Rapid evaluation of multispecies connectivity (REMC)

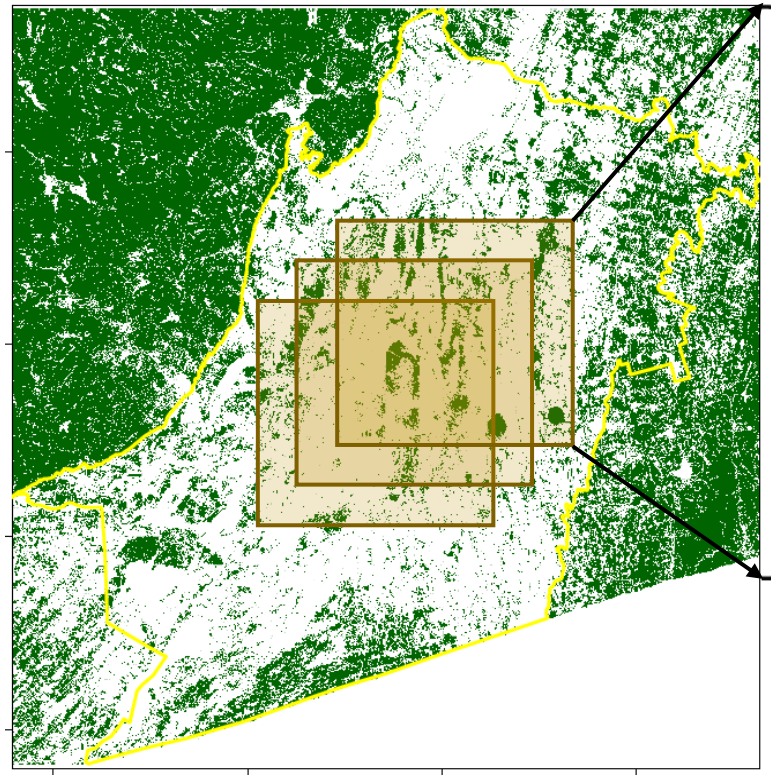
R-tool to efficiently compute multiple connectivity indicators for multiple species needs and across large regions of interest

by

Jacqueline Oehri

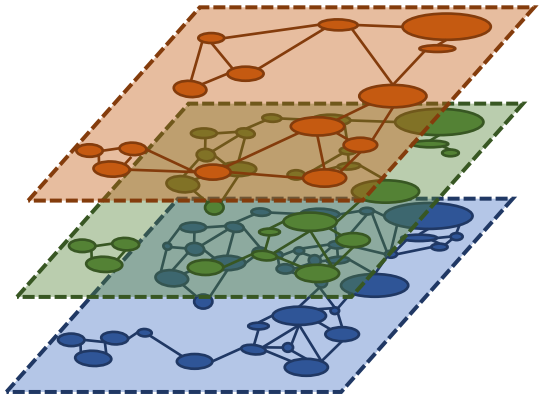
Rapid evaluation of multispecies connectivity (REMC)

1) Habitat map
species specific minimum patch size



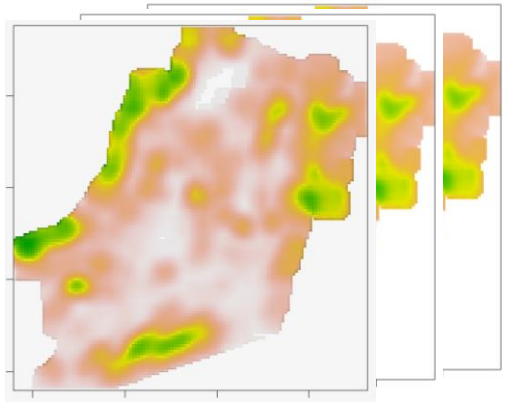
Scalable moving windows: size dependent on species dispersal capacity

2) Multilayer networks
species specific dispersal capacity

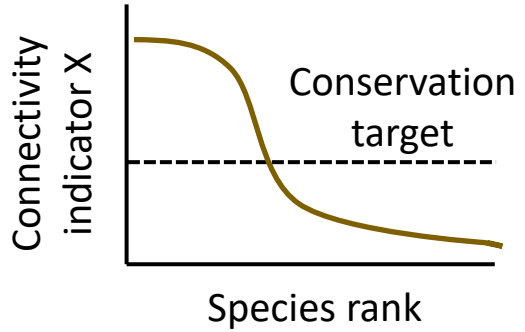


Species 1
Species 2
Species 3

3) Connectivity maps



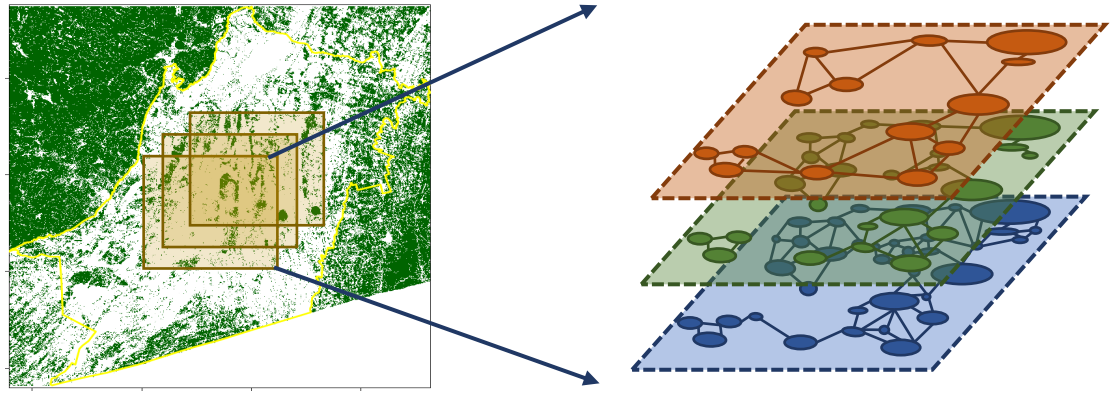
4) Multispecies persistence in region of interest



REMC R-tool core functions

1) REMC_wrap()

- Implement moving windows, scales and resolution of interest
- Read inifile (a), apply connectivity functions in moving windows using REMC_core (b)



1a) REMC_inifile.xlsx

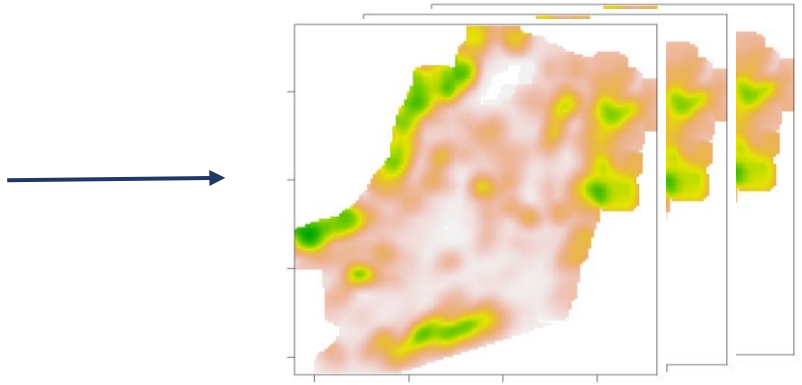
- define connectivity functions
- define species needs (habitat, dispersal)

1b) REMC_core()

- Apply connectivity functions in moving windows

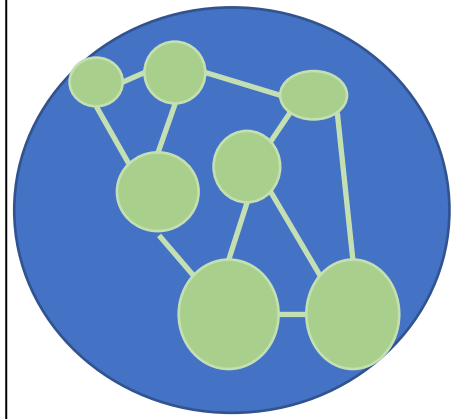
2) REMC_summary()

- Summarize moving window outputs into seamless maps
- At pixel, patch and landscape-level



Connectivity indicator – functions

1. Metapopulation capacity (MPC)



Highlights:potential long-term species persistence. Metapopulation carrying capacity, based on area and connectance of habitat (Hanski & Ovaskainen 2000, Schnell et al. 2013).

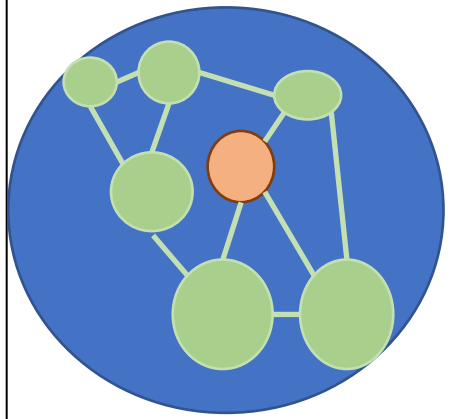
2. Equivalent Connected Area (ECA)

Highlights: size (area) of connected habitat. The size of a single habitat patch providing the same probability of connectivity than the actual habitat pattern in the landscape (Saura et al. 2011).

3. Fraction of connected habitat (ECA_{AP}, ECA_{AL})

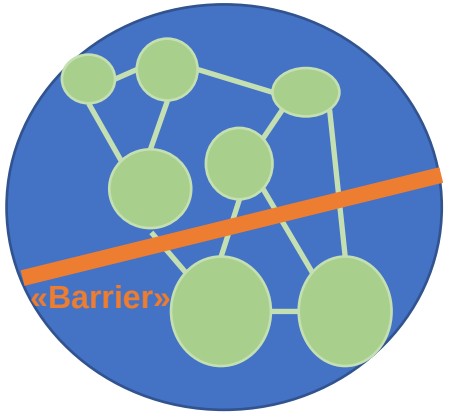
Highlights: underused connectivity potential. Fraction of habitat that is connected: ECA divided by the total habitat area (AP) or landscape area (AL; cf. ProtConn index, Saura et al. 2017).

4. Betweenness centrality (BC), node degree (ND)



Highlights: stepping stones. BC (Brandes 2001): nr. of shortest paths between pairs of habitat patches passing through a focal patch. ND (Minor & Urban 2008): nr. of habitat patches connected to a focal patch.

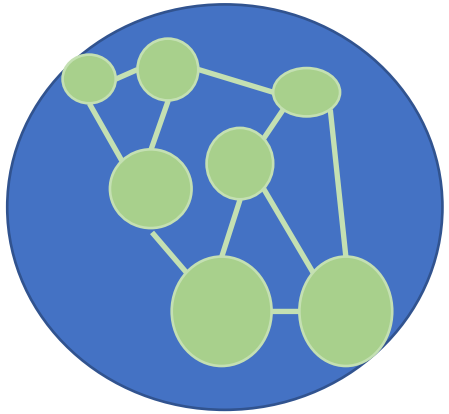
5. Inverse cumulative resistance (invCR)



Highlights: ease of landscape traversability. Omnidirectional inverse cumulative resistance (Albert et al. 2017).

Connectivity indicator – functions

Metapopulation capacity (MPC)



Highlights potential long-term species persistence.

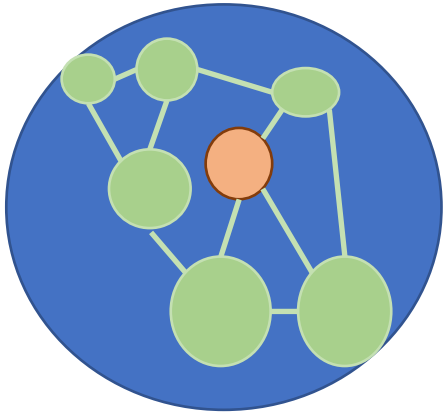
Equivalent Connected Area (ECA)

Highlights size (area) of connected habitat.

Fraction of connected habitat (ECA_{AP}, ECA_{AL})

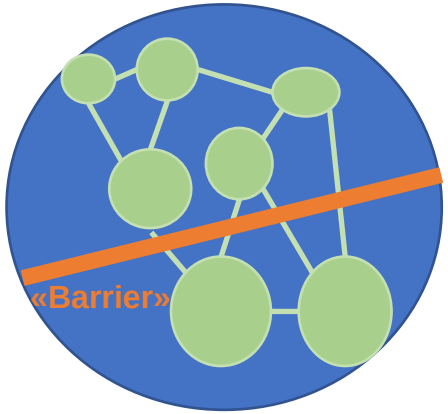
Highlights underused connectivity potential.

Betweenness centrality (BC), node degree (ND)



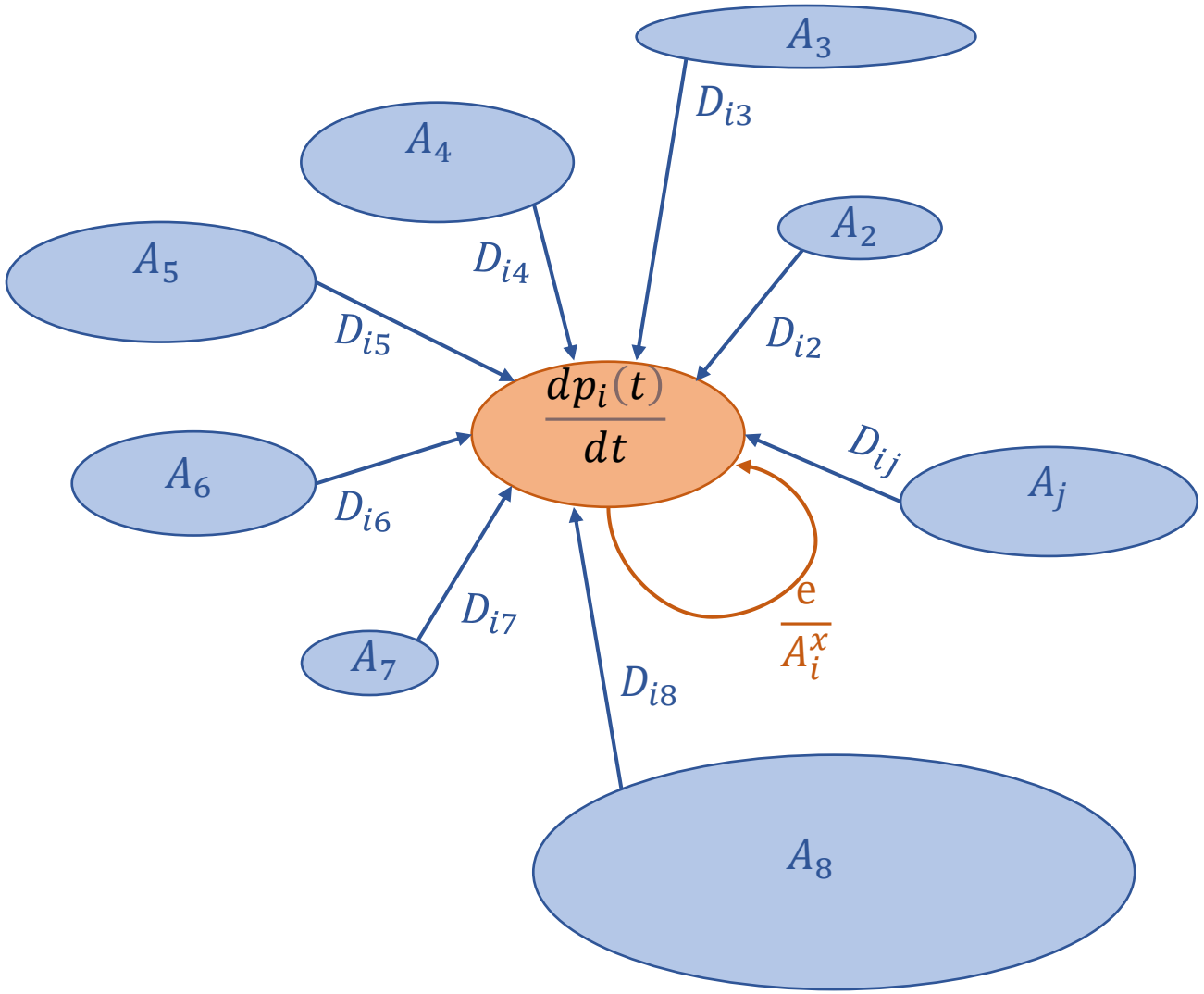
Highlights stepping stones.

Inverse cumulative resistance (invCR)



Highlights: ease of landscape traversability.

Metapopulation capacity indicator – based functions



Occupancy-based, spatially explicit metapopulation model (SEM)

$$\frac{dp_i(t)}{dt} = C_i[1 - p_i(t)] - E_i p_i(t)$$

$$C_i = c \sum_{j \neq i} f(D_{ij}) A_j p_j(t)$$

$$E_i = \frac{e}{A_i^x}$$

Metapopulation capacity (MPC) as leading eigenvalue of 'landscape matrix' (M)

$$M_{ij} = \begin{cases} f(D_{ij}) A_j A_i^x & i \neq j \\ A_j A_i^x & i = j \end{cases}$$

$$MPC = \lambda_M$$

Neutral landscape models

Generate simulated landscapes «libraries» covering a gradient in habitat amount & fragmentation (clumping)

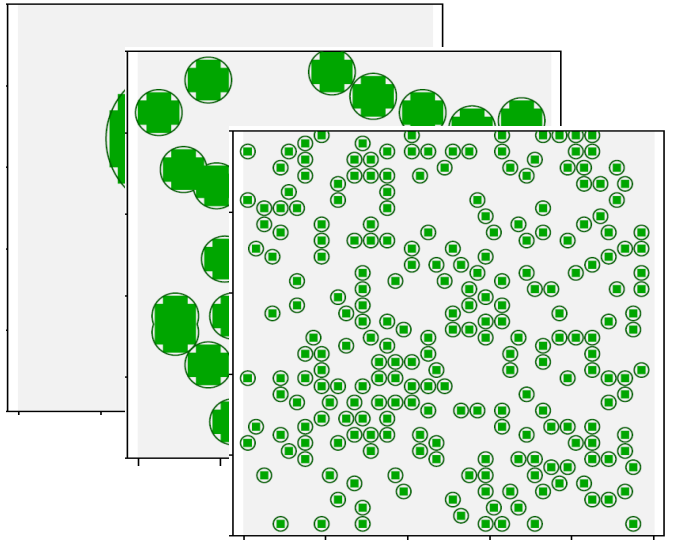
- Functions for two types available:

Random cluster

Based on the algorithm by Saura & Martínez-Millán 2000. and the NLMR R-package (Sciaini et al. 2018)

Simple-circle

Simple indication of habitat amount and number of patches.



Introduction

Ecological connectivity:
The 'unimpeded movement of species and the flow of natural processes that sustain life on Earth'

(Convention on Migratory Species, UN, 2019)

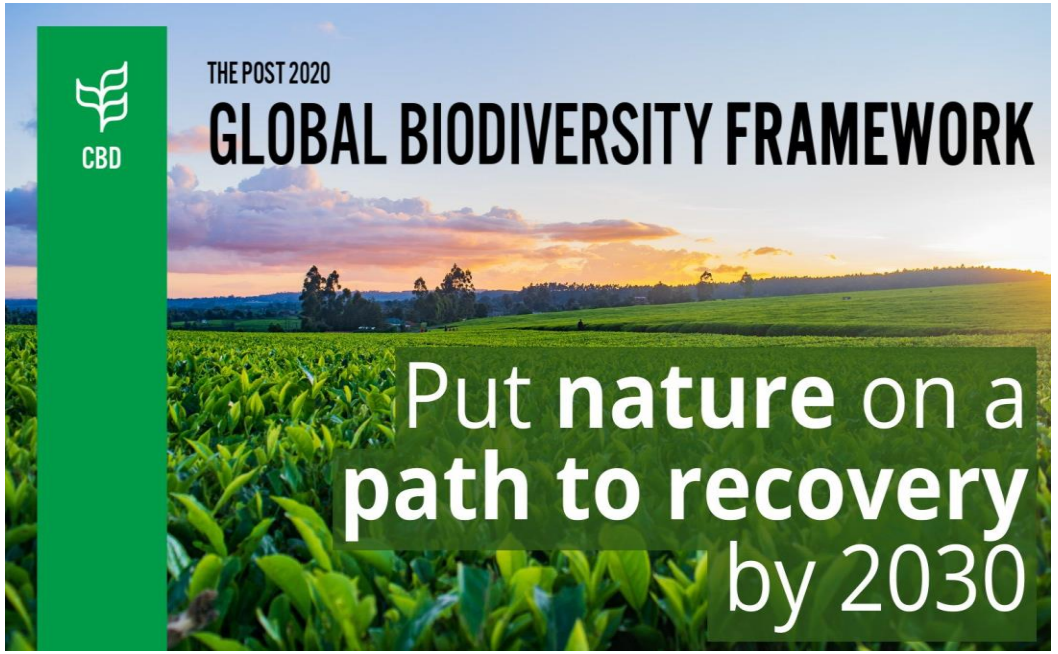
Important for

- Persistence of biodiversity
- Landscape ecosystem functioning & resilience
- Access to Nature's Contributions to People

Central to

- the targets of the Kunming-Montreal Global Biodiversity Framework

Kendra Hoff, CLLC

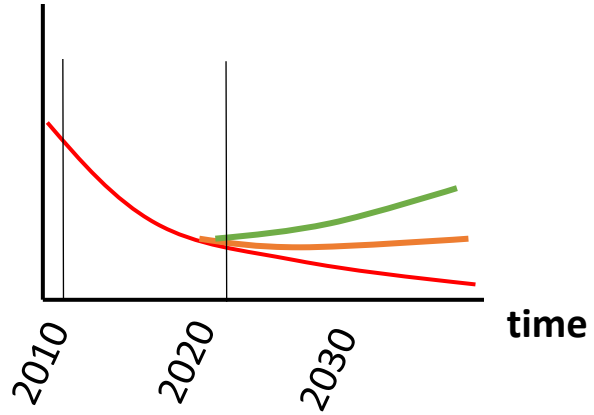


Motivation

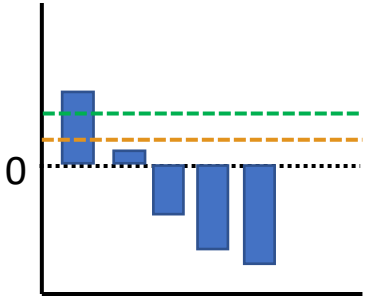
Safeguarding connectivity for biodiversity (many species!)

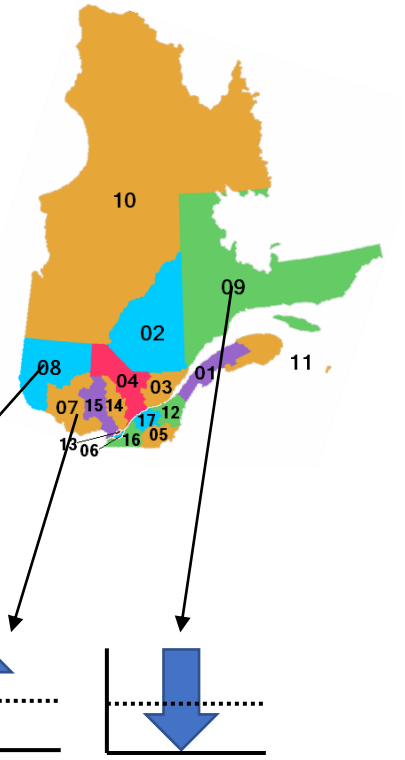
Conservation targets

Connectivity for biodiversity



Status or trend in connectivity





Spatial planning for connectivity

Need for tools that enable <u>monitoring</u> of <u>multiple aspects of connectivity</u> for <u>multiple species</u> that are <u>efficient, scalable, validated</u> & that <u>allow evaluation</u> regarding conservation targets!

Rapid assessment of multiple connectivity indicators for multiple species and large regions of interest

REMC data input

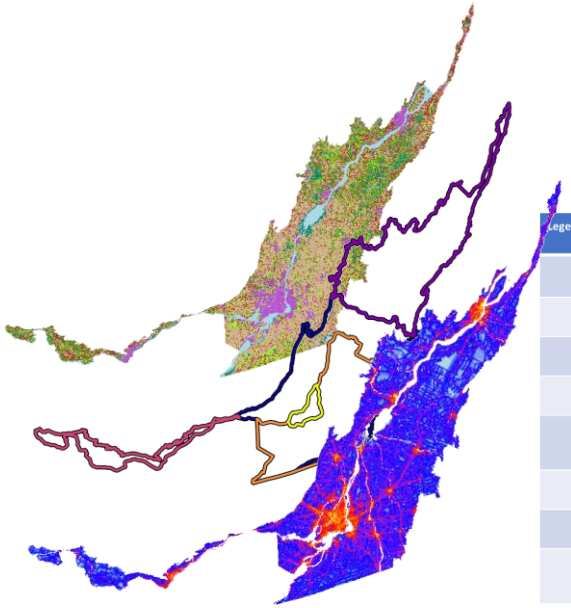
1. Land cover map
2. Species habitat needs and dispersal capacity
3. Region of interest (optional)
4. Resistance map (optional)

REMC settings

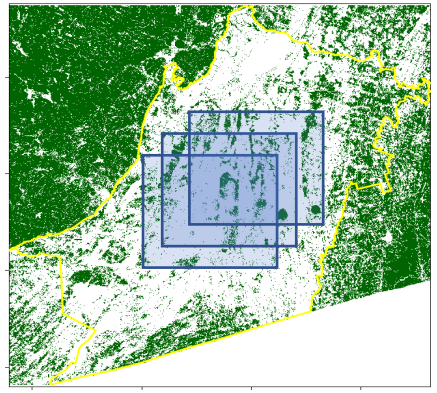
1. Moving window size
2. Spatial overlap
3. Connectivity functions
4. Landscape, patch and/or pixel level?

Runtime dependent on..

- Resolution & extent of Data input
- Number of species
- Moving window size and overlap
- Number and complexity of connectivity functions…



Legend	Common name	Habitat needs		Dispersal capacity
		Habitat type	Minimum patch size (ha)	Gap crossing distance (m)
	American marten	Forest (mixed and coniferous)	150	220
	Barred owl	Forest (broadleaf and mixed)	1	209
	Black bear	Forest (broadleaf and mixed)	1200	236
	Northern short-tailed shrew	Forest (broadleaf and mixed)	1	39
	Red-back salamander	Forest (broadleaf and mixed)	0.27	10
	Ovenbird	Forest (broadleaf and mixed)	5	54
	Wood frog	Forest (broadleaf, mixed and coniferous)	0.5	39



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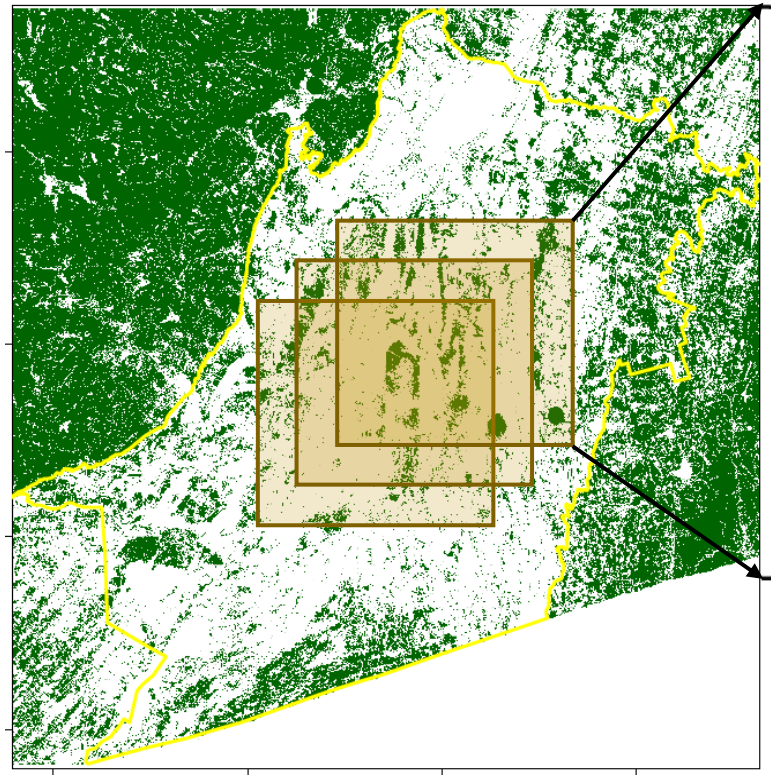

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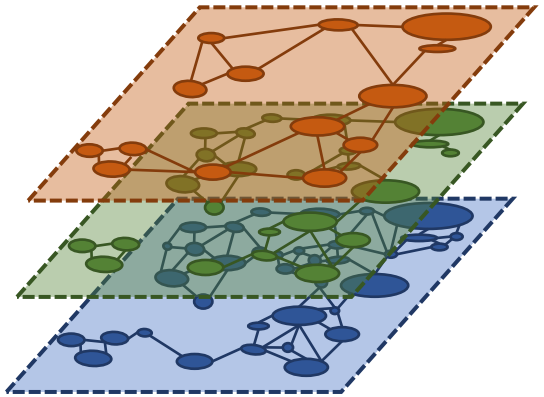

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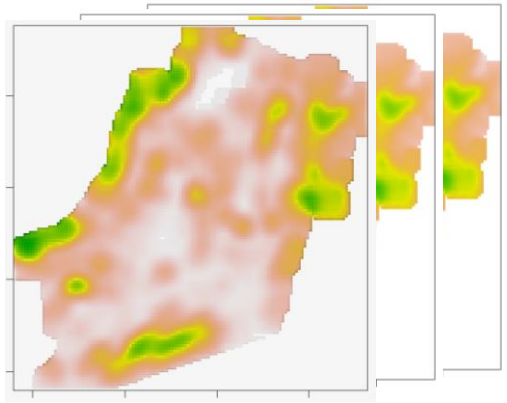
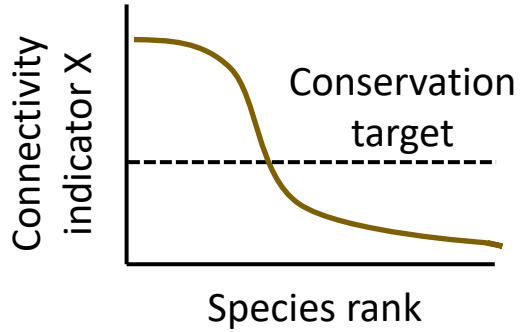
Species 2
Species 3

3) Connectivity maps

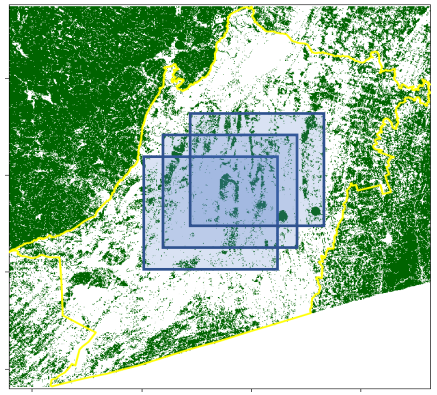


4) Multispecies persistence in region of interest



REMC R-tool core functions

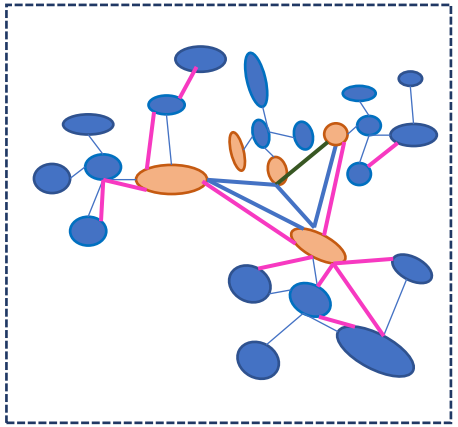
1 a) REMC_wrap
make moving windows



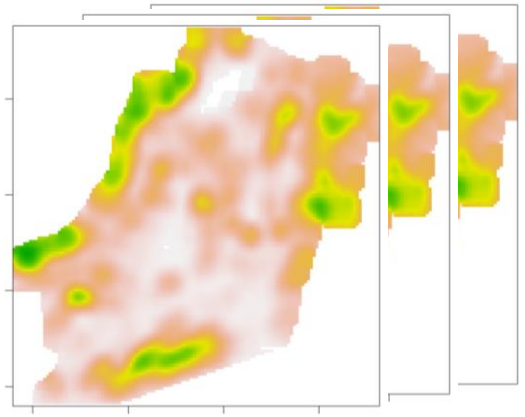
1 b) inifile.xls

- define functions*
- define species needs (habitat, dispersal)

2) REMC_core
Apply connectivity functions in moving windows



3) REMC_summary
Summarize outputs from moving windows



*Any function applicable to raster or shapefiles!