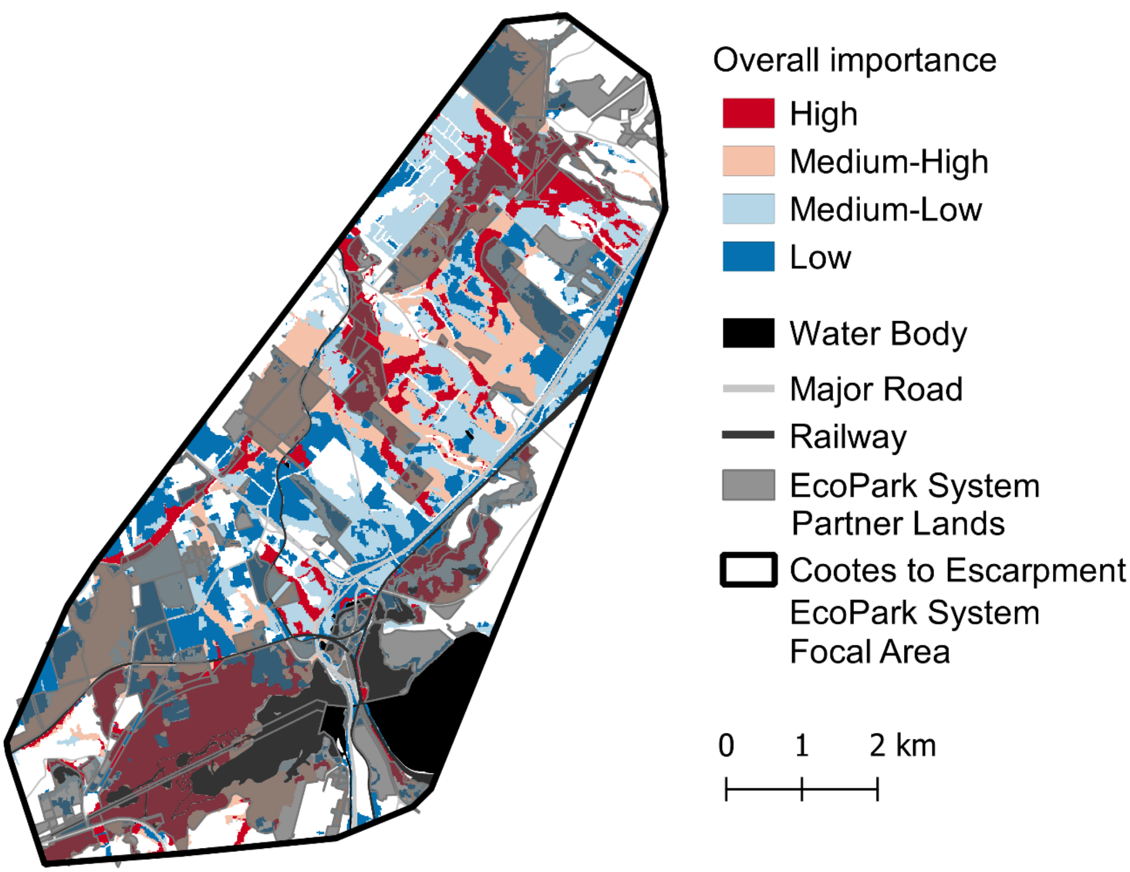

Figure 11. Overall summary of priority areas for multispecies connectivity conservation in the Cootes to Escarpment EcoPark System focal area. Priority areas in this map integrate the results of the generalized connectivity analysis and the focal species habitat suitability and connectivity analyses. The overall summary ranges from 0 to 3 and is the sum of the three summary maps in Figure 10.

7.0 Stakeholder Consultation Workshops

Key research and mapping findings from this project were shared with partner agencies and stakeholders associated with the EcoPark System, in the fall, 2020. A series of five inter-active virtual workshops engaged participants in large and small group virtual discussions on the existing barriers and opportunities for wildlife movement and ecological restoration within and outside of the EcoPark System.

A broad range of stakeholders, representing diverse interests attended the workshop series. They included members of the EcoPark System Management Committee, City of Burlington and Hamilton Planning, Engineering and Parks and Recreation departments, the Region of Halton Planning Services, Conservation Halton, Hamilton Conservation Authority, Friends of the Cootes to Escarpment EcoPark System, McMaster University, Special Interest Groups, partner agencies, the Friends of the Greenbelt Foundation, and RBG staff. Over 40 individuals participated in this process, sharing their expertise, experience, and ideas in large and small discussion groups.

For the purposes of discussion, the study area was divided into the following focal areas:

1. Lower Grindstone
2. Cootes Paradise South
3. Cootes Paradise North/Rock Chapel
4. Waterdown
5. North Aldershot

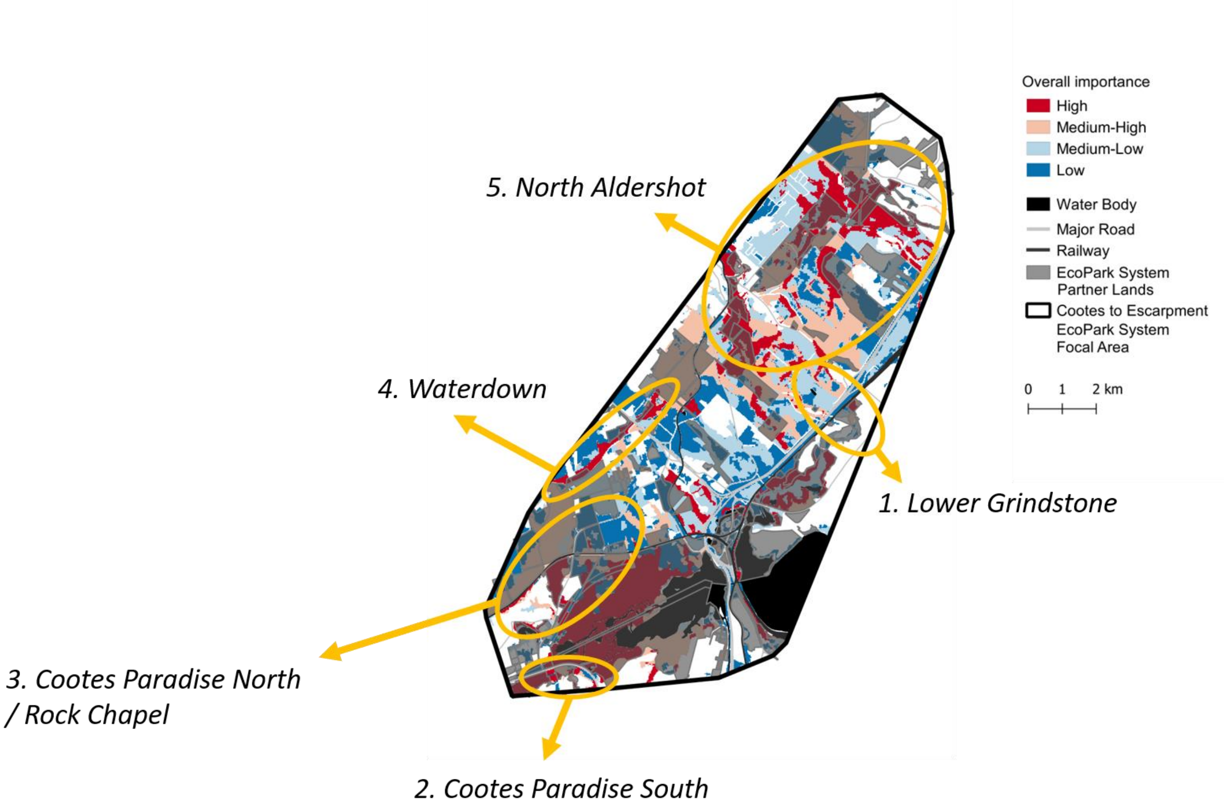

Figure 122. Overall summary of priority area with focal areas highlighted.

description of the area characteristics, land use, land cover, focal species general movement probability, habitat patches and habitat suitability mapping was included on the work sheets.

Participants were asked to think about the following questions in preparation for the workshops:

i. What is currently happening in each of the focal areas? (e.g. state of the landscape; species; policies and practices; infrastructure).
ii. What are the barriers to this wildlife corridor? (e.g. existing and potential barriers – man-made and natural).
iii. What are the opportunities to protect and enhance the wildlife corridors? (e.g. landscape; planning practices, policies, decision-making, best practices, public engagement and awareness and collaboration/partnership opportunities).

Each workshop was supported by *Zoom* (a virtual platform) and recorded for the sole purposes of documenting the presentations, small and large group discussions and emerging themes. Comments and questions from participants were elicited from the *Chat Box* feature and were addressed in the large group setting.

Workshop 1 - provided an overview of the methodology, analysis and key findings of the Wildlife Corridor Mapping Project by the ApexRMS consulting team. This information set the context for the workshop discussions.

Workshops 2-4 - provided participants the opportunity to deepen the conversation about what is currently happening in each of the four focal species areas within the study area, to identify barriers to species movement, and to brainstorm opportunities for planning and improving habitat and wildlife connectivity within and outside the study area.

Workshop 5 - provided participants the opportunity of presenting and listening to the highlights from the small break- out group discussions from workshops 2-4 and to bring forward ideas on whom and how to share the findings of the study to a broader audience.

8.0 Workshop Highlights

Participants reconvened for the last virtual workshop in the series. A reporter from each of the small group break- out sessions from the previous workshops in November were asked to share their top three (3) Barriers and Opportunities within and outside of the study area based upon the conversation questions provided by the facilitator. The following is a summary of this information and the large group discussion, organized by themes. This information is not in any order of importance.

Existing Barriers

Infrastructure Planning and Design

- Corridor infrastructure – it would be beneficial to know what projects are being considered and the status of their review to influence decision-making and inform impacts
- Roads and infrastructure that divides and significantly fragments the existing EcoPark System is an impediment to safe wildlife crossings (e.g. Waterdown Road; Valley Road; Patterson Road; Olympic Drive, York Road; Highway 403; Coach Road, Highway 6; Osler Drive between McMaster along Main Street and between the University Plaza and McMaster)
- Roads within and outside of the EcoPark System were not designed or planned with wildlife crossings in mind

On-going Maintenance

- Lack of on-going and timely maintenance (e.g. repairs to fencing; turtle crossings; wildlife corridors for deer movement)
- Lack of uniform maintenance standards and enforcement

Sustainable Funding

- Lack of sustainable funding for projects from all levels of government
- Need to diversify funding sources to support on-going and new projects

Decision-Making Structure

- Lack of pro-active development review and decision-making process/models
- Lack of an integrated systems approach to decision-making and policies
- Silo decision-making among municipalities, agencies, etc. that do not take into consideration the ecology of the area affected

Development Pressures and Impacts

- Pollution and poor water quality negatively impacts amphibians and fish garbage like fishing line, is strangling birds
- Impact of new development on the landscape, habitat and wildlife movement
- Increase urban development pressures on the landscape (e.g. roads; infrastructure; housing)
- Impact on the environment and habitat with encampments – this is a broader issue of affordable housing

Land Use Policies and Plans

- Lack of policies to enforce use and encroachment
- Provincial Policy Statements – there is currently an absence of policies to integrate wildlife corridors into provincial planning
- Increase in poaching and the need for more law enforcement from the Ministry of Natural Resources (e.g. checking for fishing licenses)

Invasive Species

- Managing invasive species is a challenge and generally impacts the quality of an area
- Tree species, especially those critical for butterfly and moth larvae, pollinators, migrating birds, browsing animals over time, can be replaced by invasive shrubs that negatively impact biodiversity and species wellbeing (e.g. lack of nesting areas for breeding)

Leadership and Political Will

- Lack of political will, leadership and long-term planning

Data sharing and management

- Organizational policies restrict certain data sharing, creating difficulty in retrieving relevant information for decision-making and pro-active planning/design purposes

Land Ownership and Acquisition

- Lack of money to acquire key landholdings to enhance corridor connectivity
- Challenge to negotiate with landowners for land acquisition - market value is not affordable
- Poor and ill –informed private property landowner management/maintenance practices (e.g. invasive species; encroachment; poor maintenance standards).

Increased Public Use

- Current use of multi-use trails is negatively impacting the landscape and disturbing wildlife habitat and movement
- Usability of some of the corridors between natural areas is poor due to existing conditions
- Increased trail use create erosion issues in certain locations within the EcoPark System
- How people are interacting within the landscape and between corridors – not always compatible or safe
- Challenge and competition for moving between areas - people and wildlife create limitations
- Human use can also affect the quality of an area if there are too many areas opened for human use or if there are simply too many people around. Certain species will avoid the area.
- Pollution and poor water quality negatively impacts amphibians and fish garbage like fishing line, is strangling birds

Opportunities Moving Forward

Biodiversity and Connectivity

- Preserve and create new connections/corridors within and outside the EcoPark System to become thriving spaces and biodiverse ecosystems
- McMaster Restoration Project – excellent design and repurposing a parking lot to become an important wildlife corridor and habitat restoration – example of an innovative best practice and a project worth replicating
- Be creative and look for effective ways to integrate human activity and nature – seeking balance in urban and rural areas
- Discover new things. There is so much going on already with regards to research and the long history of ecological restoration across all the landscapes that we need to build upon (e.g. the rehabilitation and naturalization of Kerncliffe Park in the heart of Burlington –a former quarry)
- Engage property owners and partners/agencies in activities and decision-making that supports the wellbeing of the EcoPark System (e.g. hydro corridor the runs through the North Shore region of Cootes from Olympic Drive to York Road. could be managed as a grassland or native shrub land with the cooperation of Hydro One) to attract greater biodiversity (e.g. ground nesting birds; bobolink, meadowlark, and grasshoppers)
- Preserve spaces for wildlife restoration and preservation
- Identify unique open spaces, including cemeteries, railway and hydro corridors to improve connectivity (e.g. Turtle Conservation Authority working collaboratively with Hydro One and Toronto Hydro)
- Improve the quality of the habitat patch size for animals that tend to avoid edge habitat, whether they prefer grassland or forest, particularly during breeding season for birds and mammals. This would increase species like Acadian, flycatcher and bobolink, or span from grassland
- Remove and manage invasive species from habitat patches (e.g. native trees have a hard time establishing in areas overrun by buckthorn and honeysuckle)

Infrastructure Design and Approvals

- Bring forward new development and design review processes – i.e. infrastructure design and planning to consider ecological and habitat impacts in the initial phases
- Incorporate public art installations that tell a powerful story or message (e.g. Fishing line art installation; part of infrastructure projects)
- Participate and have a voice during the development application review process to ensure biodiversity and landscapes are built into the design (e.g. roads; corridors; residential plans)
- Opportunity to influence the design and decision-making for the Highway 6 underpass – policy making to enhance wildlife connectivity within this area of the EcoPark System
- Explore solutions for storm water management to support biodiversity (e.g. plants)
- Communicate among our partners and decision- makers and share best management practices in engineering, from color design, permeability, green engineering and solutions that work
- Adapt a pro-active road design and construction versus re-active road repairs
- Demonstrate the cost benefit of data sharing for maintaining and designing appropriate infrastructure for wildlife corridor movement versus number of deaths associated with vehicles and wildlife incidents
- Cost benefit of good design – pays off in the long term
- Influence development approval process – provide information – design process at the outset of the development process and incorporate green engineering and design features to maintain and enhance the ecosystem's health and sustainability

Recreation Demand and Design

- Create a balance between the demand for recreation and human movement with wildlife movement and preservation – a policy framework is needed, education and public awareness
- Improve the conditions of the trails - avoid wet areas where there is water runoff and restrict public access in these locations to reduce impact (e.g. walking around the wet areas widen the area if impact)
- Discourage trail users from going off trail in particular steep inclines
- Design trails with a more gradual grade/incline

Information Sharing and Learning

- Write articles and share information within our working networks
- Host and/or facilitate internal staff workshops to share information, generate dialogue and ideas
- Share information with volunteers to engage and recruit new volunteers (e.g. stewardship projects)
- Share open data and GIS information to inform decision-making among partner agencies, organizations and government
- Always be curious to new learning and be an explorer – this is when innovation happens
- Open data sharing among partners to inform effective and timely decision-making at all levels (e.g. information about mortality rates of turtles and other species, along with roadkill or species risk data would be helpful to inform decisions regarding road improvements, bypasses and infrastructure design)

- Develop an online data network and/or a GIS database (e.g. identify areas with high amounts of deer strikes to install fencing or culverts to avoid the deer strikes).
- Consolidate data and methods of collection to avoid duplication among user organizations and partners
- Develop a common platform in a central location with access to the history of infrastructure projects and relevant information to inform decision-making
- Determine who is the central data administrator
- City of Hamilton – historical, feature and animal data is available to share with partners
- Consider data applications such as I -accessible for road maintenance staff, hydro workers, etc. for easy retrieval and reporting in the field (e.g. road kill)

Funding

- Engage donors and funding partners (e.g. showcase the benefits of the EcoPark System Strategic Plan)
- Apply for funding/grants for key projects (public/private partners)
- Develop multi-year funding strategies
- Diversify funding opportunities (e.g. government; private sector; foundations, individual donors)
- Secure sustainable funding from all levels of government – need to address human and material capital

Public Awareness and Education

- Embed in education curriculum to engage students – citizen science opportunities
- Public education and awareness (eco-tourism; marketing strategies; social media)
- Engage the media in story-telling to reach a broader audience
- Offer courses to the public/property owners – assist with native species planting and landscaping (front and backyards are important contributors to biodiversity in an urban area)
- Use social media to showcase achievements, to engage public dialogue and promote programs/projects
- Continue to create brochures to market projects (e.g., water testing and benefits)
- Use plain English in communicating with the public remembering that not everyone is a scientist – this will increase understanding, buy-in and engagement (e.g., programs, social media, interpretive signage, news articles)
- Increase public awareness of the EcoPark System, wildlife, natural environment and the sensitivity of the ecosystem – passive recreation – appropriate areas to walk and areas to avoid
- Educate private landowners about invasive species in their landscape plans

Leadership and Advocacy

- Participate on Management Committee and other project teams to support the EcoPark System
- Be champions within our organizations/departments and in community
- Demonstrate leadership and bring your voice forward at key decision-making and planning tables
- Implement the Water Leaders program (began as a citizen science project to test water quality at Bayfront Park)
- Be a delegation in front of Council, Boards, and Steering Committees

- Advocate and be a leader/voice for long term planning – it is critical to look forward beyond the immediate future for environmental sustainability
- Align with political leadership who support the vision and goals of the EcoPark System
- Continue to engage political leaders in the dialogue

Land Acquisition

- Develop a multi-year land acquisition strategy and financial plan to support the strategy with a focus on key properties within the EcoPark System that will improve connectivity, protect sensitive areas and create safe wildlife corridors within and outside the area
- Review land acquisition strategy in light of current provincial policies, market trends and landowner expectations – there are key parcels of land that would create a large and permanent green and connected corridor

Decision-Making

- Integrate decision-making among government, local authorities and agencies to better inform policy decisions, development approvals and projects that affect the eco-system and wildlife corridors within the urban environment
- Take a long-term versus a short-term, immediate decision-making approach to policy/approvals/projects that affect the sustainability of the ecosystem

Partnerships

- Forge partnerships to support new projects that align with the research findings (e.g. collaborations; funding; stewardship; research)
- Explore partnership opportunities with businesses within the EcoPark System
- Build upon and leverage existing cross-disciplinary and departmental consultation, collaboration and partnerships, particularly for programming, research and policy development (e.g. engage Universities) within the EcoPark System – support those programs and activities that align with the vision and goals of the EcoPark System

Engage Stakeholders and the Community

- Host events to engage community and stakeholders (e.g. community hikes/walks; demonstration projects)
- Undertake habitat creation projects – engage the community in restoration initiatives
- Explain the benefits of conservation and good design in communicating goals and vision for the EcoPark System to stakeholders and users (e.g. rationale why trails are located in specific areas and not in other areas; benefits to certain hobbyists who enjoy fishing, birding and photographers; eco-tourism; hydrogeology, and natural pest control)
- Continue strategic and on-going stakeholder consultation to inform and influence decision-making
- Include input from landowners and businesses within the EcoPark System
- Continue to support and advocate for stewardship projects – engage community volunteers that will broaden support and shift awareness of activities

- Engage different groups and agencies to work collaboratively on stewardship projects to increase community education/awareness and engagement

Report, Plans and Policies

- Write report to councils, boards, committees with relevant information to educate and inform decision-making
- Develop land use policies that align with the vision and goals of the EcoPark System
- Consider, and if appropriate, incorporate the research findings of the Wildlife Corridor Mapping Project into best practices, policy formulation and decision-making practices
- Influence Provincial Policy Statements – review and updates – get involved locally
- Enforce standard management policies and guidelines across the partnerships to provide a unified message for how we're managing our properties, using our trail systems, our corridors, and how we want to interact with the people who live and work here

Research

- Explore opportunities to undertake collaborative research projects with educational institutions and research experts locally, nationally and internationally
- Align with international initiatives such as the International Union for Conservation of Nature (IUCN)
- Create “living laboratories” for research and learning (i.e. the partnership between McMaster University and the RBG)

SHARING IDEAS AND COMMITTING TO ACTION

In the large group, participants were asked to share their ideas in response to the following questions:

i. Whom do we want to share the outcomes of the research and findings of the Wildlife Corridor Mapping Project?
ii. How do we want to share and communicate the Project findings?
iii. What commitment will you take within and outside your organizations/departments?

We would like to share the research and findings with …

- Management Committee
- Local area Councils
- All levels of government/policy makers
- Partner agencies and organizations
- Universities and Colleges
- Research institutions
- Volunteers who align with our vision and goals – stewardship
- Special Interest Groups
- New Canadians as part of an education and awareness initiative to the features and benefits of the EcoPark System
- Utilities – Railway; Hydro
- Private landowners within the EcoPark System and fringe
- Businesses with the EcoPark System

- Peers within your organization (e.g. Engineers, Biologists, Planners, Researchers, Landscape Architects, Finance, Senior Management)

We would like to share and communicate the research and findings through ….

- Publications
- Media releases
- Social Media channels/networks (Twitter, Instagram, Facebook
- E-Newsletters
- Websites
- Workshops – colleagues and the public on specific topics
- Interpretive trailhead signage and storyboards
- Elementary and Secondary school curriculum – imbed early learning to engage students to become champions/leaders in stewardship projects and other activities that support the vision and goals of the EcoPark System and the research outcomes of this project
- Create educational videos, mapping and story boards to broaden awareness and learning

We are collectively committed to…

- ✓ continue to work collaboratively
- ✓ find innovative ways to secure sustainable funding from all levels of government
- ✓ develop a long-term land acquisition strategy and implementation plan
- ✓ engage the community, private landowners and businesses within and outside the study area in stewardship initiatives and other projects/collaborations
- ✓ share data and best practices
- ✓ continue the dialogue
- ✓ broaden awareness and education related to the benefits of preserving and enhancing biodiversity, corridors and connections for wildlife and human movement within EcoPark System
- ✓ bring a strong voice and leadership to decision-making tables
- ✓ pro-actively influence land use policies, plans and infrastructure design
- ✓ partner with educational institutions for research opportunities, sharing resources and exploring curriculum development

9.0 Discussion and Potential Next Steps

The analyses and workshops presented in this report provide a high resolution (15 m) snapshot of current landscape connectivity across the EcoPark System and discuss potential opportunities and challenges when integrating landscape connectivity into management of the EcoPark System.

Landscape Connectivity Enhancement and Restoration

Based on the most up to date land use and land cover data available, the analysis assesses connectivity among natural areas both within and between EcoPark System partner owned properties and the surrounding landscape. The focal species analyses express connectivity for different scales of movement and for different habitat types within the EcoPark System. Together, these connectivity analyses paint a vivid picture of current connectivity hotspots, connectivity breaks, and conservation priorities.

The EcoPark System is connected to the broader landscape by five key movement corridors extending north-west and south-west. These corridors serve as critical connections between the natural areas within the EcoPark System to the natural areas in the broader landscape. Many of the high value areas fall within existing EcoPark System partner lands and defined management areas, such as Royal Botanical Gardens' Cootes Paradise Marsh.

EcoPark System partner agencies attending the workshops noted restoration opportunities to increase their value. For example, within existing grassland restoration projects, there may be an opportunity to incorporate forest corridors. Stakeholders noted that high value areas that fall outside of partner lands should be cross-referenced with the EcoPark System land securement strategy. Similarly, any proposed land-use projects that affect high value areas should be assessed in terms of the negative consequences they may pose for landscape connectivity.

In addition, culverts and bridges seem to play a role in maintaining connectivity. It is important to continue to manage these areas as both high quality habitat and as movement corridors. Workshop participants were interested in using these findings for culvert and bridge management, maintaining native vegetation, and minimizing human disturbances.

Ultimately, the results presented here are a hypothesis about high value connectivity areas and high-quality habitat areas based on the best available data and science. They provide a strong for additional research. Stakeholders noted ground-truthing wildlife corridors to see if wildlife species are using them for dispersal and the degree of human use within these identified wildlife corridors to be able to manage potential human-wildlife conflicts (e.g. trail use policies) as priorities. In addition, surveying invasive species in these high connectivity areas to manage their spread.

Modeling Future Priorities

The EcoPark System secretariat sees the connectivity prioritization map as an opportunity to identify target areas for protection (land acquisition) or restoration. For example, unique open spaces such as cemeteries and hydro corridors may be managed to promote connectivity. As such, repeating these connectivity analyses in the near future to get an updated picture of connectivity, to incorporate any new data or more complete data (e.g. more complete culvert and bridge data), and to track connectivity trends will be considered.

A landscape change model to project spatial patterns of land use into the future driven by scenarios that combine land-use management plans with regional climate projections was recommended by workshop participants. The robustness of connectivity priority areas to these future scenarios could be assessed in terms of their ability to sustain connectivity across the landscape. Conservation priorities would be assigned to habitat patches and linkages based on their contribution to the connectivity of natural areas for all focal species and across the full range of possible future climate and land-use scenarios.

Lastly, these connectivity maps do not account for any expected changes due to land-use or climate change. Existing natural areas within the EcoPark System may continue to be further lost or fragmented due to urbanization and agricultural expansion while currently degraded lands may be restored. We expect improved outcomes for the biodiversity of the EcoPark System when habitat patches and linkages are prioritized based on their contribution to both present and future landscape connectivity.

This research and subsequent series of workshops introduced ideas for an integrated, broad-scale perspective which recognizes that declines in habitat suitability and connectivity in one part of the landscape may affect the habitat quality and connectivity in another part of the landscape. As such, an integrated, broad-scale perspective to help to assess the cumulative impacts associated with many small projects on overall landscape connectivity and biodiversity conservation will be encouraged by the EcoPark System partnerships and its stakeholders.

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