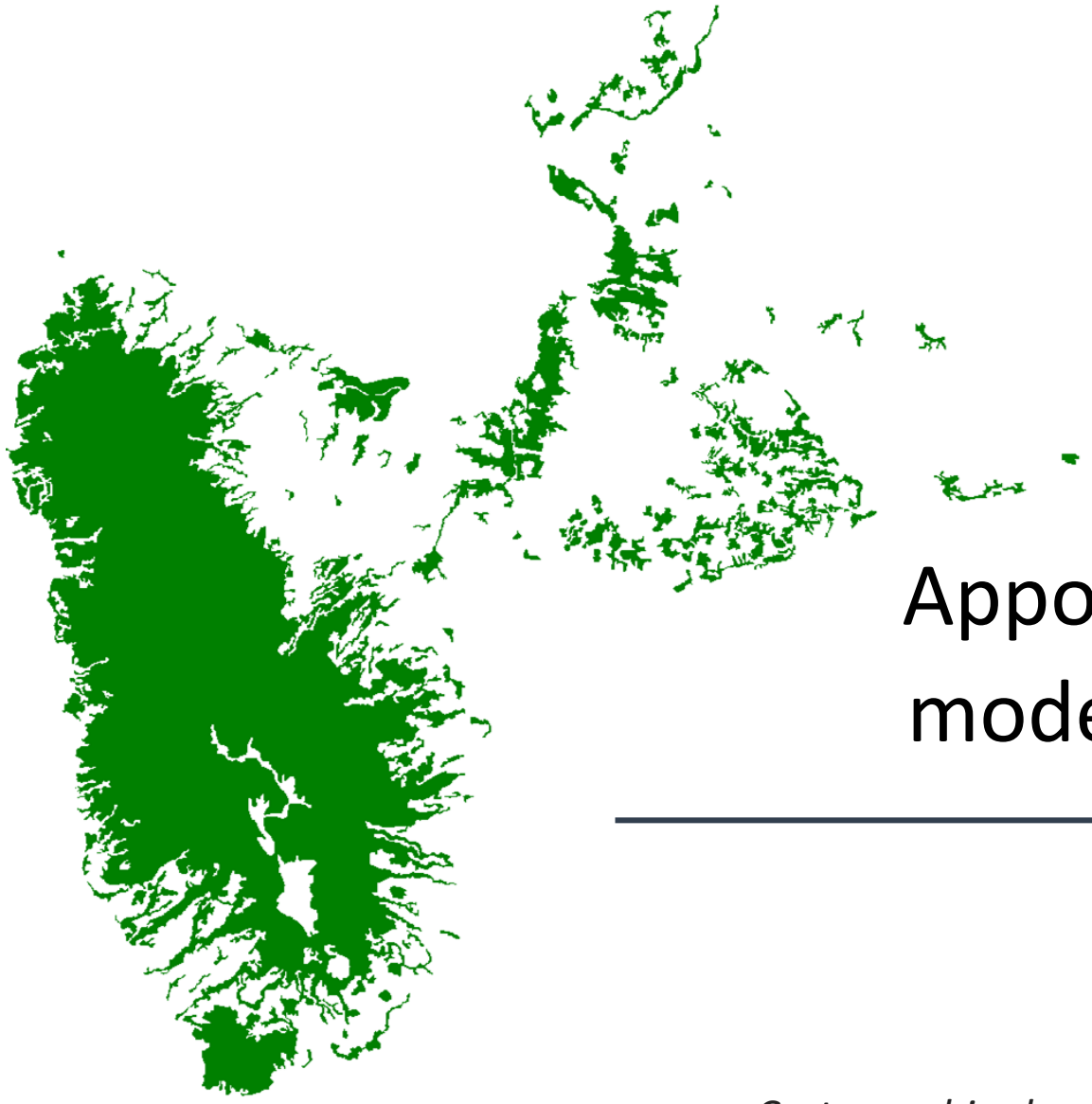


Apport des données génétiques pour modéliser la connectivité du paysage

Webinaire Thématique | 26 juin 2025

Cartographier la connectivité écologique : trames, données génétiques et paysages

Influence de la structure du paysage sur la connectivité des populations de passereaux forestiers

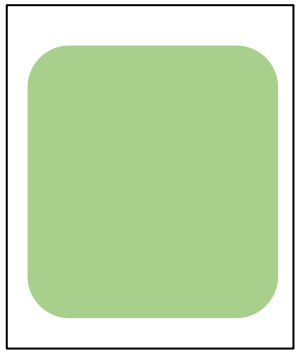
Khimoun Aurélie, Daniel Alexandrine, Faivre Bruno and Garnier Stéphane

Univ. Bourgogne Franche-Comté, CNRS, Biogéosciences UMR6282, F-21000 Dijon, France

Habitat fragmentation – Forest Fragmentation

Continuous forest habitat

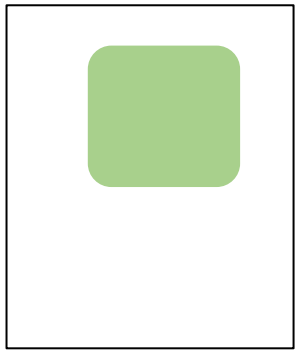
Fragmented forest habitat

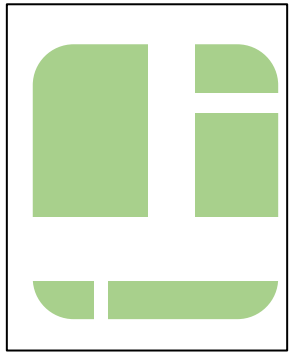


Habitat fragmentation process = 2 components

Habitat loss

Habitat fragmentation (*sensus stricto*)



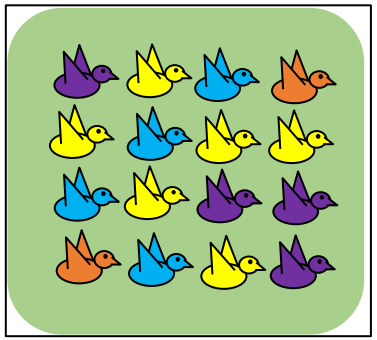


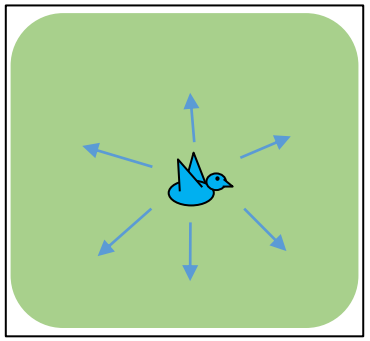
↘ Habitat surface

↗ number of habitat patches
↗ isolation between habitat patches

Habitat fragmentation – One of the major threats to biodiversity

Continuous habitat landscape





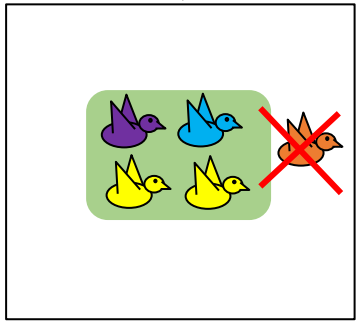
Isotropic dispersal events only constrained by geographic distance

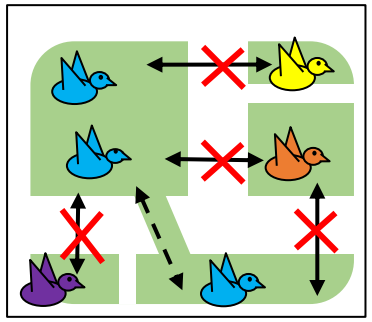
- How landscape features influence dispersal and gene flow between populations?
  - Infer consequences of habitat fragmentation

Habitat loss

↘ Habitat connectivity

Fragmented landscape





Anisotropic dispersal events

↘ Population connectivity

↘ Local population size

↘ Migration & gene flow (= genetic exchanges) between populations

↘ Genetic diversity within populations & ↗ Genetic differentiation between populations

Ultimately
- ↘ Adaptive potential of species
- ↗ Potential risk of local extinction

A forest specialist bird species – In a fragmented landscape


Plumbeous Warbler

- Forest specialist species
- Endemic from Guadeloupe and Dominique

Guadeloupe

Urbanized isthmus

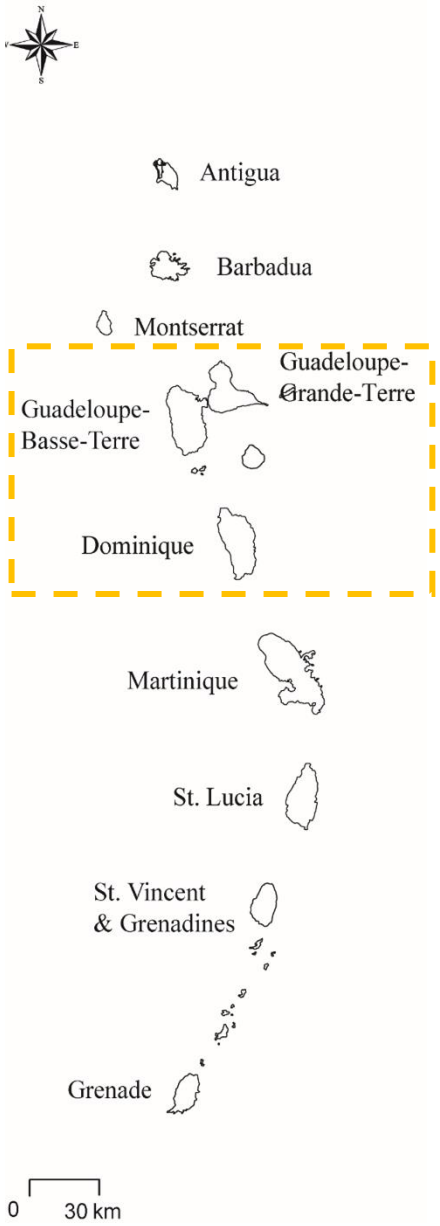
Grande-Terre

Basse-Terre

Forest

Non-forest matrix

- Does landscape structure influence population connectivity?
  - ↳ Need to estimate gene flow between populations

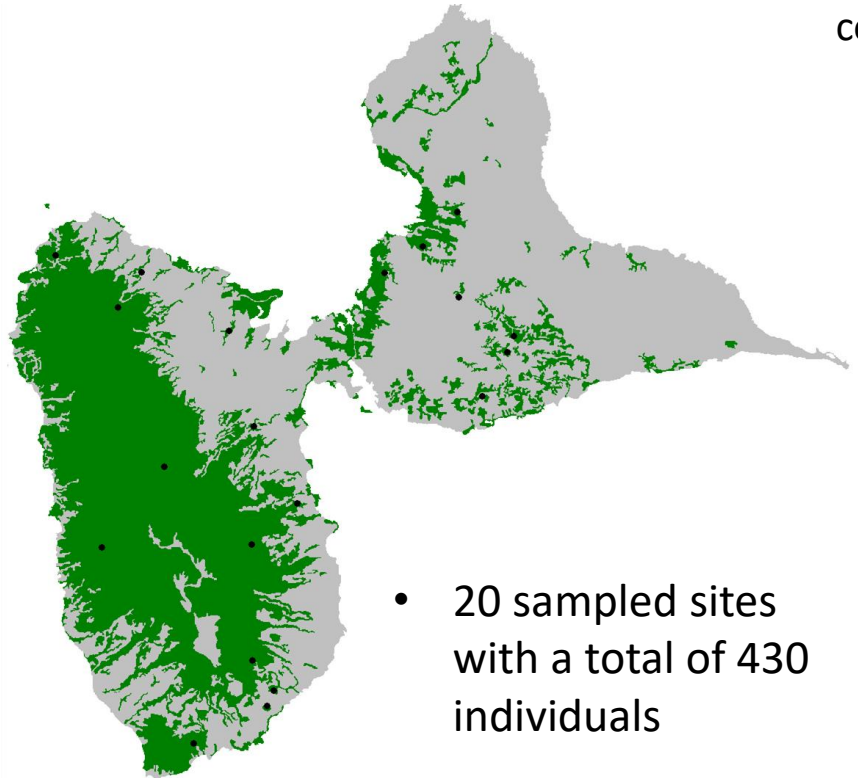


Indirect estimation of gene flow – genetic data

In the field

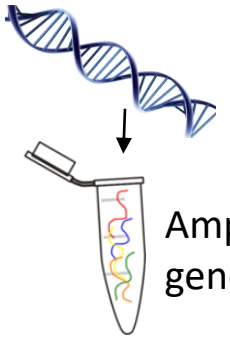
Birds are captured with mist-nets

Blood samples are gently collected for each individual



- 20 sampled sites with a total of 430 individuals

Plateforme d'écologie moléculaire



DNA extraction

Amplification and genotyping of neutral genetic regions (microsatellites)

	Pop1	Pop2	Pop3
Pop1	0		
Pop2	X_{1-2}	0	
Pop3	X_{1-3}	X_{2-3}	0

Measure of genetic differentiation between pairs of populations

- Low genetic differentiation = high level of gene flow
- Strong genetic differentiation = low level of gene flow

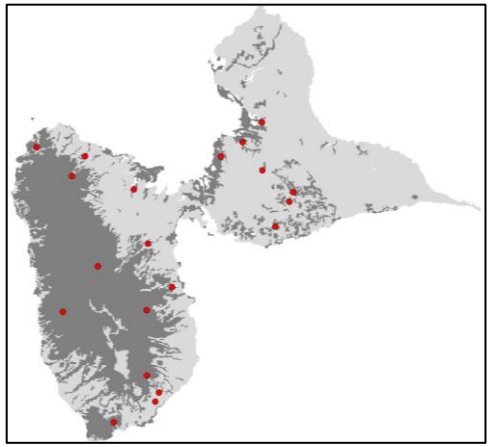
Genetic similarity between pairs of populations is an estimate of the landscape functional connectivity

Link **functional connectivity** & **structural connectivity**

Landscape genetics

Landscape genetics framework – Combining landscape ecology & population genetics

1/ 20 sampled sites



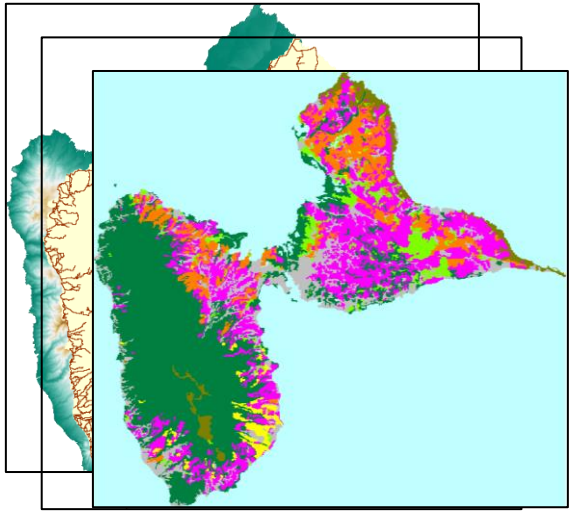
- Genetic data (12 µsats)

Matrix of pairwise genetic differentiation between populations *FST*

Indirect estimation of gene flow

2/ Environmental surfaces (raster)

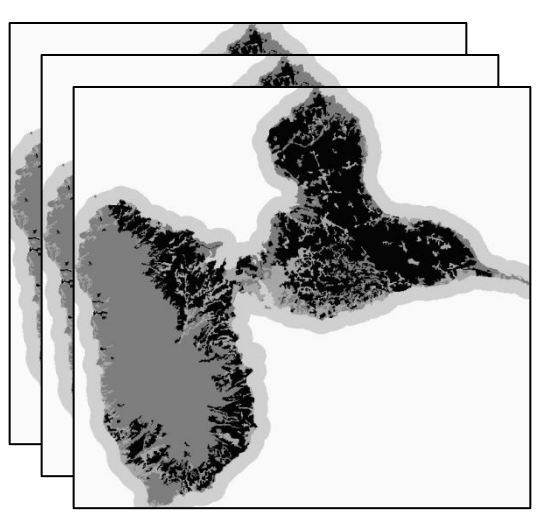
1 pixel = Altitude value/ 1 land cover class



Topography – Road network – Land cover

3/ Resistance surfaces (raster)

1 pixel = Resistance value



? How to compute ecological distances

Landscape functional connectivity

4/ Test for relationship

Landscape structural connectivity

Matrix of pairwise ecological distances between populations

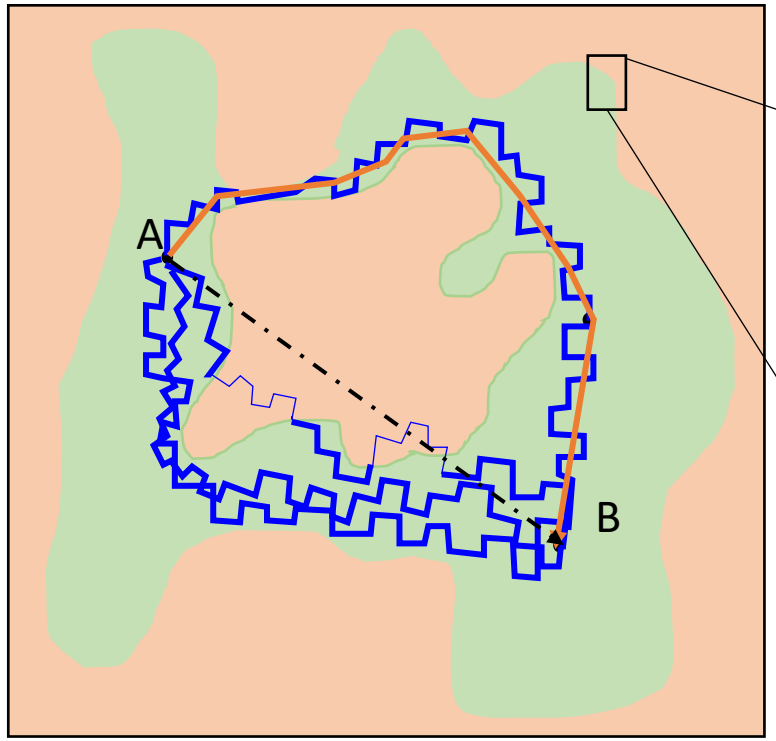
Two classical measures of ecological distances

- **Least cost distance (LCP)**

Each population pair is connected following the **optimal route** = least cost cells

Suitable habitat (low cost value of pixels)

Unsuitable matrix (high cost value of pixels)



Limitation

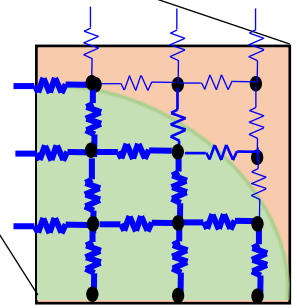
- Cannot incorporate the effects of
  - corridor size

  - independant parallel paths connecting A-D

- **Resistance distance** (McRae 2006)

- Distance metric based in **circuit theory**

Analogy between **gene flow** and **conductance** in electronic circuits



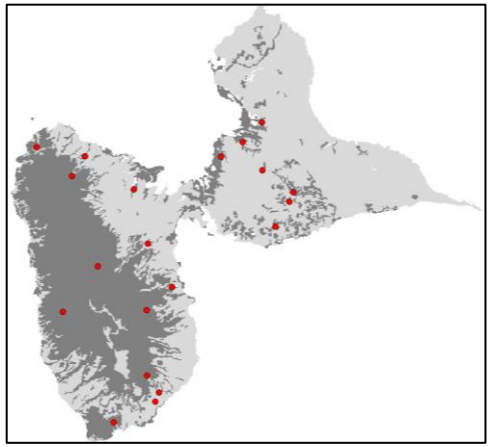
Landscape = network of nodes connected to their neighbors by resistors

- Resistance distance integrates **all possible paths** connecting each population pair

-> Resistance distance ↘ when several high conductance paths are followed

Landscape genetics framework

1/ 20 sampled sites



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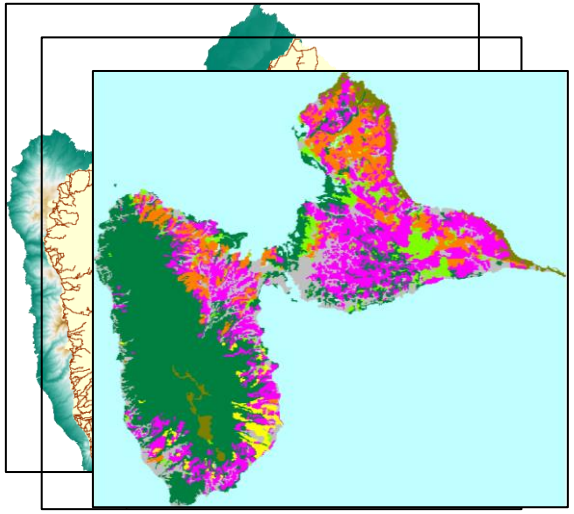


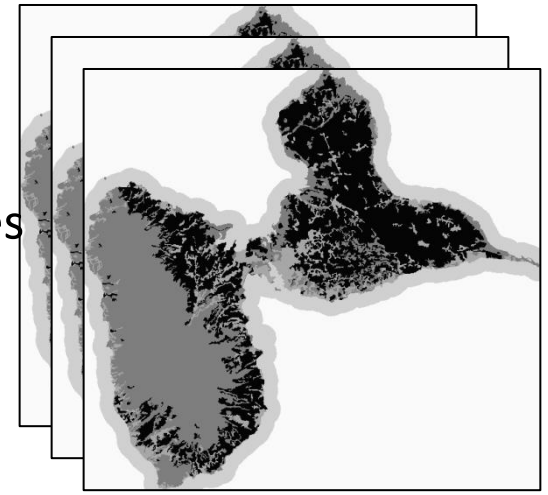
Topography – Road network – Land cover

How to derivate resistance surfaces

?

3/ Resistance surfaces (raster)

1 pixel = Resistance value



High resistance

Low resistance

Resistance & **LCP** distances

Landscape functional connectivity

4/ Test for relationship

Landscape structural connectivity

Matrix of pairwise ecological distances between populations

Parameterization of resistance surfaces: no consensus about the best method

- *A priori* assignation of resistance values for each landscape feature

Commonly based on

- Expert optinion about species ecology -> poor performance
- Habitat suitability maps (from SDM; high suitability = low resistance value)

Less ofen based on

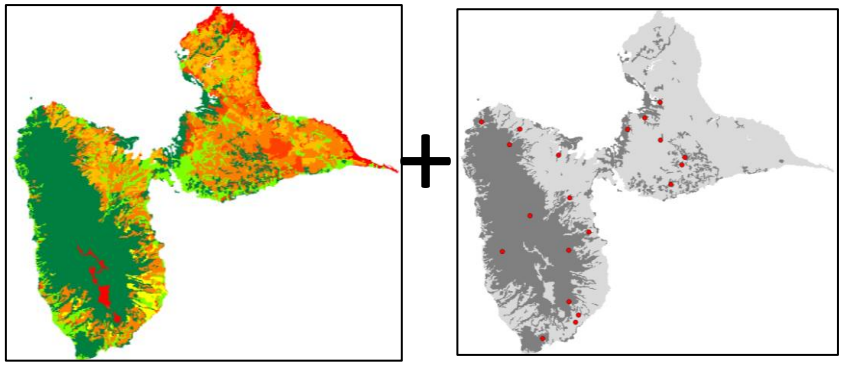
- Empirical movement studies

- No such available data for the Plumbeous warbler
  - Optimization procedure using Genetic Algorithms (GA); R package *ResistanceGA (*Peterman 2004*)*
  - Exploration of parameter space without any *a priori*

Framework for optimization of resistance values

Random values of resistance for each land cover class

Geographic coordinates of sampled sites



Environmental surface

Least-cost distance

Resistance distance

Matrix of pairwise ecological distances

Linear mixed effect model

non-independance among pairwise data

Matrix of pairwise genetic differentiation

Y

~

Matrix of pairwise ecological distances

X

Evaluation of the model fit

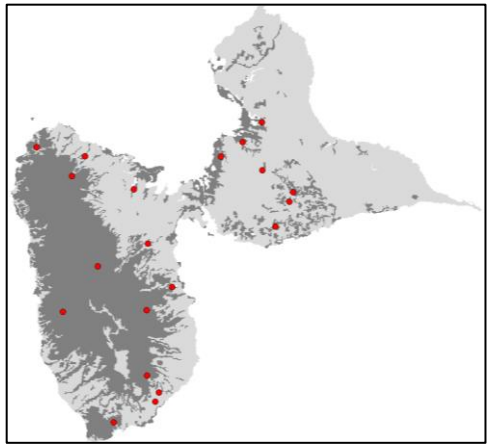
AICc

Best

The optimized resistance values of each land cover class

Landscape genetics approach – General framework

1/ 20 sampled sites



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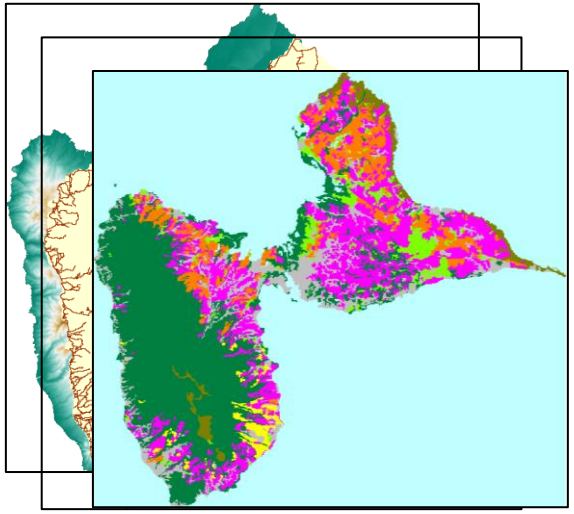
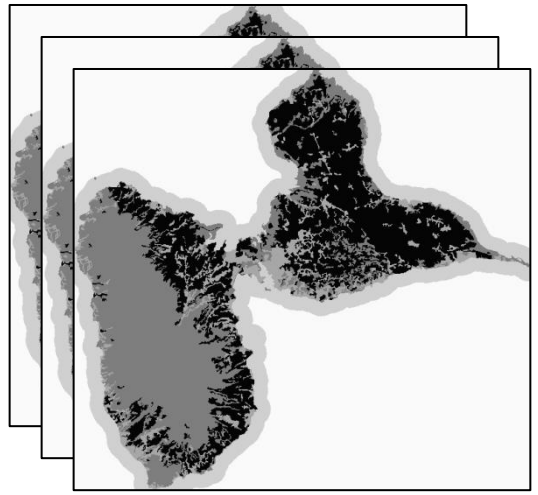


Topography – Road network – Land cover

Optimization

3/ Resistance surfaces (raster)

1 pixel = Resistance value



Resistance & **LCP** distances

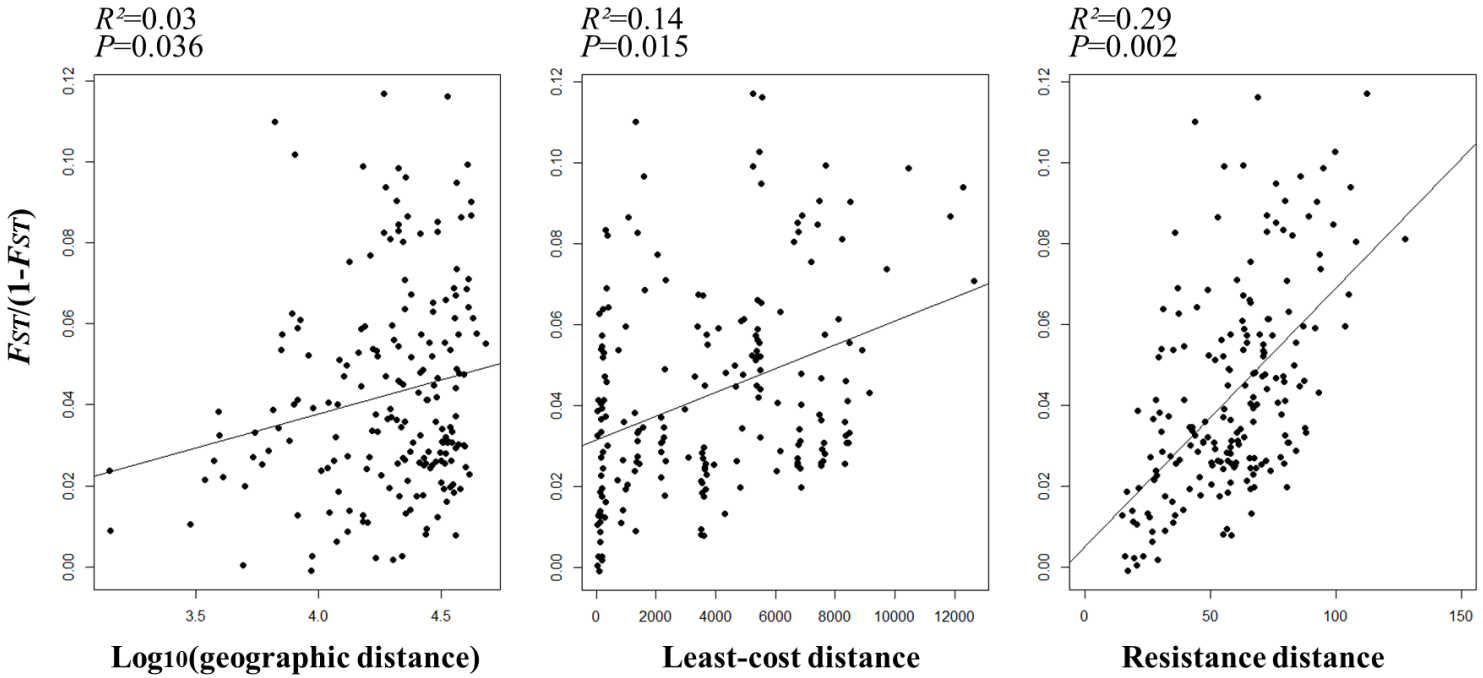
Matrix of pairwise ecological distances between populations

4/ Test for relationship

Landscape functional connectivity ⟷ Landscape structural connectivity

Relative performances of LCP and Resistance distances

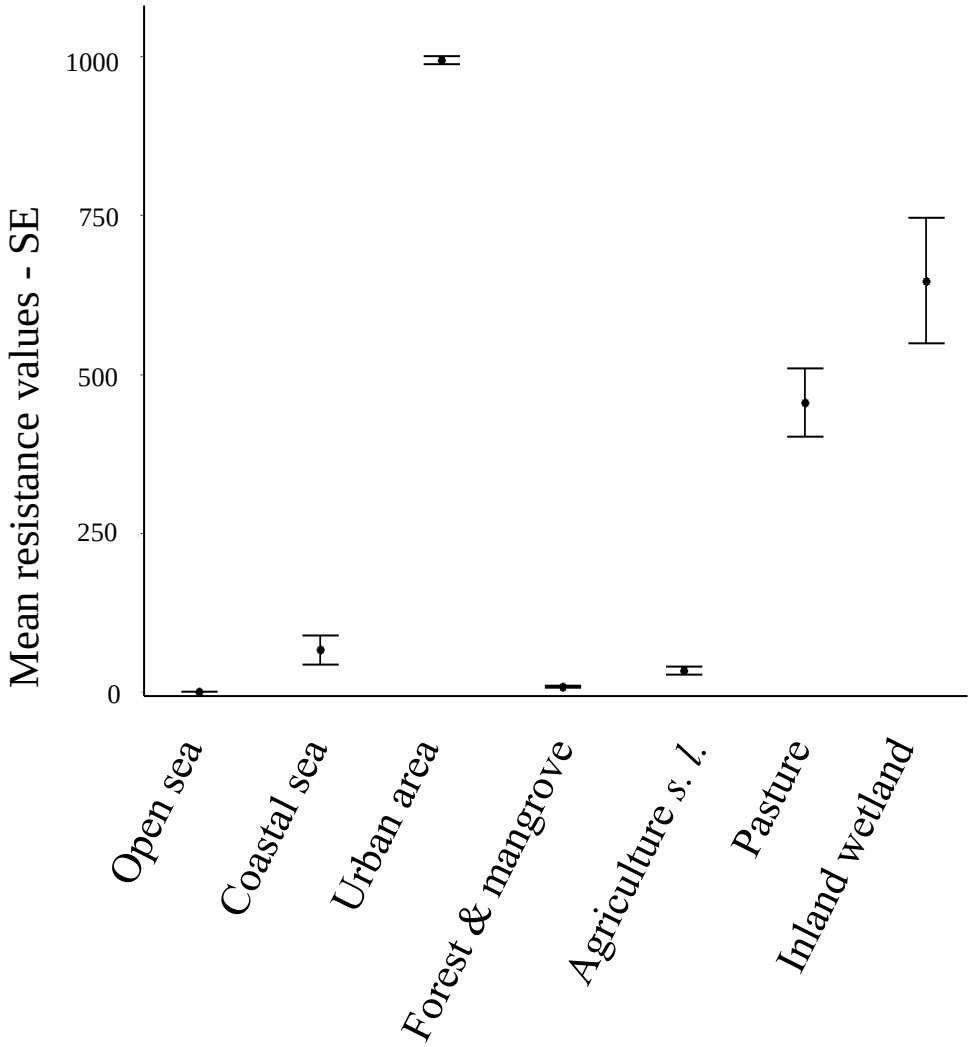
- **Simple Mantel Tests**



→ Significant simple correlations
Genetic dist ~ Geographic or Ecological distances

→ Higher variance explained by Resistance distances

Resistance of land cover types – Optimization from resistance distances



- High consistency of optimized values across the 10 replicates

Resistance

Urban area (1000X)

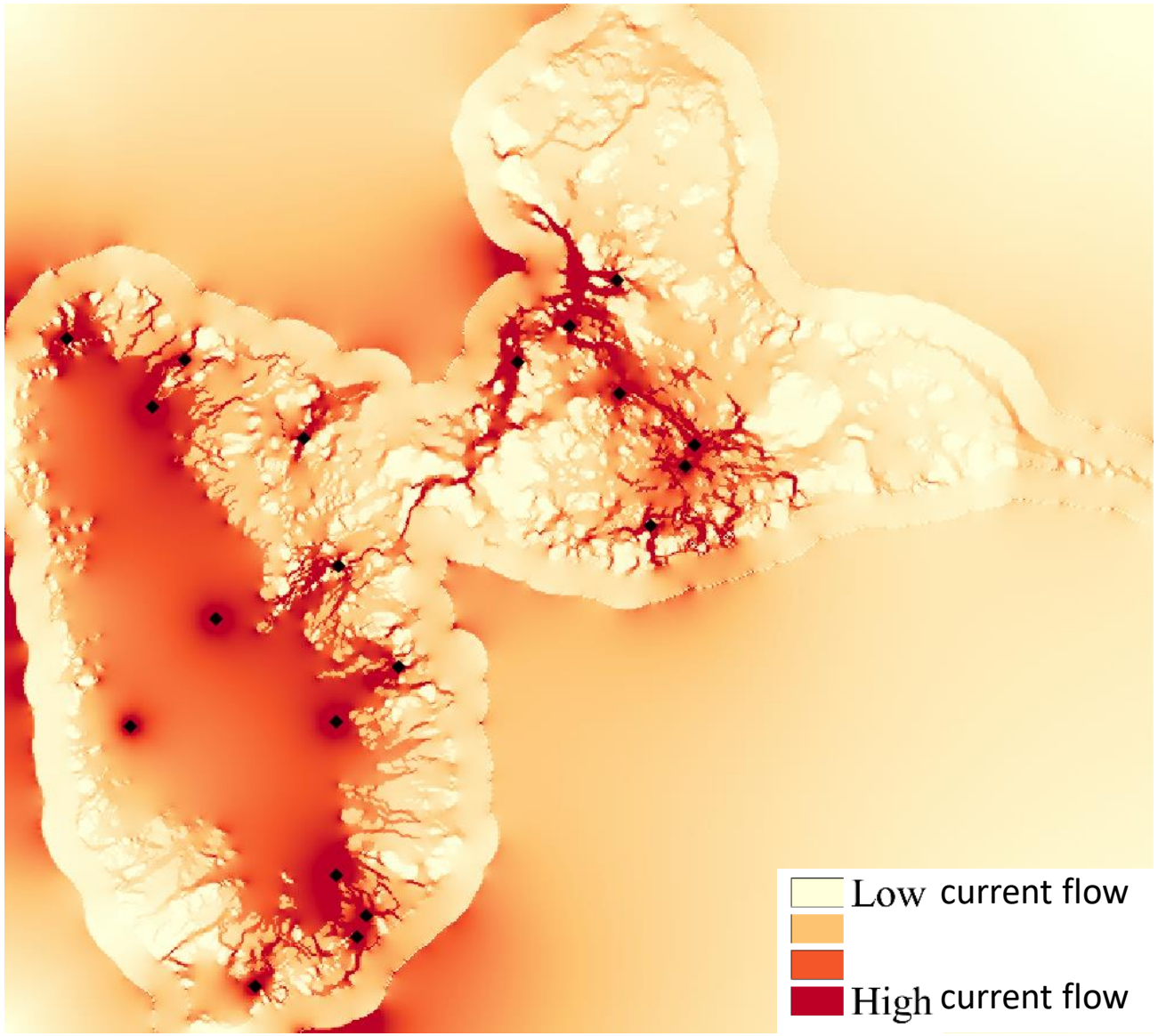
Pasture and Inland wetland

Agriculture s. l. (4X) and Coastal sea (7X)

Forest & Mangrove and Open sea

Khimoun *et al. MolEcol* 2017

Current flow among samples locations



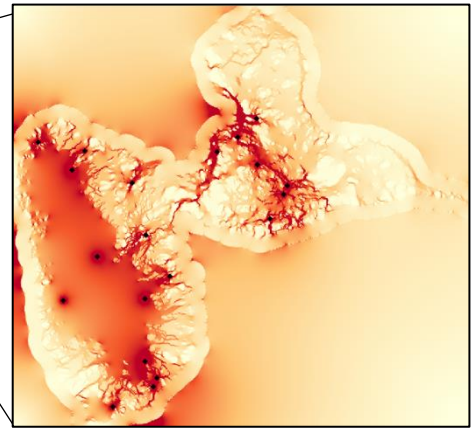
Density of current in each pixel = probability of use during dispersal

- Connectivity between BT-GT populations rely on a narrow corridor of suitable habitat

→ Special attention in conservation effort

Khimoun *et al. MolEcol* 2017

Next steps…



Species-specific vision of landscape resistance

Scaly-breasted

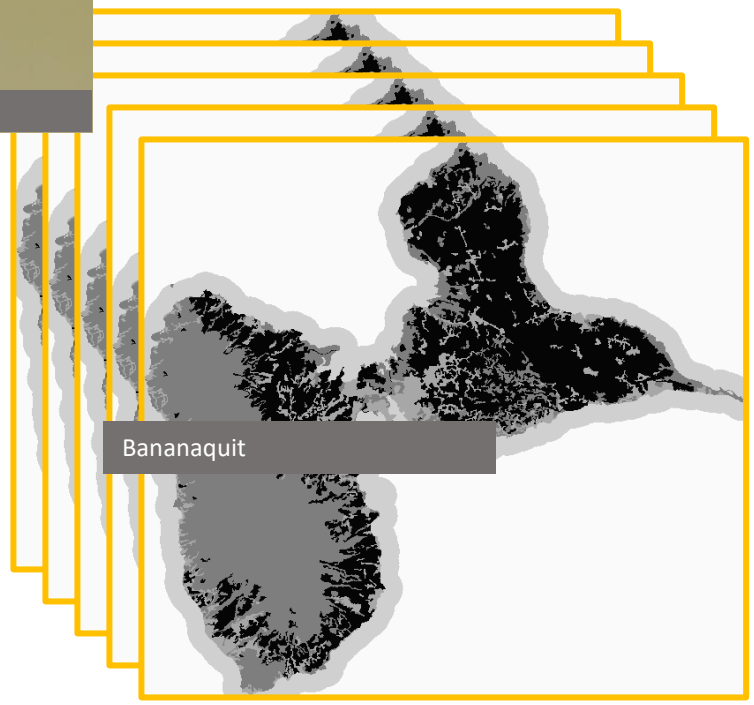
Purple-throated Carib

Lesser Antilean Saltator

ananaquit

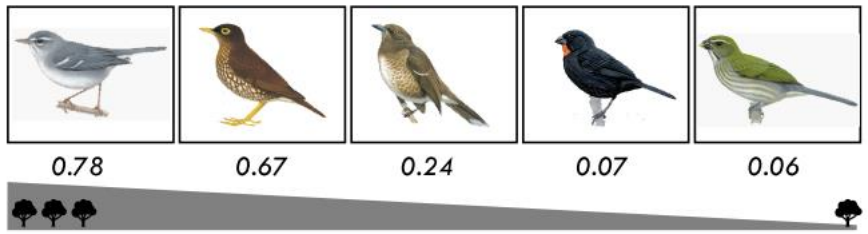
Caribbean Elaenia

Plumbeous Warbler



Bananaquit

Multi-species assessment of landscape resistance



→ Integrative strategies of habitat conservation/restoration


Merci
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