ESSM 600 Principles of Ecosystem Science and Management

Fall 2019

The Role of Green Corridors for Wildlife Conservation in Urban Areas

https://psmag.com/environment/forging-new-path-working-build-perfect-wildlife-corridor-91105

Highway crossing bridge for animals, Banff National Park, Canada. (Photo: Robert Crum/Shutterstock)

https://ahbelab.com/2016/07/28/green-lung-infrastruct

Bishan Park, Singapore | Green corridor with Kallang River which connects Singapore Strait and Lower Peirce Reservoir. CC photo: ***commons.wikimedia.org***

The Meadoway: Scarborough's 16 km Green Corridor, Toronto, Canada

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Outline

1. Brief Introduction
2. Case Studies
3. Conclusion

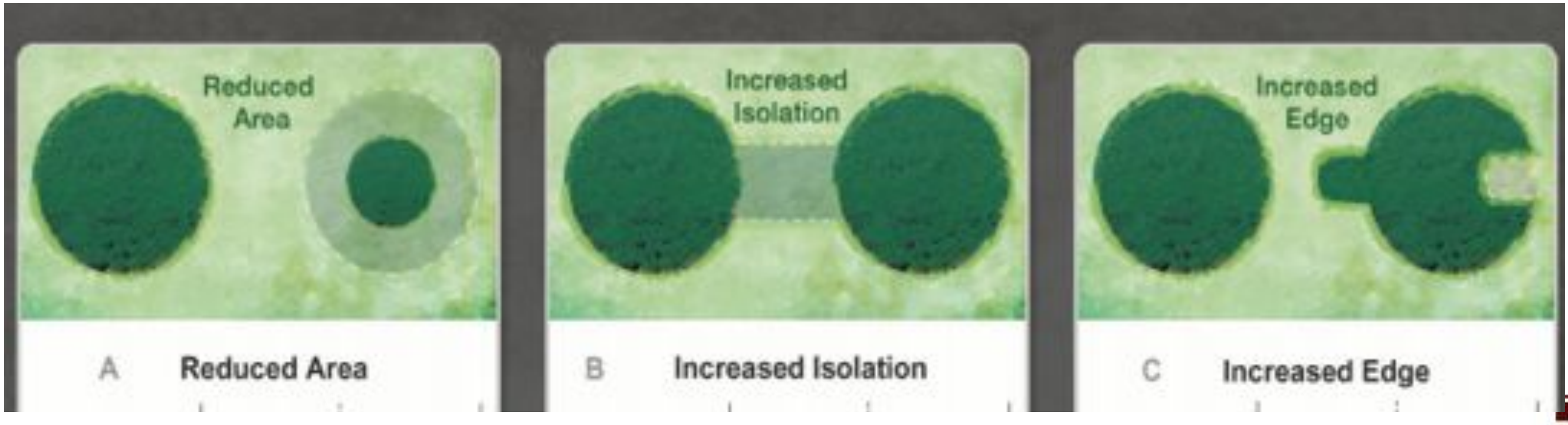
Landscape Ecology

- Three basic elements: matrixes, patches, and **corridors.**
- Corridors are narrow strips of land which differs from surrounding matrix.
- Corridors can form as a result of environmental resources such as streams and geological formations.
- Corridors can also originate from spot disturbances and anthropogenic **habitat fragmentation.**


Urbanization

Habitat Fragmentation and Loss

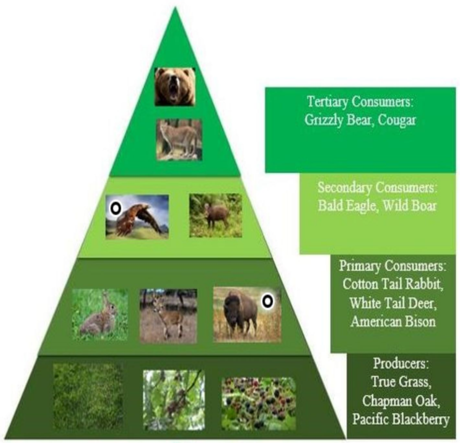
- At a global scale, both reduce the quality and quantity of suitable environment by altering nutrient cycles and decreasing biomass.
- Causes natural ecosystems to divide into smaller (A), more isolated fragments (B) with increased edge effects (C) separated from the matrix.
- Threaten the conservation of biological diversity by <u>hindering movement and disperse activity.</u>



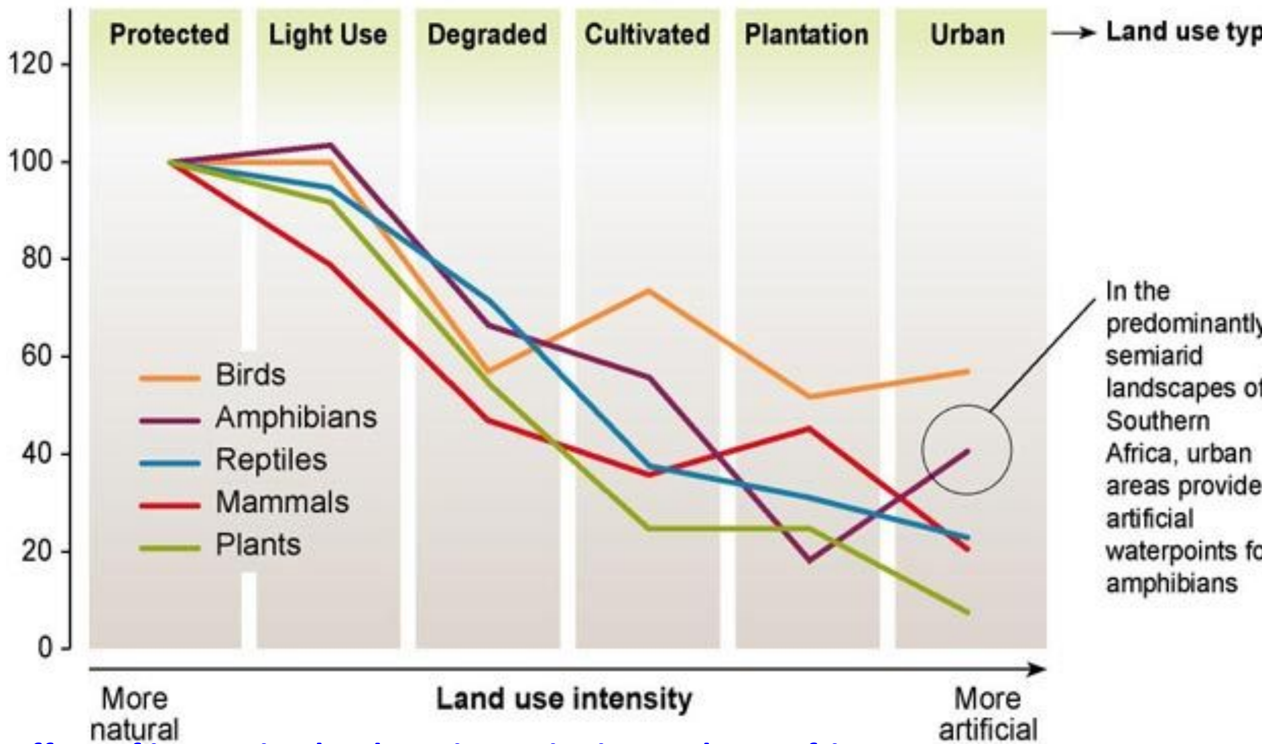
Nick M. Haddad et al. Sci Adv 2015;1:e1500052

Fragmentation Affects the Whole Ecosystem

- **Initial exclusion, isolation, and edge effects lead to loss of biota in all trophic levels.**



Average remaining percentage of population under each land use
compared with the pre-colonial period (index =100), 300 years ago



Effect of increasing land use intensity in southern Africa

Protected areas: assumed to have intact biodiversity and therefore used as a reference
Light use: natural vegetation productively used (e.g., for grazing) within the limits of sustainability
Degraded: natural vegetation where intensity of use exceeds the natural productive capacity
Cultivated: cropland and planted pastures
Plantation: monocultures of exotic trees, mainly eucalyptus and pine species
Urban: built-up urban and high-impact mining landscapes

Source: Scholes and Biggs 2005

Solution: Green Corridors

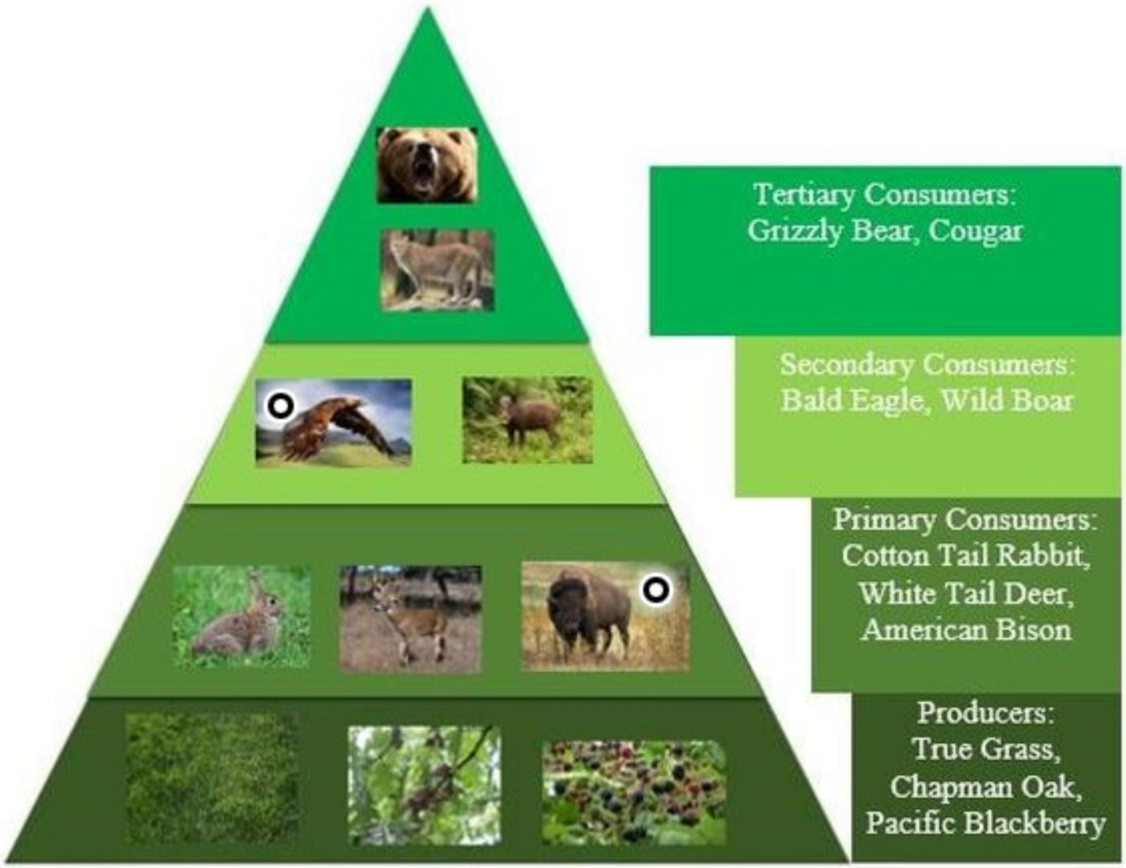
- Used to mitigate the negative effects of the built environment of cities by increasing connectivity among fragments.
- Provide natural routes of movement for both people and urban wildlife by linking fragments of habitat.
- Promote biological conservation in urban areas.

Nick M. Haddad et al. Sci Adv 2015;1:e1500052

Our Objectives

1. Discuss the effectiveness of green corridors as possible solutions for habitat fragmentation through two case studies.
2. Address the feasibility of implementing green corridors in urban landscapes.

Case Study: Corridor Considerations for Avian Communities



Why birds?

- Sensitive to environmental change

- Easy to locate and identify
- Provide many ecosystem services

Why birds?

- Increase NPP through predation
- Import and export of nutrients
- Pest regulation
- Seed dispersal promotes Carbon sequestration
- Bird watching/ ecotourism

Circuit Theory and Landscape Connectivity

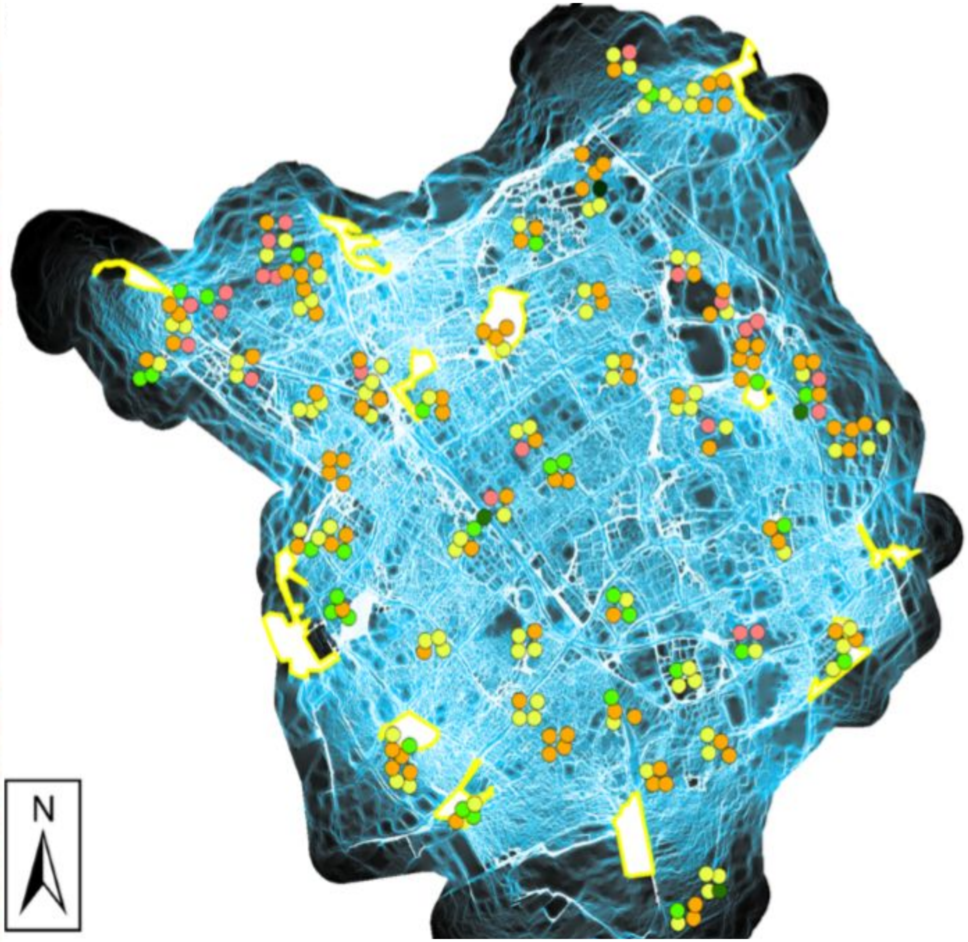
- Circuit Theory is a set of techniques used to describe the flow of energy around an electrical loop.

- Resistance values were assigned to mapped pixels based largely on LULC class to produce a map of "cumulative current" across the landscape.

Table 1 Assigned resistance values (unitless, but on a 0–100 scale) by mapped land use/land cover (LULC) class, and modifications based on additional factors and features, for *P. major* and *C. caeruleus*

Class/feature	Assigned resistance value	Justification
Woodland patches larger than 5 ha	1	Song and Kim (2015) found *P. major* individuals prefer large woodland patches
Tall/mature woodland patches (>15 m)	2	Optimal habitat type (Perrins 1979); presence of tall trees indicates older, more structurally complex patches
All other woodland	5	Core habitat type but fewer ecological resources than mature stands
Tall grassland/shrub	10	Cover and some ecological resources
Short grassland	25	Some ecological resources but lack of cover
Paved/non-vegetated ground	30	No physical impediment to flight but few ecological resources
Water	45	Tremblay and St. Clair (2009) observed reluctance to cross waterbodies
Buildings	50	Physical impediment to flight
Land greater than 45 m from nearest woodland patch	Initial +50	Tremblay and St. Clair (2009) observed increased reluctance to cross gaps larger than 45 m
Major road (A roads, primary roads and motorways in OS MasterMap)	Initial +20	Tremblay and St. Clair (2009) observed reluctance to cross roads with heavy vehicle traffic

Lower Resistance = Higher Connectivity/Current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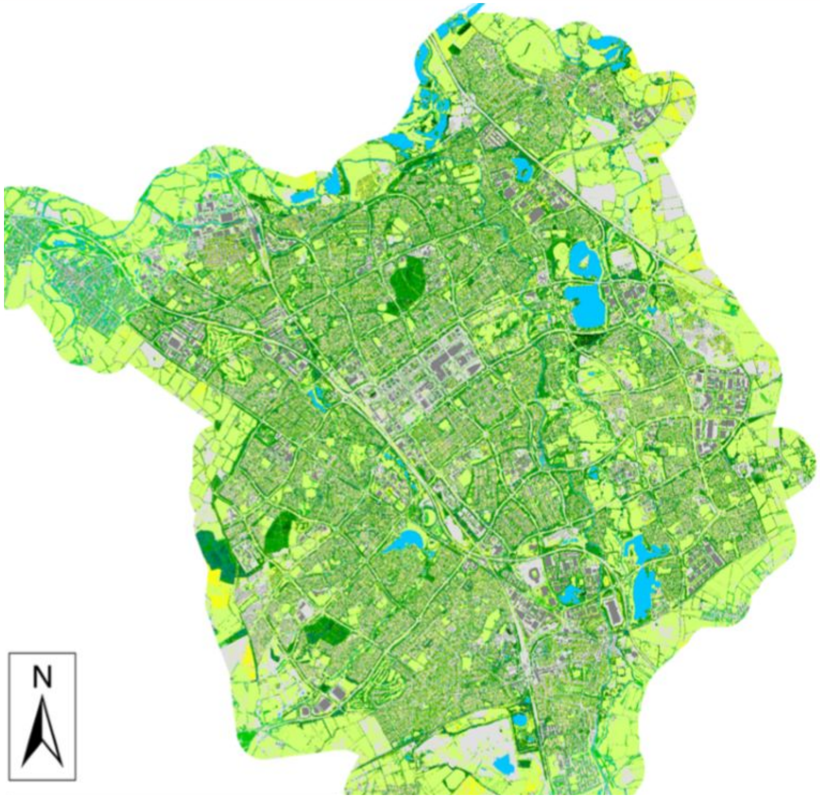
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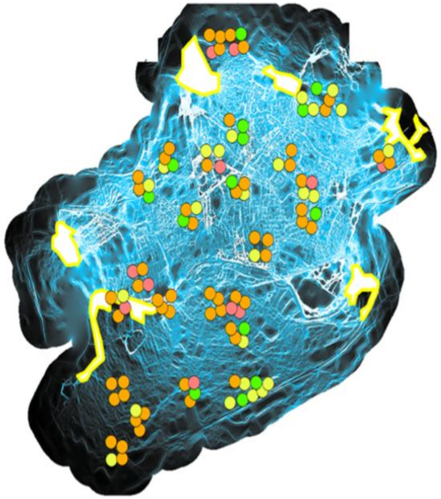
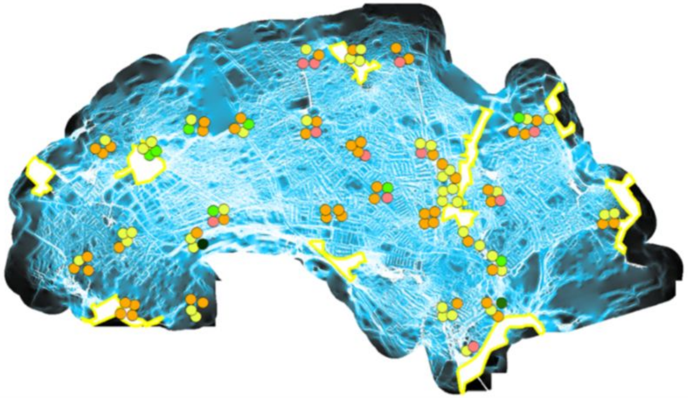
Bedford

Woodland



Bedford

Luton



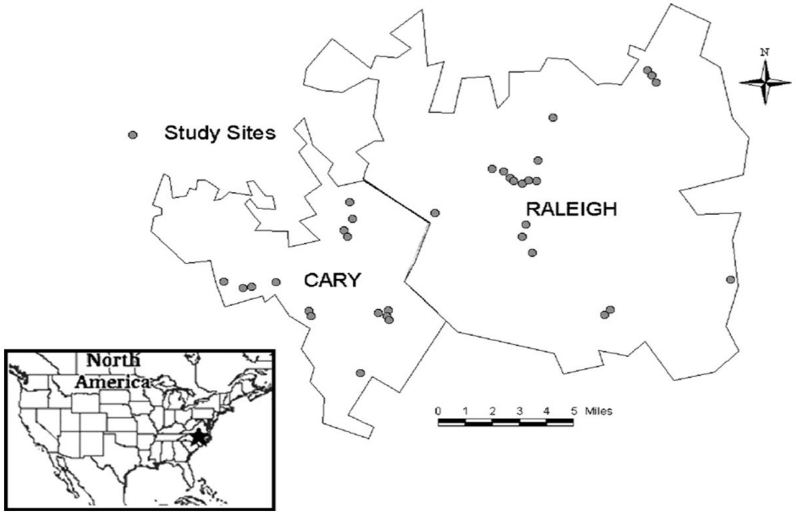
Luton

Circuit Theory and Landscape Connectivity

- The amount of core habitats is a good indicator of urban resistance and their proximity typically increases “current” in the areas surrounding and joining them.
- Modelled “current” either follows wooded corridors, where available, or jumps between small wooded islands dispersed between core habitat.

Designing Corridors for Urban Birds

- Surveyed birds in 34 corridor segments 300 m long with various widths



1. Distribution of greenway segments in Raleigh and Cary, North Carolina, USA (2002).

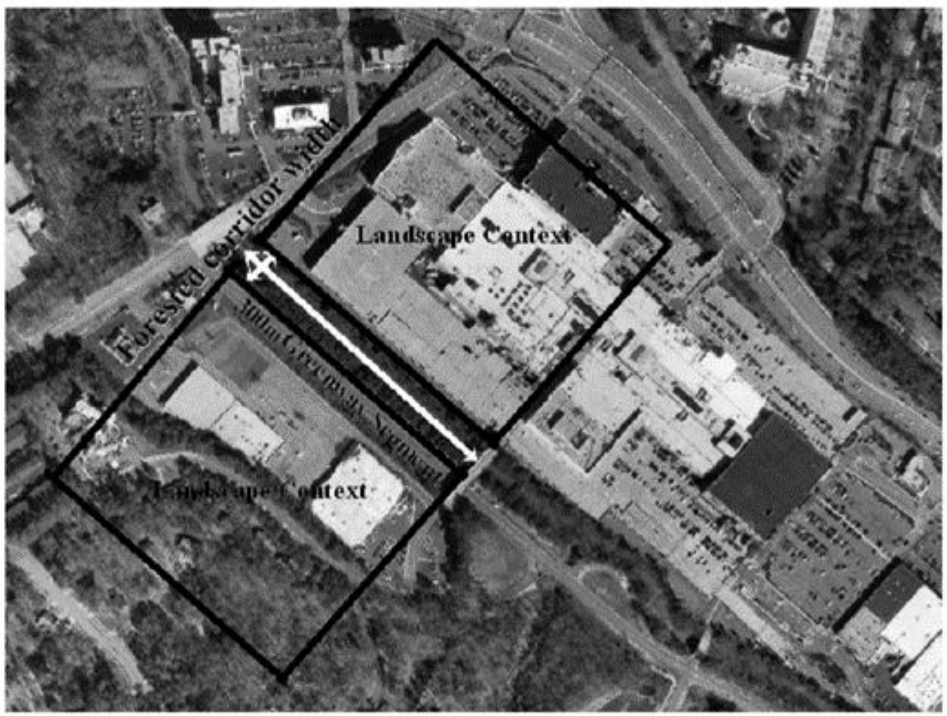


Fig. 2. Forested corridor width and landscape context were measured for each 300 m greenway segment using aerial photography in ArcGIS. Width was measured perpendicular to the greenway orientation and context was measured in two 300 m × 300 m areas on either side of the forested corridor.

- Placed birds into different habitat, migration and foraging guilds

Designing Corridors for Urban Birds

Table 1
Greenway forested corridor width, landscape context, and greenway composition and structure measures used in multiple regression analyses on total species richness and abundance, and guild species richness and abundance measures from Raleigh and Cary, NC greenways (2002–2003)

Variable	Description
Corridor width	Average width (m) of the greenway forested corridor
Landscape context (in two 300 m × 300 m areas adjacent to either side of the segment)	
Canopy	Proportion of canopy
Building	Proportion of building
Paved	Proportion of pavement
Lawn	Proportion of lawn cover
Earth	Proportion of bare earth
Water	Proportion of water
Greenway composition and structure	
TrailDist	Distance (m) from the point count center to trail edge
YoungFor	Percent of count area covered in young forest (1–6 m)
Managed	Percent of count area covered by human management (lawn, trail, etc.)
StrWidth	Width (m) of greenway stream or river
Hardwd	Percent of the mature forest in count area composed of hardwoods
CanHt	Height (m) of tallest tree in count area as measured by sonar hypsometer
Vine	Index of percent vine cover in count area in 20% intervals (1–5)
Shrub	Index of percent shrub cover in count area in 20% intervals (1–5)
Ground	Index of percent ground cover in count area in 20% intervals (1–5)

- Three classes of adjacent land use: low-density land use, high-density land use and office/institutional
- Measured land cover in those classes
- Measured greenway composition and structure

- No forest-interior species were recorded in greenways ≤50 m wide
- Several species in other guilds were also more common in greenways wider than 50 m.

	Adjacent Land Use			Forested Corridor Width (m)				
	LDR	HDR	OFC	≤50	51-100	101-150	151-300	>300
Species	(10)	(11)	(13)	(7)	(6)	(7)	(8)	(6)
Forest-interior Species								
Acadian Flycatcher (*Epidonax virescens*)[a]	5	2	5		1	2	5	4
Black-and-white Warbler (*Mniotilta varia*)	1							1
Hairy Woodpecker (*Picoides villosus*)[a]	4	3	3			3	5	2
Louisiana Waterthrush (*Seiurus motacilla*)			1					1
Ovenbird (*Seiurus aurocapillus*)		1						1
Pileated Woodpecker (*Dryocopus pileatus*)	2	1	2		1	1	1	2
Prothonotary Warbler (*Protonotaria citrea*)			1					1
Red-shouldered Hawk (*Buteo lineatus*)[a,b]	4		1		3			2
Scarlet Tanager (*Piranga olivacea*)	1							1
Wood Thrush (*Hylocichla mustelina*)[a]	5	3	2			3	5	2
Yellow-throated Warbler (*Dendroica dominica*)			1					1
Interior-edge Species								
Blue-gray Gnatcatcher (*Polioptila caerulea*)[a]	8	7	8		4	6	7	6
Brown-headed Nuthatch (*Sitta pusilla*)	4	5	5	2	4	4	2	2
Carolina Chickadee (*Poecile carolinensis*)	10	10	11	5	5	7	8	6
Carolina Wren (*Thryothorus ludovicianus*)	10	11	12	6	6	7	8	6
Downy Woodpecker (*Picoides pubescens*)[a]	6	5	5		2	3	7	4
Tufted Titmouse (*Baeolphus bicolor*)[a]	10	9	10	2	6	7	8	6
Eastern Wood-Pewee (*Contopus virens*)		1				1		

Fish Crow (*Corvus ossifragus*)		2	3	2	2			1
Great Crested Flycatcher (*Myiarchus crinitus*)	7	5	6	2	4	3	4	5
Northern Cardinal (*Cardinalis cardinalis*)	10	11	13	7	6	7	8	6
Northern Parula (*Parula americana*)	3	1	1	1	1		1	2
Pine Warbler (*Dendroica pinus*)	3	1		2				2
Red-bellied Woodpecker (*Melanerpes carolinus*)[b]	10	10	7	4	5	7	6	5
Red-eyed Vireo (*Vireo olivaceus*)[a]	6	5	6		2	4	5	6
Red-headed Woodpecker (*Melanerpes erythrocephalus*)	2		1	2				1
Ruby-throated Hummingbird (*Archilochus colubris*)	2		1		1	1		1
Summer Tanager (*Piranga rubra*)		1	2			1		2
White-breasted Nuthatch (*Sitta carolinensis*)	7	9	5	3	4	6	6	2
White-eyed Vireo (*Vireo griseus*)[a]			2					2
Edge Species								
American Crow (*Corvus brachyrhynchos*)[b]	4	1	9	5	3	1	2	3
American Goldfinch (*Carduelis tristis*)	6	9	8	6	4	6	5	2
American Robin (*Turdus migratorius*)	9	9	11	7	5	7	7	3
Blue Grosbeak (*Passerina caerulea*)			1			1		
Blue Jay (*Cyanocitta cristata*)	7	5	4	3	5	4	2	2
Brown Thrasher (*Toxostoma rufum*)	2	3	2	3	3		1	
Brown-headed Cowbird (*Molothrus ater*)	2	2	5	3	3	2	1	
Chipping Sparrow (*Spizella passerina*)	1	5	2	2	1	2	2	1
Common Grackle (*Quiscalus quiscula*)	5	5	10	6	4	4	2	4
Eastern Bluebird (*Sialia sialis*)[b]		3			1	2		
Eastern Towhee (*Pipilo erythrophthalmus*)	7	7	7	4	4	5	5	3
Gray Catbird (*Dumetella carolinensis*)	6	3	7	5	4	2	3	2
House Wren (*Troglodytes aedon*)[a]	3	5	1	3	4		2	
Indigo Bunting (*Passerina cyanea*)[a]	3	1	4			1	3	4
Mourning Dove (*Zenaida macroura*)[a]	3	3	5	6	3	1	1	

Northern Flicker (*Colaptes auratus*) [b]	4	5		2	2	2	2	1
Northern Mockingbird (*Mimus polyglottos*)	2	4	2	3	2	3		
Urban Species								
European Starling (*Sturnus vulgaris*) [a]	1	1	5	5	1		1	
House Finch (*Carpodacus mexicanus*) [a]	3	6	8	6	4	4	3	
House Sparrow (*Passer domesticus*)	1		1	1	1			
Water Species								
Belted Kingfisher (*Ceryle alcyon*)		1	2			1	2	
Canada Goose (*Branta canadensis*)			3	2			1	
Mallard (*Anas platyrhynchos*)		1	3	1		2	1	

- All urban-adapter species were more common in narrower greenways, especially in greenways ≤50 m wide.

- Total avian richness decreased with increasing amounts of managed area within the greenway, as did richness and abundance in other guilds.

Dependent variable[a]	R^2	Intercept	Width	Greenway composition and structure					
				Managed	Hardwd	StrWidth	Shrub	Ground	Vine
Total richness	0.439	4.432		−1.023, $P=0.003$	−0.934, $P<0.001$				
Total abundance	0.550	3.458			−0.832, $P<0.001$		+0.187, $P=0.002$		
Neotropical richness	0.685	2.568		−1.502, $P=0.005$					
Neotropical abundance	0.689	1.754		−1.562, $P=0.001$		+0.020, $P=0.036$	−0.146, $P=0.045$	+0.132, $P=0.026$	−0.165, $P=0.030$
Insectivore richness	0.815	4.304		−2.101, $P<0.001$	−0.693, $P<0.001$				
Insectivore abundance	0.725	3.595		−1.197, $P<0.001$	−0.673, $P=0.001$				+0.113, $P=0.026$
Forest-interior richness	0.698	0.353	+0.001, $P=0.002$	−1.889, $P<0.001$	+0.612, $P=0.031$				
Forest-interior abundance	0.593	0.722		−1.960, $P<0.001$		+0.019, $P=0.009$			

- Total bird abundance declined as percent of the adjacent landscape covered by pavement and bare earth increased.
- Neotropical migrants and Insectivores are similarly affected by these land cover types.

Dependent variable[a]	R^2	Intercept	Landscape context		
			Paved	Earth	Building
Total richness	0.439	4.432			
Total abundance	0.550	3.458	−1.374, $P=0.002$	−7.654, $P=0.041$	
Neotropical richness	0.685	2.568	−1.748, $P=0.014$	−16.540, $P=0.004$	−4.052, $P<0.001$
Neotropical abundance	0.689	1.754			−2.651, $P=0.010$
Insectivore richness	0.815	4.304	−1.805, $P=0.005$	−9.812, $P=0.001$	
Insectivore abundance	0.725	3.595	−1.871, $P<0.001$	−11.896, $P<0.001$	
Forest-interior richness	0.698	0.353		−10.710, $P=0.030$	
Forest-interior abundance	0.593	0.722			

Conclusion:Designing Corridors for Urban Birds

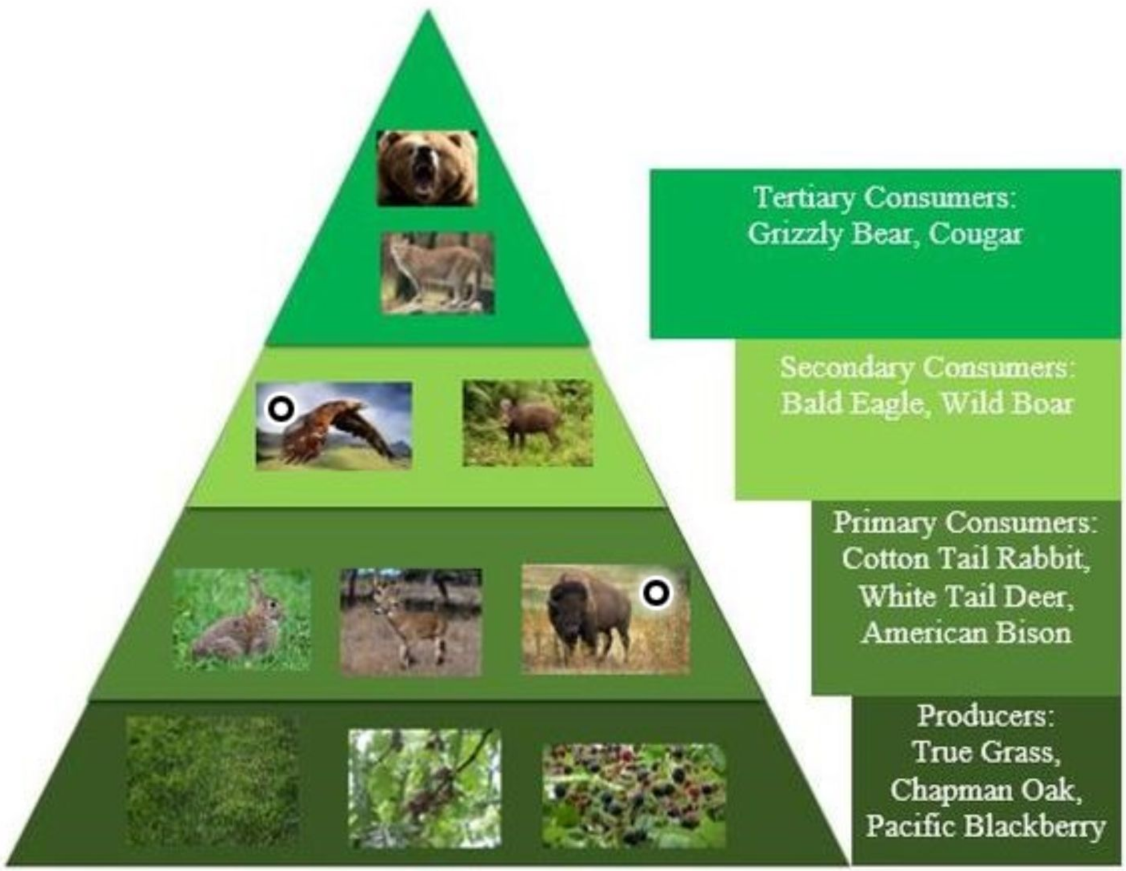
- Wider greenways increase avian diversity, especially for birds of higher conservation priority (forest-interior, neotropical migrants, etc.). Wider greenways are also less likely to contain nest parasites (Brown-headed Cowbirds), nest predators (Blue Jay) and aggressive, urban-adapted species.

- Nest success and survival in greenways should be measured to determine if greenway habitats act as sinks that provide habitat for birds establish territories but do not survive or reproduce successfully.

Conclusion: Designing Corridors for Urban Birds

- Greenways wider than 50 m might not be feasible for many cities, so larger nature preserves, or public parks could be necessary to conserve certain development-sensitive species.
- Use education and outreach to encourage landowners and developers of property adjacent to greenways to minimize the amount of managed area as well as pavement and bare earth cover.

Case Study: Corridor Considerations for Large Carnivores



The Need for Corridors

- Roads disrupt animal movement. As roads are upgraded to accommodate greater traffic volume, the rate of successful wildlife crossing decreases significantly.

- Large carnivores are specifically vulnerable to road effects due to their great mobility and extensive spatial requirements for survival.

Statistics

- The Ljubljana-Postojna highway in Slovenia opened in 1972, and by 1990 at least 9 bears were killed by motor vehicles (Kaczensky et al. 1996).

- Similar mortality rates reported for brown bears along major highways in Croatia (Huber et al. 1998).

- Highways were responsible for nearly half of all documented mortality among Florida panthers (Maher et al. 1991).

- The single greatest cause of Cougar mortality was from motor vehicles in Southern California (Beier & Barrett 1991).

Effectiveness of Crossing Structures

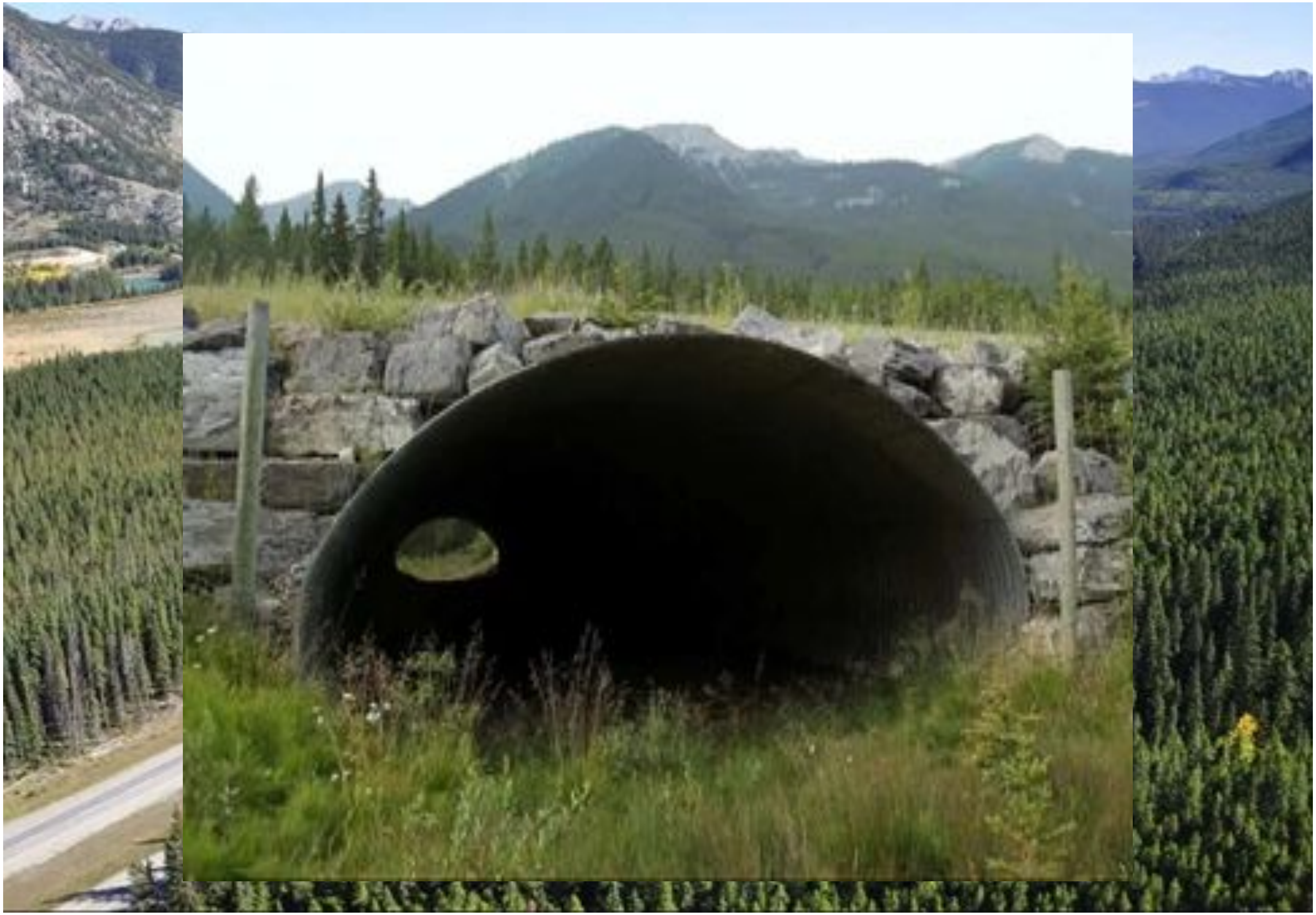
Table 1. Cougar frequency of passage and habitat quality indices at wildlife crossing structures in Banff National Park, Alberta, Canada, during 1997-2000. Wildlife overpasses are listed in italics along with neighbouring underpasses located within 2 km. The habitat quality index gives the summed habitat quality ratings (see Holland & Coen 1983) within a 1,000 m buffer of the wildlife crossing structure.

Crossing structure	Phase	Design type	No of passes	Habitat quality index
East gate	1&2	Open-span	43	92
Carrot	1&2	Creek bridge	20	183
Morrison	1&2	Metal culvert	32	198
Duthil	1&2	Open-span	46	180
Powerhouse	1&2	Open-span	27	117
Buffalo	1&2	Open-span	8	165
Vermilion	1&2	Open-span	25	154
Edith	1&2	Open-span	36	217
Healy	1&2	Open-span	34	105
Wolverine OP	*3A*	*Overpass*	*11*	*95*
Wolverine UP	*3A*	*Metal culvert*	*8*	*95*
Bourgeau	*3A*	*Metal culvert*	*12*	*115*
Wolverine Creek	3A	Creek bridge	15	131
Massive	3A	Metal culvert	5	86
Sawback	3A	Box culvert	2	79
Pilot	*3A*	*Box culvert*	*5*	*59*
Redearth UP	*3A*	*Box culvert*	*8*	*64*
Redearth OP	*3A*	*Overpass*	*0*	*72*
Redearth Creek	*3A*	*Creek bridge*	*12*	*79*
Copper	*3A*	*Metal culvert*	*14*	*96*
Johnston	3A	Box culvert	14	76
Castle	–*	Metal culvert	0	107

* This crossing was constructed in 1991, after completion of phase 1&2 but prior to phase 3A.

Location: Banff National Park. Alberta Canada

Gloyne, C.C. & Clevenger, A.P. 2001: Cougar *Puma concolor* use of wildlife crossing structures on the Trans-Canada highway in Banff National Park, Alberta. - Wildl. Biol. 7: 117-124.



Credit: Leah Hennel/Calgary Herald Archives

Results

- Positive correlation between passages made by cougars and ungulate passage.
- Significant correlation between cougar passages and quality of habitat, reinforcing idea of habitat connectivity.

*As of 2016 there are currently 44 crossing structures in Banff National Park (Calgary Herald,2016).

Pros

- Estimate of 152,000 crossings by large mammals over last 2 decades.
- 80% decrease in collision rates.

Cons

- Overpasses cost between $2-4 million each, underpasses about a tenth of the cost.

Avoiding Costly Solutions to Connectivity

- Urban planning must be more informed of the tendency of large carnivores.
- Can be understood using resource selection functions and creating least cost path models.

Resource Selection Function to Identify Corridors

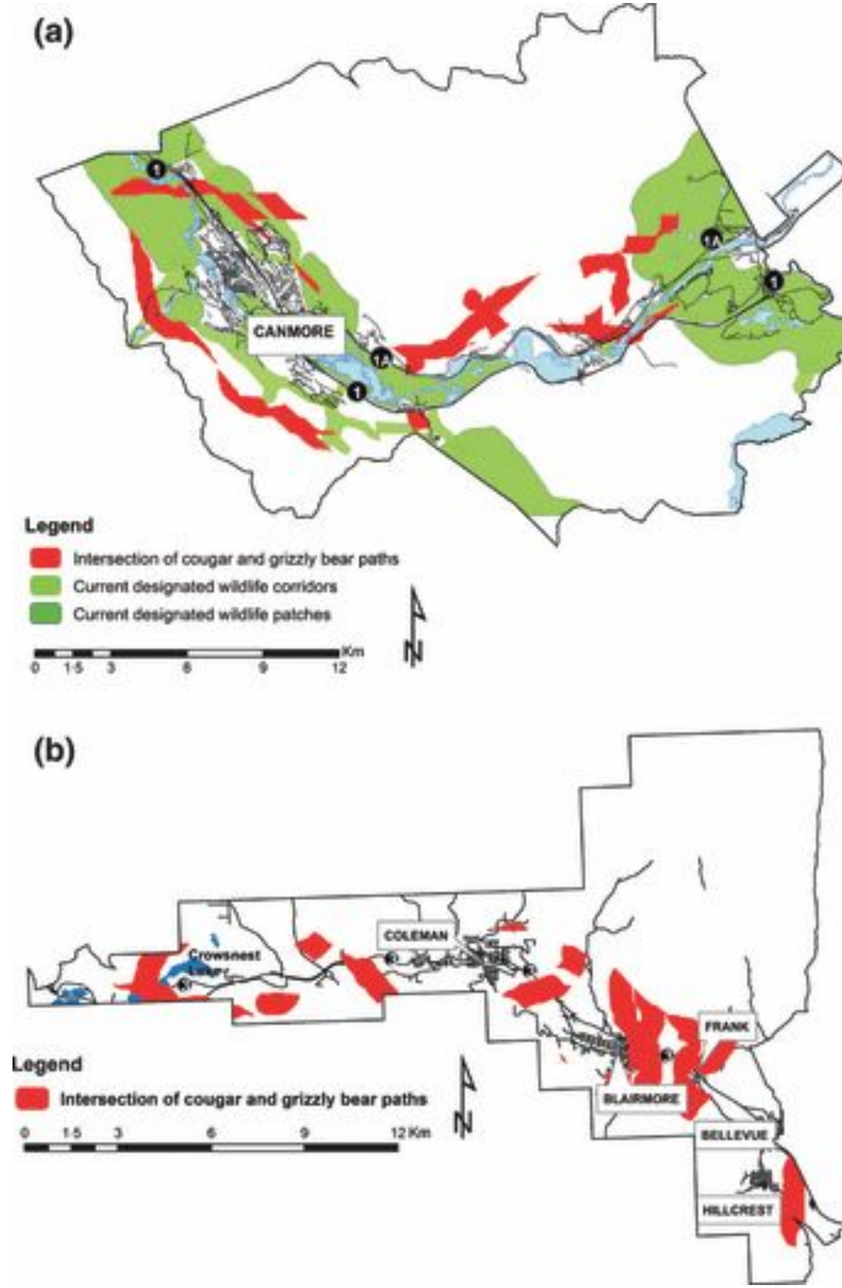
- Each variable is an RSF correlated to GPS locations of cougars and grizzly bears.
- Algorithms were entered to create least cost path values for every pixel. (8 grizzly bears, 17 cougars).

Variable group	Variable name	Abbrev.	Resolution (m)	Units	Data range
Landcover	Upland forest	UFOR	30	Category	0 or 1
	Upland herb	UHERB	30	Category	0 or 1
	Shrub	SHRB	30	Category	0 or 1
	Water	WATER	30	Category	0 or 1
	Barren	BARRN	30	Category	0 or 1
Subregions	Montane	MONT	30	Category	0 or 1
	Subalpine	SUB	30	Category	0 or 1
	Alpine	ALP	30	Category	0 or 1
	Distance to water	DWAT	30	km	0–2·3
	Distance to forest	DFOR	30	km	0–11
	Per cent crown closure	PCC	30	%	0–99
Food resources	Greenness	GVI	30	Unitless	0–85
	Elk RSF	ELK	30	Unitless	1·7–8·1
	Compound topographic index	CTI	30	Unitless	2·3–26
Terrain	Topographic ruggedness index	TRI	30	Unitless	0–249
	Slope	SLP	30	degrees	0–74
	Elevation	ELEV	30	m	1213–3069
Humans	Road density	RDENS	30	km km^{-2}	0–12

Location: Alberta, Canada

Resource Selection Function to Identify Corridors

- Higher value pixels represented lower cost to movement.
- Used values to create single pixel path connecting high quality habitat which was then buffered by 350m.



Chetkiewicz, C. L. B., & Boyce, M. S. (2009). Use of resource selection functions to identify conservation corridors. *Journal of Applied Ecology*, *46*(5), 1036–1047. https://doi.org/10.1111/j.1365-2664.2009.01686.x

Conclusions for Large Predators

- Urban planning/development must be more informed of favorable habitats and movement patterns of carnivores (ie. RSF algorithms and LCP analysis).

- In areas where connectivity is reduced by large roads, crossing structures can offer a solution if placed in the right locations. However, they are costly.

Implementation of Green Corridors

Implementation

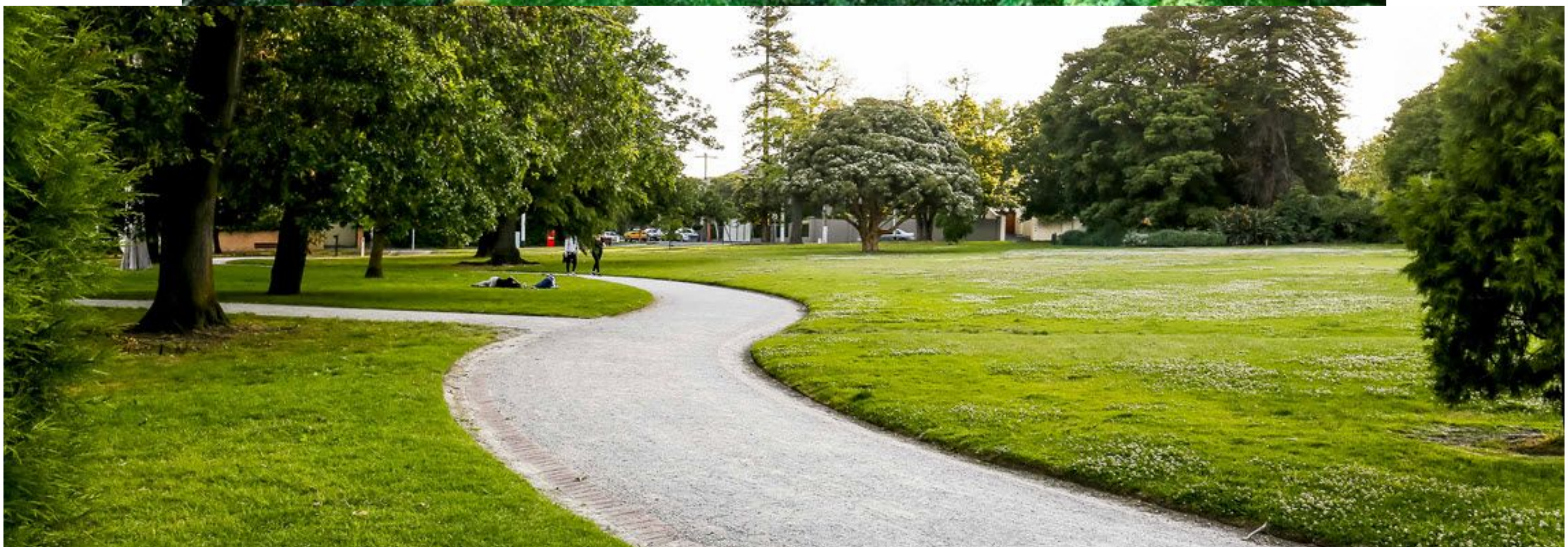
Table 4. Characteristics of habitat and corridor in relation with dispersal activity among urban wildlife in the city.

Habitat & Corridor Category	Characteristics	Width/Area	Environmental elements	Species Presence
Primary habitat	• Greatest conservation value which include source of water, food, larger size and open access to forage	• 100ha-core area • 50m-edge buffer	• Primarily forest, water body	• Mammals, birds
Secondary habitat	• One or more requirements are missing • Provide forage and protection for dispersing animals as they are moving to new areas of primary habitat	• 50ha-core area • 30m-edge buffer	• Small forest/ city park, water body	• Small mammals, birds
Primary potential corridor	• Safety area indicating to animals species for traversing in any time, such as at night	• 30m-edge buffer	• City park, water body	• Small mammals, birds, insects
Secondary potential corridor	• Areas that are known to be traversed by the species in question, but which constitute much riskier to the vegetal cover types	• 10m-edge buffer	• Vegetate d area, water body	• Small mammals, birds, insects
Unsuitable	• Areas that are not suited for habitat and corridor	• none	• Lawn/ bushes	• Insects

H A Aziz and M H Rasid (2014)

- Target species should be taken into consideration
- Needs of people
- Government ability to implement

Human Interactions & Wildlife



- Too Manicured
- Not very much underbrush
- Food Sources
- Native Vegetation
- Water Source

- Good variety of trees
- Open spaces for people

Informal Urban Green Corridors

- Vacant lots
- Highways
- Brownfields
- Powerline Corridors
- Canals

The Politics of Implementation

"The guy who runs the highway department wants to defend his fiefdom and keep his little army of mowers."

-Anonymous

- Extensive & Exhaustive
- Cost to the City
- Maintenance
- Departments
- Appearance
- Accessibility
- Not In My Backyard
- Gentrification

Are Green Corridors a Good Solution?

Questions?

TEXAS A&M UNIVERSITY

Have you seen examples of green space corridors in BCS? Where are they?

Who should implement corridors?

Whom should they consult? What kind of skills are useful for successful implementation?