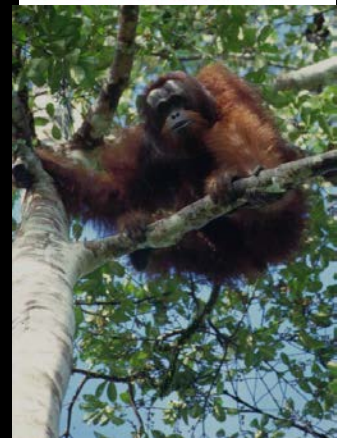
Very spatial indeed: trying to take (spatial) structure into account in population genetics inference

Laboratoire Evolution et Diversité Biologique, **CNRS, Toulouse**

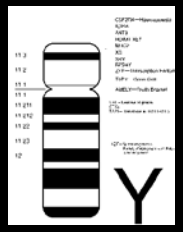
Population and Conservation Genetics Group, **IGC, Portugal**

Toulouse INRA 2013 – 11 Mars 2013



Pictures: E. Quéméré, F. Jan, B. Goossens, R. Mittermeier

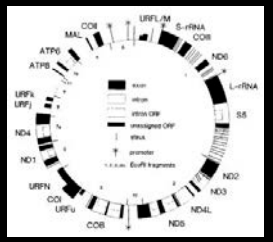
POPULATION AND CONSERVATION GENETICS



POPULATION GENETIC DATA

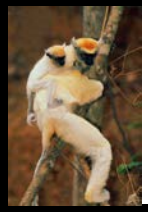
Y chromosome **mitochondrial DNA**

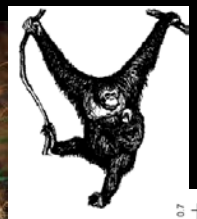
---CAGTCAGTCAGT---

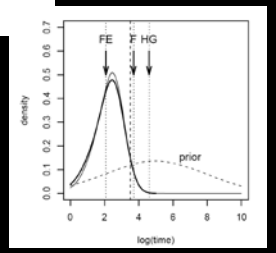


CONSERVATION GENETICS

- Habitat Fragmentation
- Population Decline
- Admixture in Domesticates

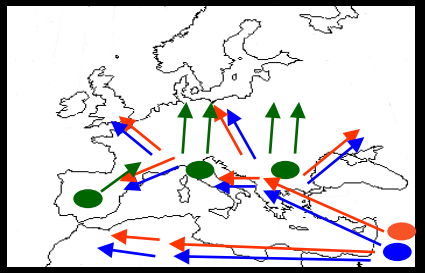


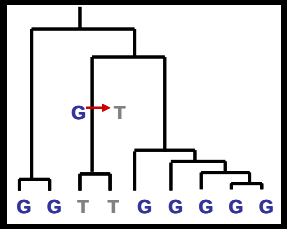


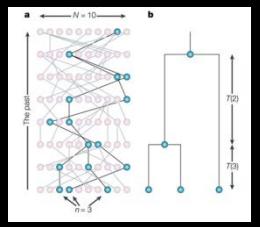


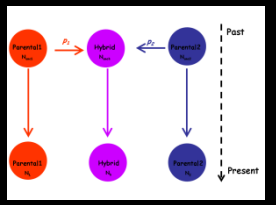
HUMAN PAST DEMOGRAPHY

- Neolithic Transition
- Admixture in Human Populations









NEW METHODS / SOFTWARE

OUTLINE

- A little reminder on population genetic diversity, bottlenecks (with some simulation results)
- Habitat loss and fragmentation in Madagascar
- Deforestation in Madagascar: humans or climate, who shaped the gene pool of the golden-crowned sifaka?

Master Students 2008-2009

Aubin Besolo

Density estimates

Emmanuel Rasolondraibe

Habitat and diet characterization

Students 2010

Mohamed Thani Ibouroi

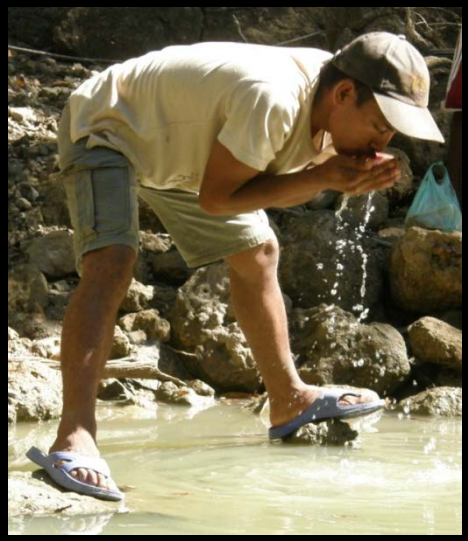
morphological variation and density estimates in mouse lemurs

Sam Viana

Optimus Alive! Grant 2010

Heriniaina Rakotoarisoa

Density estimates in crowned sifaka (Propithecus coronatus)



Volonteer 2010 /Field assistant 2011-2012:
Fabien Jan

Students 2011-2012

Tantely RALANTOHARIJAONA

morphological variation and density estimates in sportive lemurs

Célia Kun Rodrigues

Optimus Alive! Grant 2011-2012

Marion Carreira

Volunteer 2011-2012

PhD candidate: Jordi Salmona 2010-2014

Said Ali Ousseni Durham
Masters student 2011-2012

Some of the studies we develop in Madagascar

3 species of sifaka (genus *Propithecus*)

- ***Propithecus tattersalli***
- ***P. coquereli***
- ***P. coronatus***

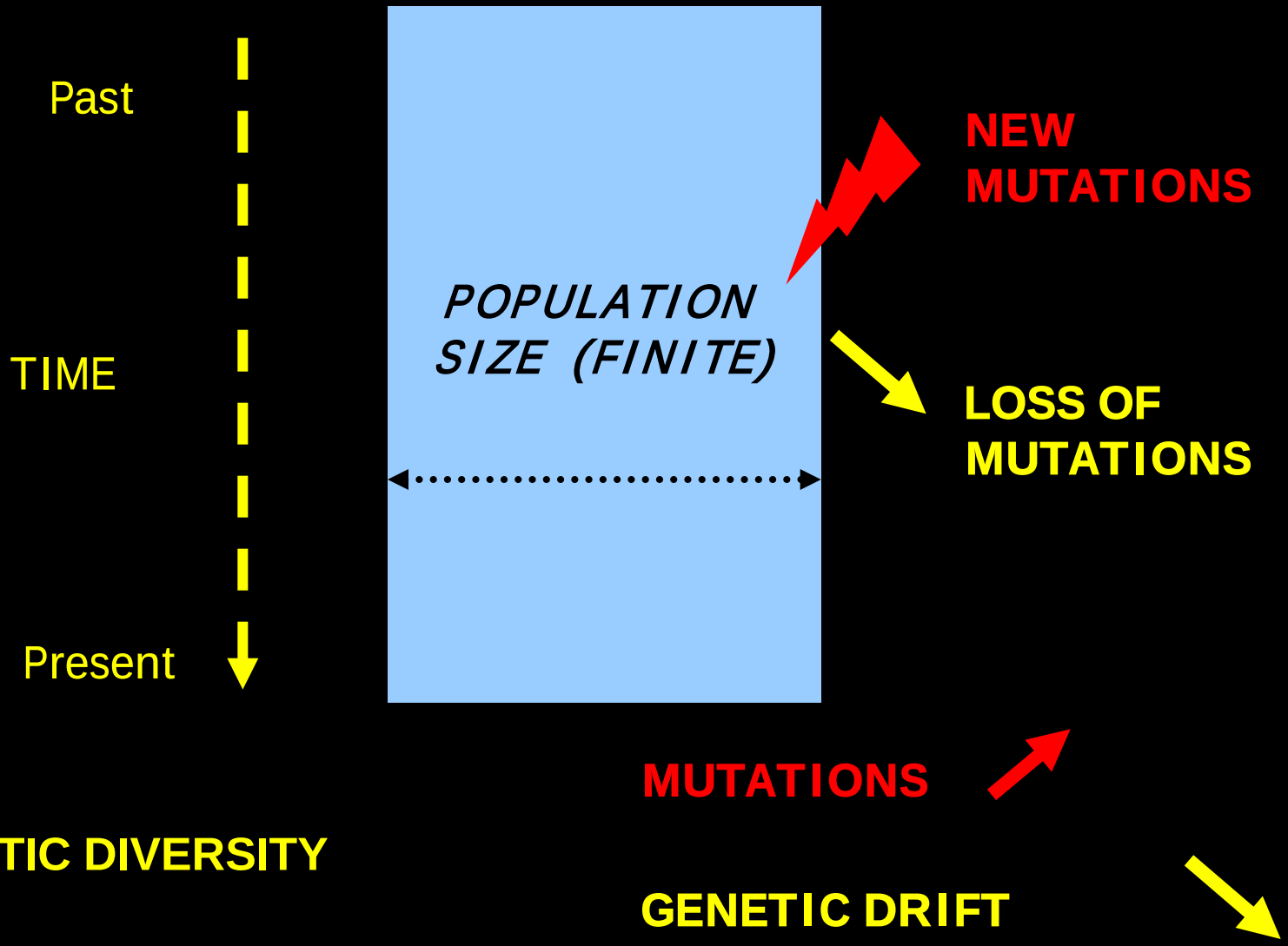
Density estimation

- **Distance sampling**
- **Census**

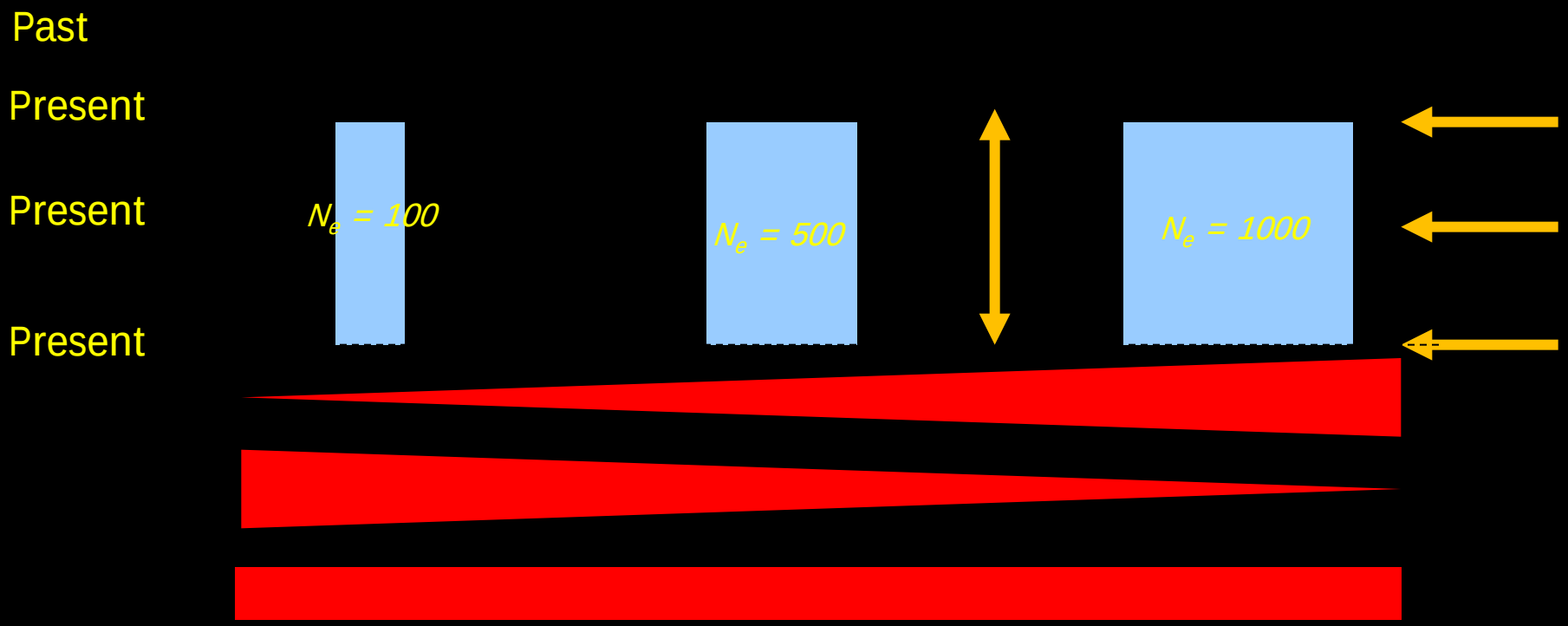
Non invasive sampling

- **Faeces**

GENETIC DIVERSITY



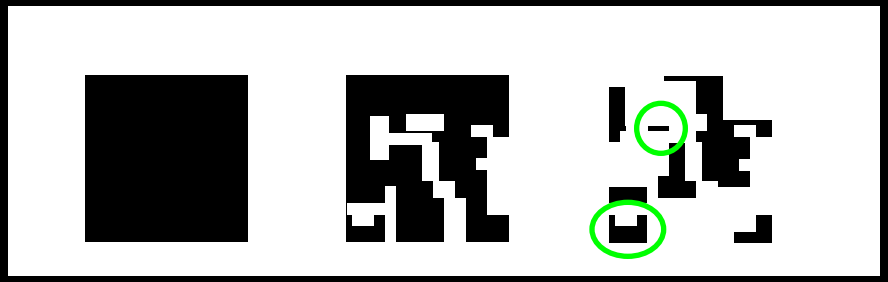
GENETIC DIVERSITY

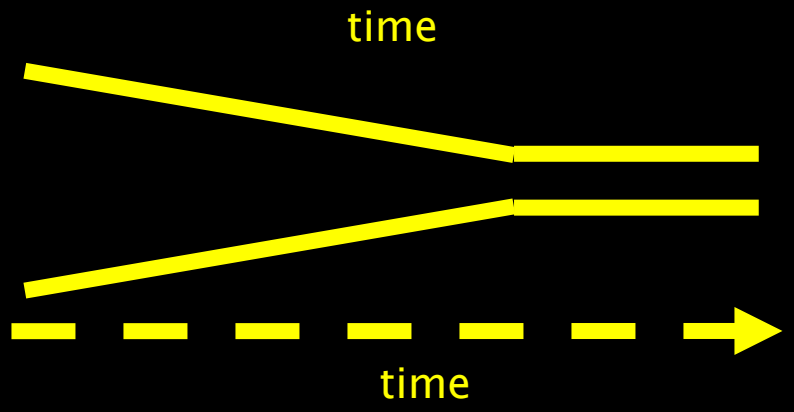


GENETIC DIVERSITY

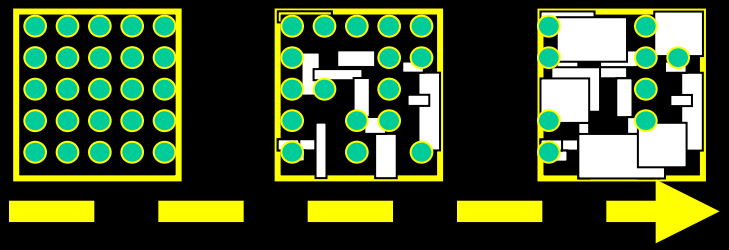
Different demographic histories can produce similar or counter-intuitive results

Habitat fragmentation and loss as a temporal process

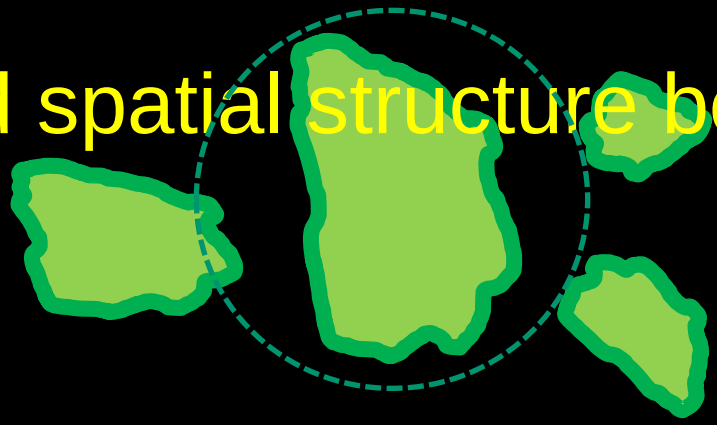


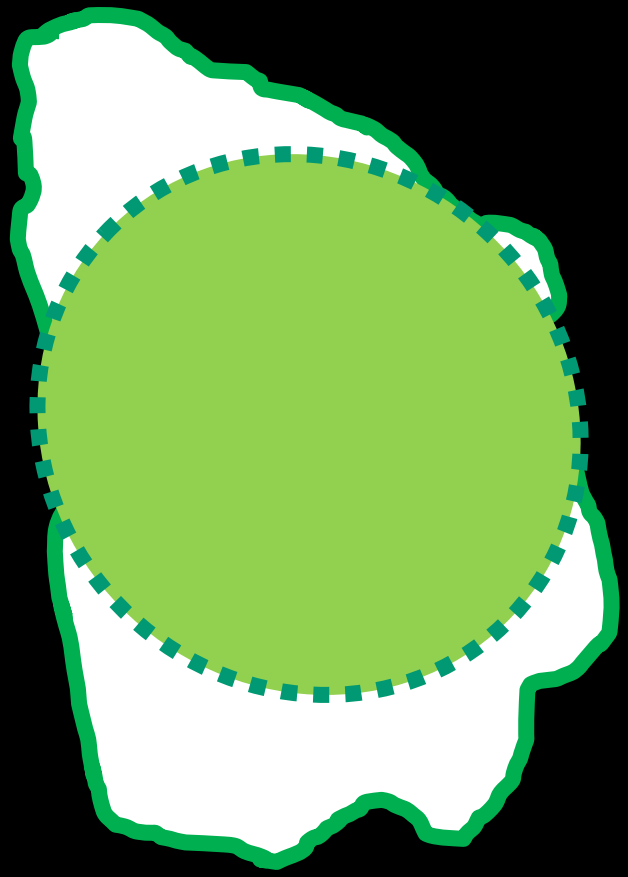


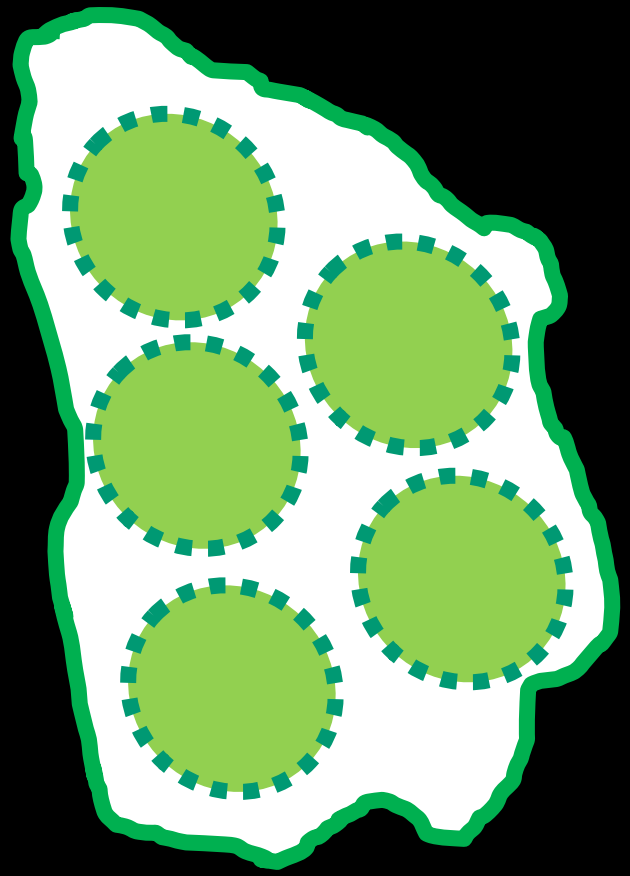
ALSO A SPATIAL PROCESS: population structure

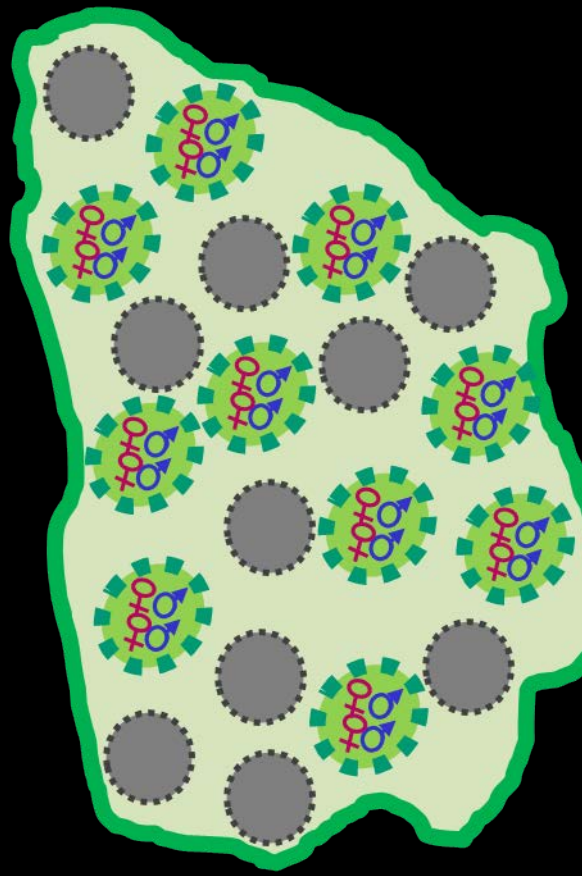


How should spatial structure be represented?



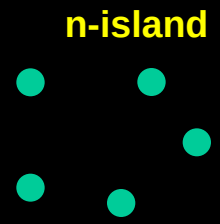


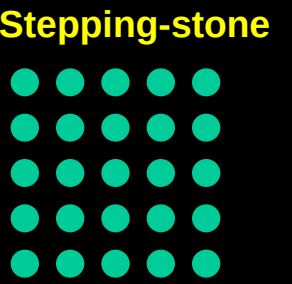




Effect of population structure on bottleneck signals

- Models of population structure (100 demes in all simulations)
  - n-island model (100 islands)
  - Stepping-stone (10 x 10) (toroidal)





- Parameters used
  - Stepwise mutation model assumed to simulate data
  - F_{ST} values used { 0.01 ; 0.05 ; 0.1 ; 0.25 }
  - θ values used { 1; 10 }
  - Number of loci { 5 ; 20 }
  - 50 individuals sampled (100 genes)

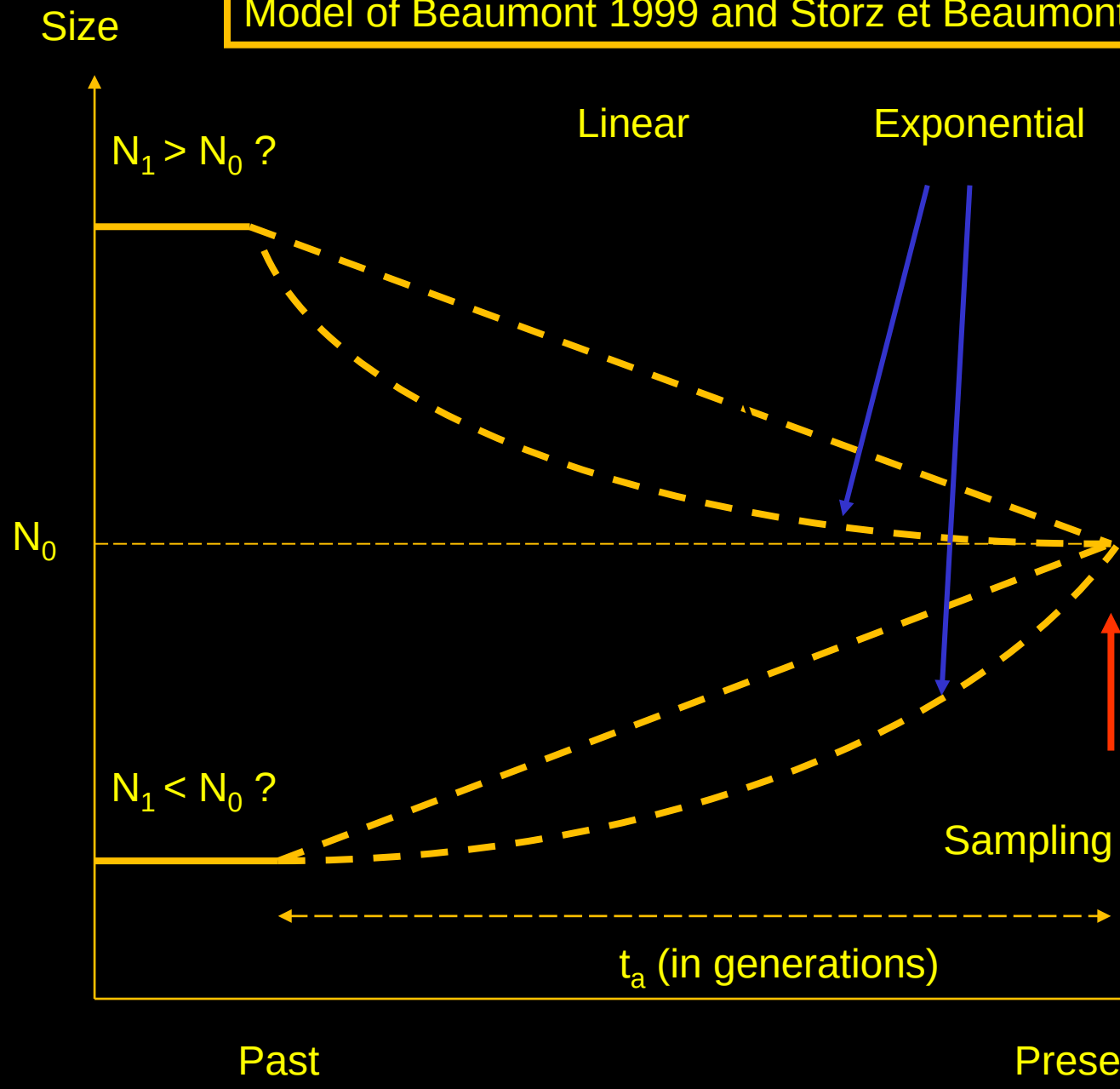
Differentiation

Diversity
(mutation and pop size)

- Sampling schemes :
  - n-islands model: samples from 1, 2, 10 and 50 demes
  - Stepping stone model: samples from 1, 2 neighbouring and 2 distant demes

- 10 independent data sets for each parameter set (except 20 loci and 10 demes)

Model of Beaumont 1999 and Storz et Beaumont, 2002



Parameters:

N_0 : current size

N_1 : ancestral size

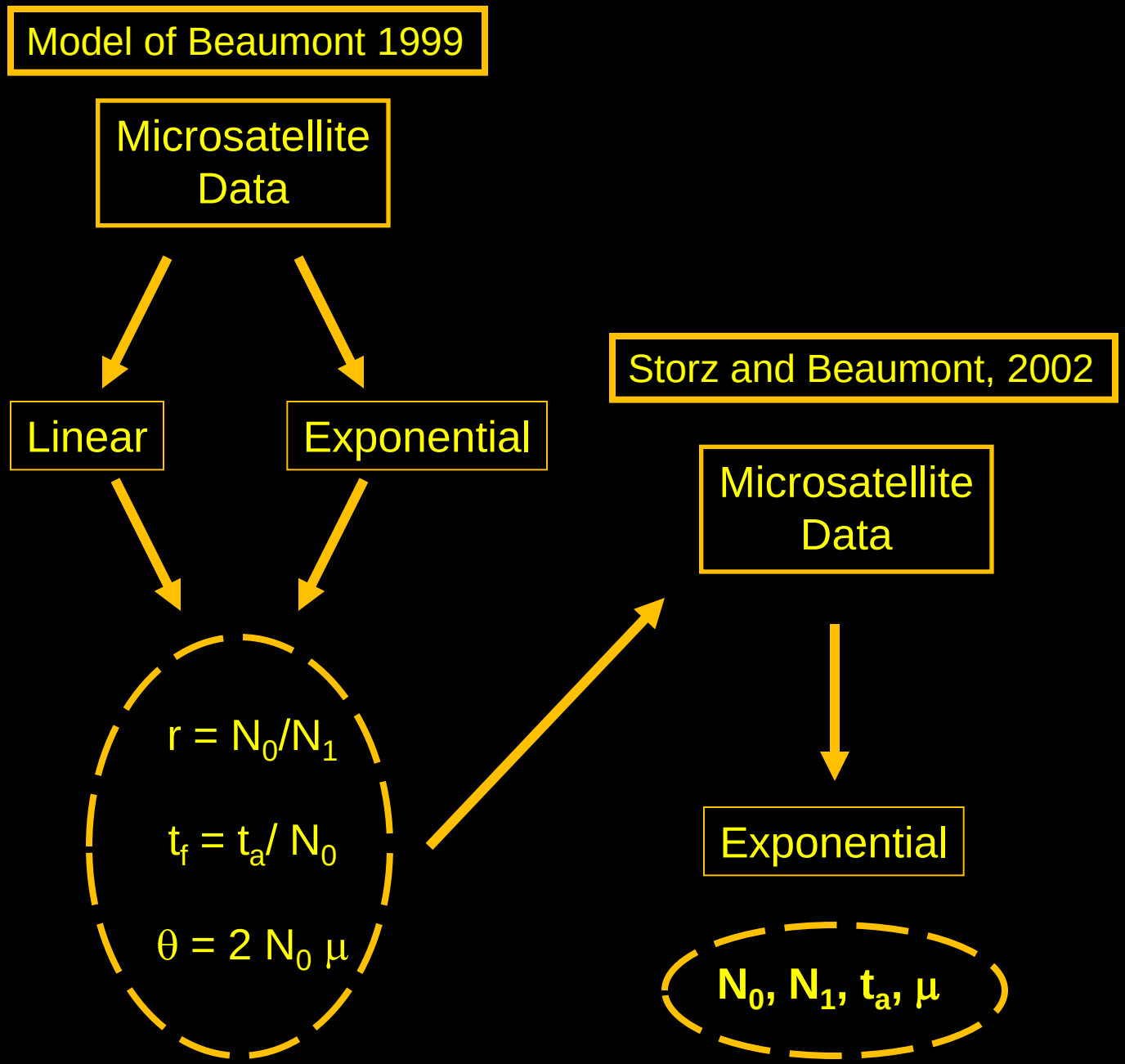
t_a: nb of generations since the pop started to increase or decrease

Reparameterize:

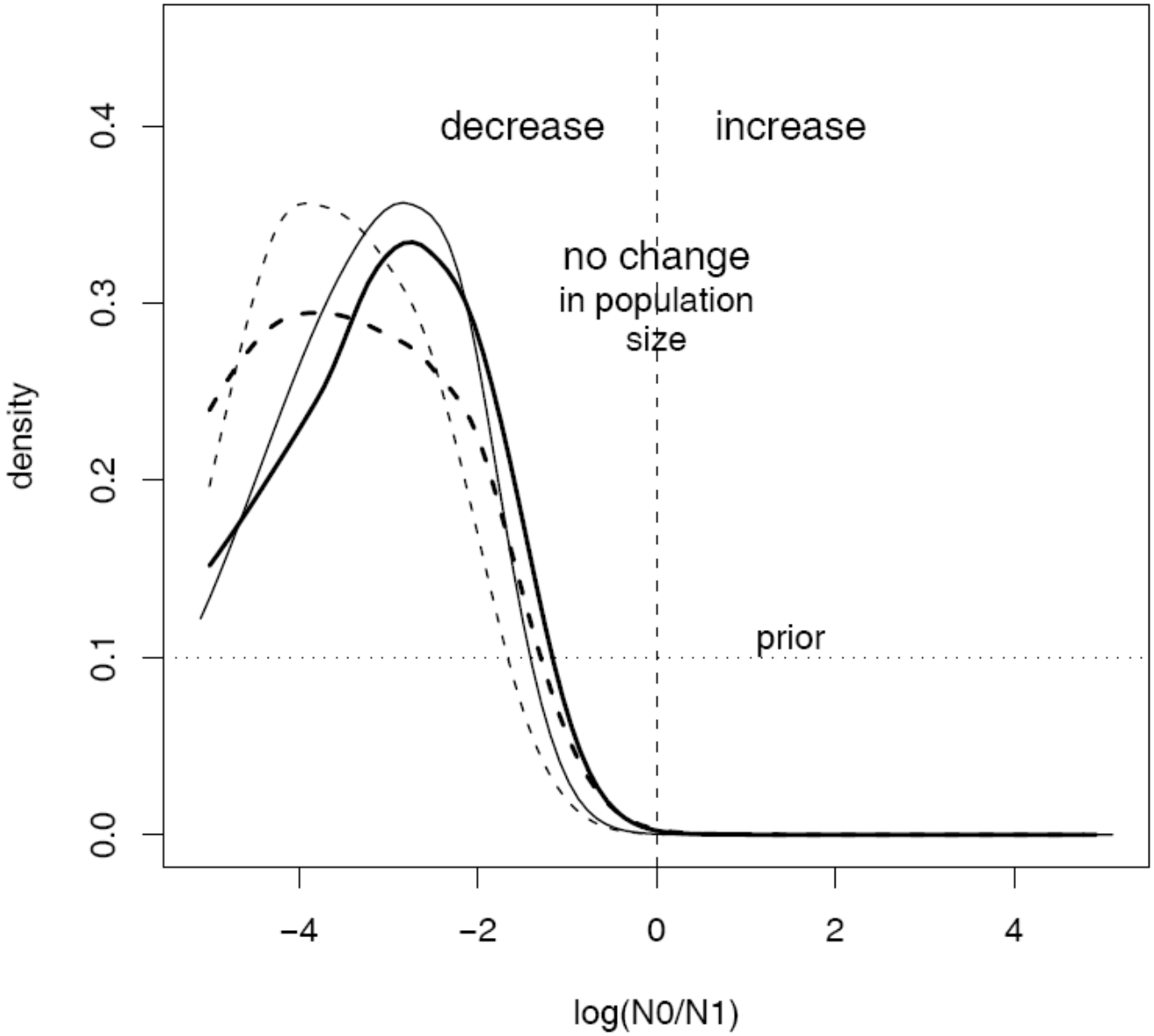
$r = N_0/N_1$

$t_f = t_a / N_0$

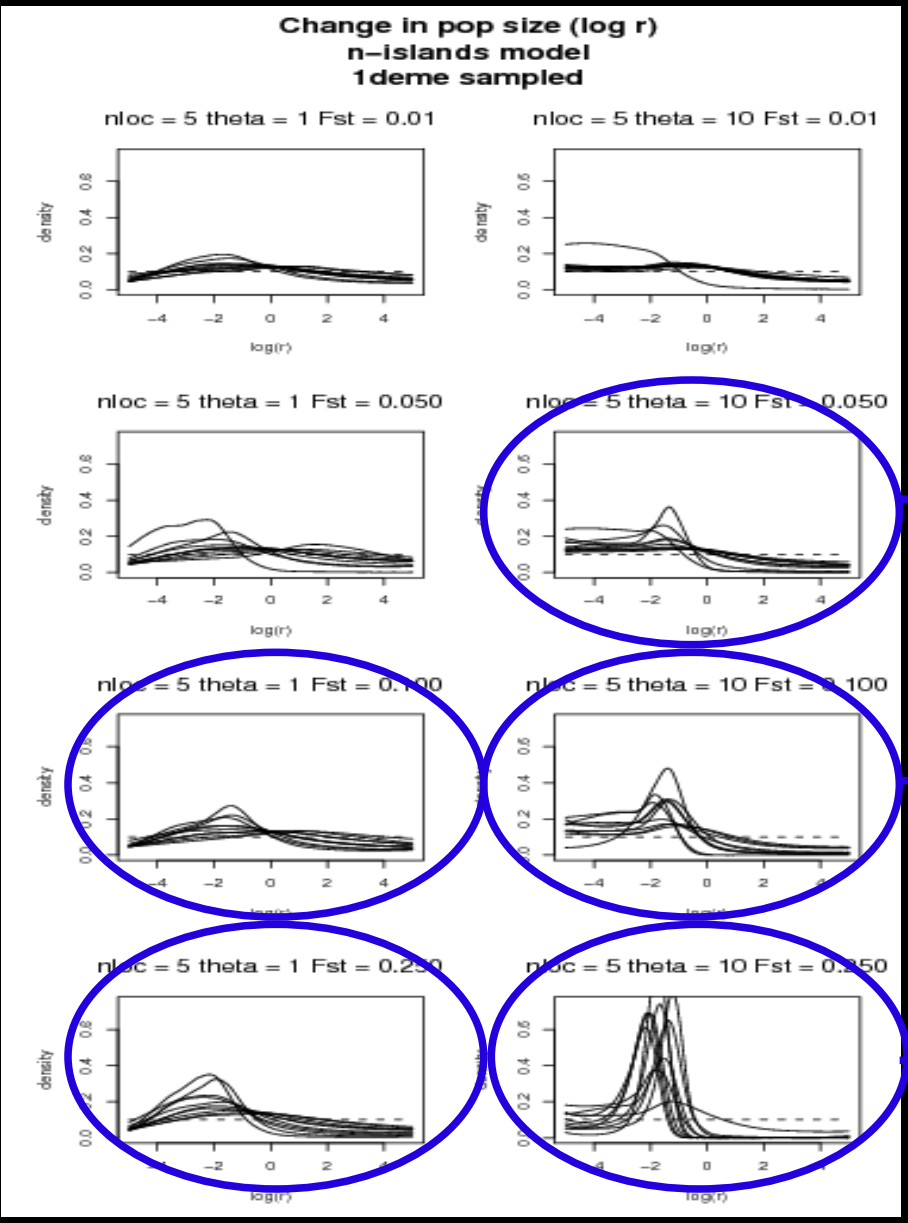
$\theta = 2 N_0 \mu$


Model of Beaumont 1999
Microsatellite Data
Linear
Exponential
$r = N_0/N_1$
$t_f = t_a / N_0$
$\theta = 2 N_0 \mu$
Storz and Beaumont, 2002
Microsatellite Data
Exponential
N_0, N_1, t_a, μ

Population size change



Effect of population structure on bottleneck signals



Can we separate population structure from population crash?

Bottleneck signals

PARTIAL CONCLUSION

1. Population structure can mimic bottleneck signals

2. The signal is particularly strong when
    1. Genetic differentiation is high (gene flow is limited)
    2. Genetic diversity is high
    3. The number of loci used is large

3. The effect is less important when more than one population is sampled

The Confounding Effects of Population Structure and the Sampling Scheme on the Detection of Population Size Changes

Lounès Chikhi,*,†,‡,1 V... r C. Sousa,‡,§ Pierre Luisi,**,†† Beno...
...d Mark A. Beaumont***

Genetics of recent habitat contraction and reduction in population size: does isolation by distance matter?

RAPHAEL LEBLOIS,*†‡ ARNAUD ESTOUP† and REJANE STREIFF†
*Laboratoire Génétique et Environnement, CNRS-UMR 5554, 34095 Montpellier, France, †Centre de Biologie et de Gestion des Populations, INRA, Campus International de Baillarguet, CS 30016, 34988 Montferrier sur Lez cedex, France

Genetic Bottlenecks Driven by Population Disconnection

THOMAS BROQUET,*†† SONIA ANGELONE,†‡ JULIE JAQUIERY,*‡‡ PIERRE JO...
JEAN-PAUL LENA,§ THIERRY LENGAGNE,§ SANDRINE PLENET,§ EMILIEN ...
AND NICOLAS PERRIN*

The Impact of Sampling Schemes on the Site F... Nonequilibrium Subdivided Popul...

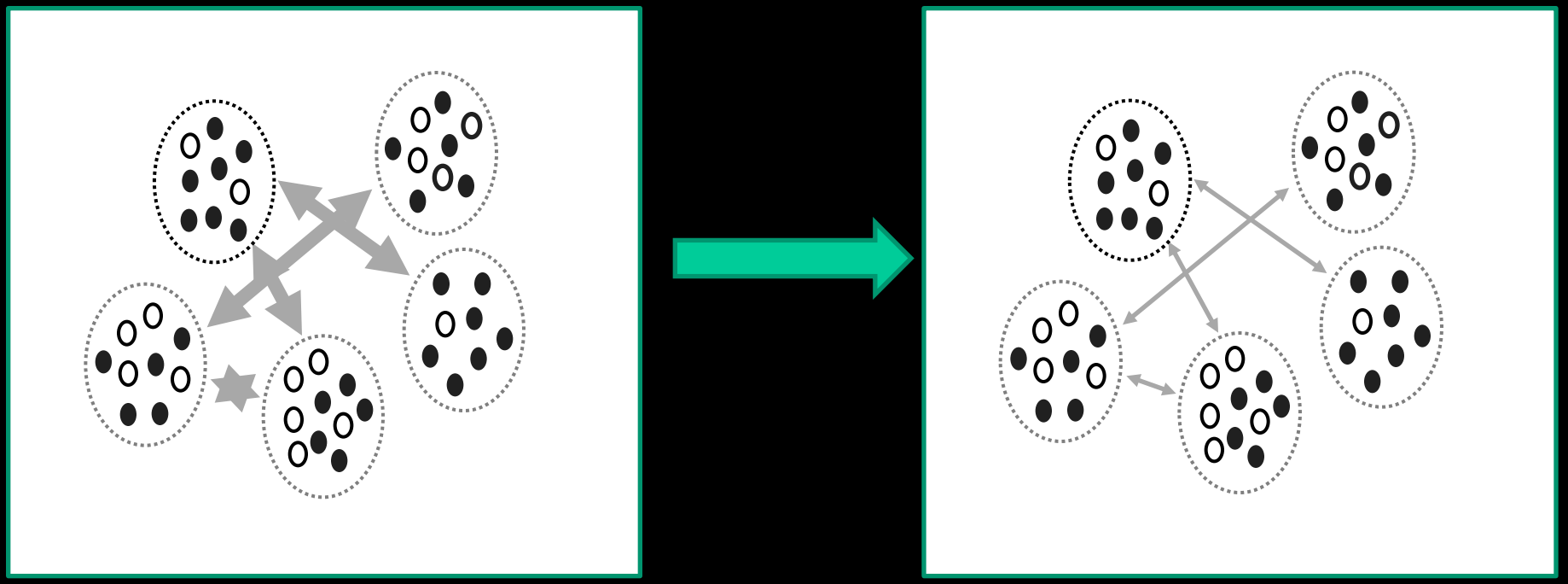
Thomas Städler,*,1 Bernhard Haubold,† Carlos Merino,‡ Wolfg...
Peter Pfaffelhuber§
...tephan‡ an...

Distinguishing between population bottleneck and population subdivision by a Bayesian model choice procedure

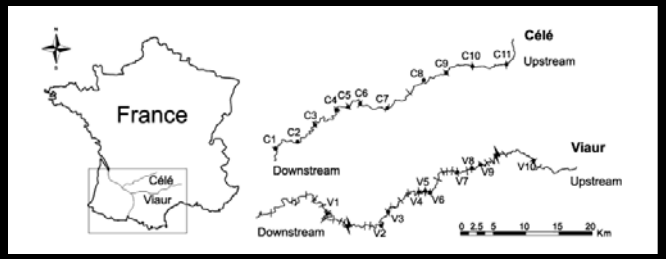
BENJAMIN M. PETER,*† DANIEL WEGMANN*1 and LAURENT EXCOFFIER*†
*Computational and Molecular Population Genetics (CMPG), Institute of Ecology and Evolution, University of Bern, Baltzerstrasse 6, CH-3012 Bern, Switzerland, †Swiss Institute of Bioinformatics, 1015 Lausanne, Switzerland

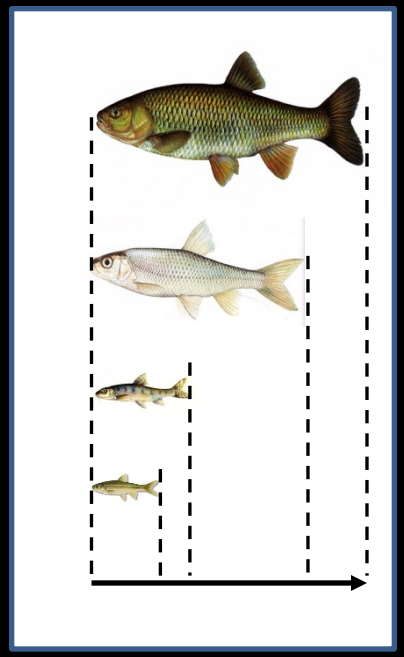
Genetic Bottlenecks Driven by Population Disconnection

THOMAS BROQUET,*†† SONIA ANGELONE,†‡ JULIE JAQUIERY,*‡‡ PIERRE JOLY,§ JEAN-PAUL LENA,§ THIERRY LENGAGNE,§ SANDRINE PLENET,§ EMILIEN LUQUET,§ AND NICOLAS PERRIN*



Do all models of population structure create genetic bottlenecks ?





Squalius cephalus

Leuciscus leuciscus

Gobio gobio

Phoxinus phoxinus

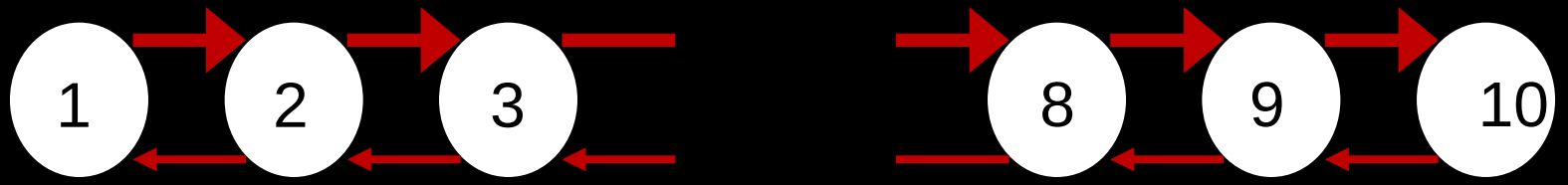
Simon Blanchet

Ivan Paz

Géraldine Loot

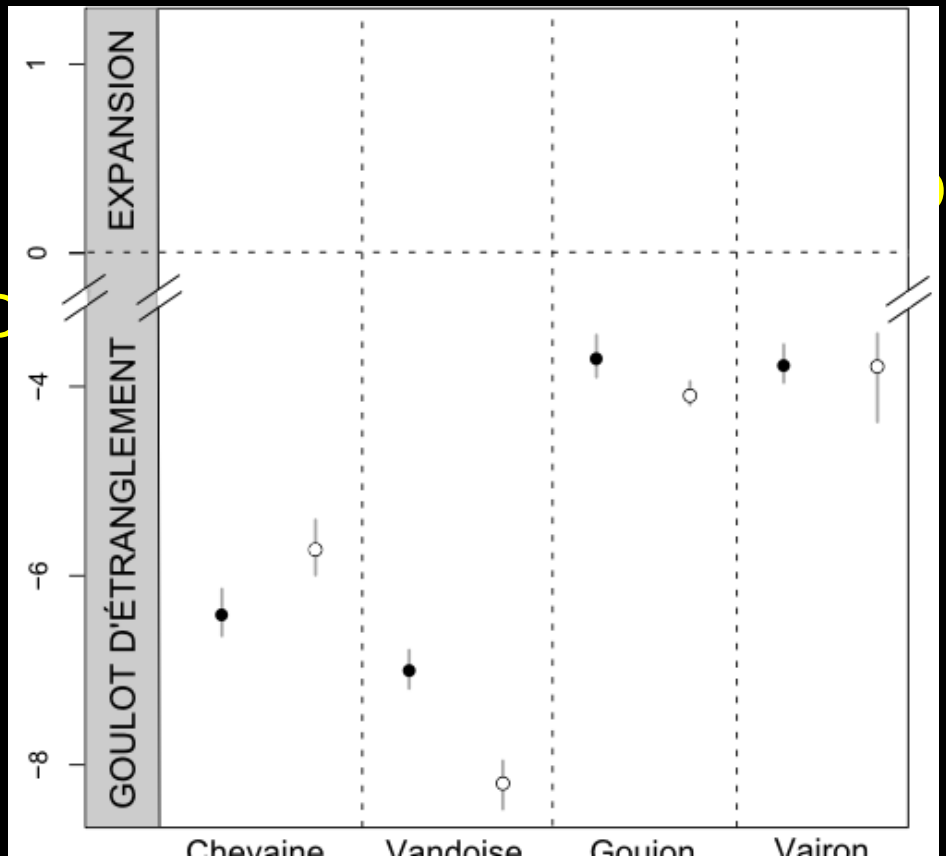
Asymetrical gene flow

SOURCE



UPSTREAM

DOWNSTREAM



PARTIAL CONCLUSION

Need to

Develop methods that can separate these two kinds of scenarios (structure *versus* bottleneck)

Develop *ad hoc* ways to minimize the genetic structure effect is to spread sampling (one individual per "population")

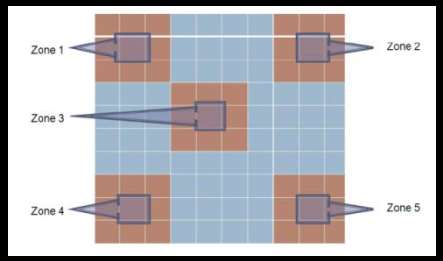
Rasmus Heller (post-doc): Skyline plots

Integrate information from other fields:

Geographic Information Systems → land cover over time

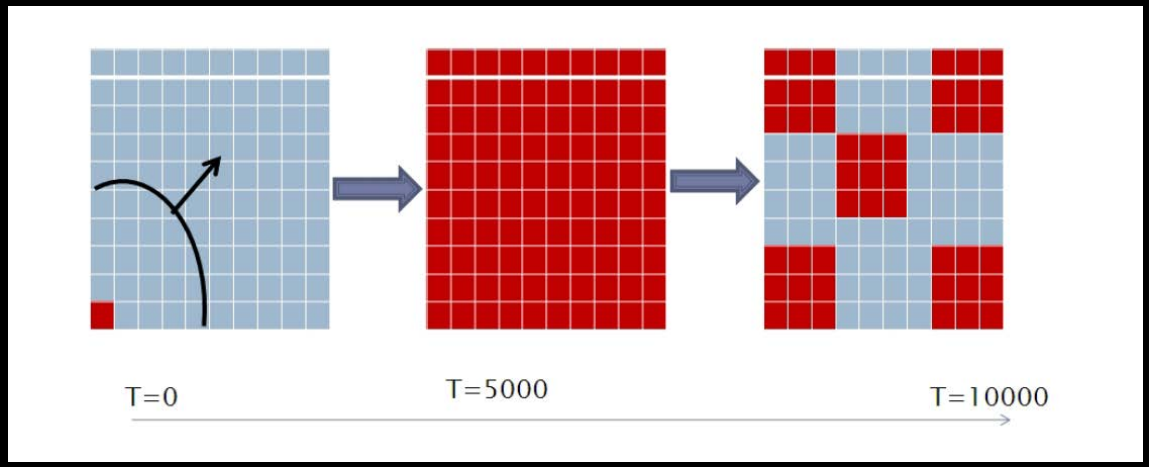
Ancient DNA

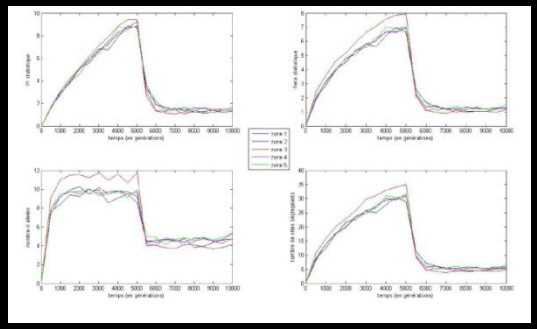
INTEGRATE SPACE AND TIME:
SINS: (Simulating INdivivuals in Space)



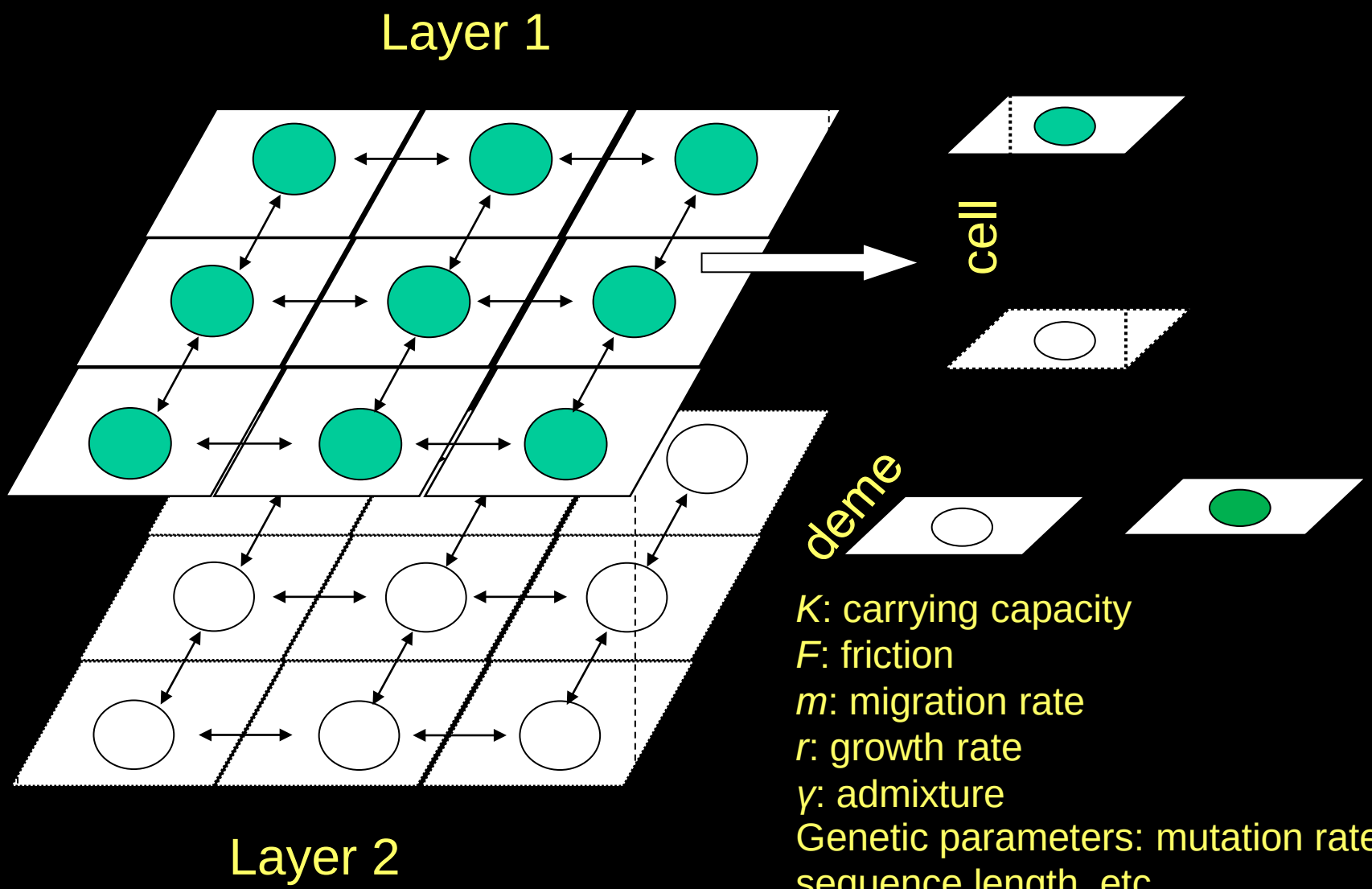
EXPANSION (Neolithic)

FRAGMENTATION





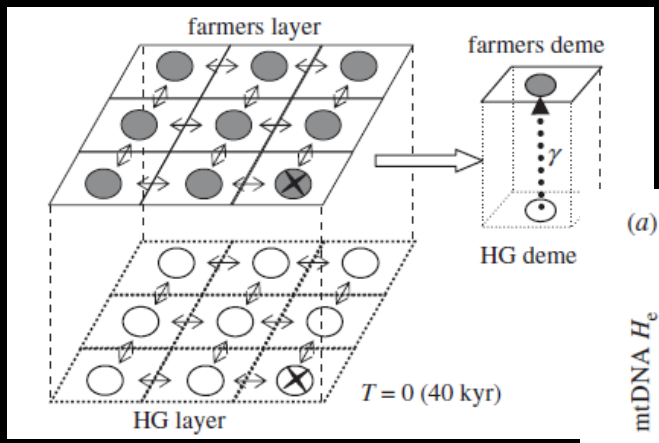
Rita RASTEIRO
Pierre Antoine BOUTTIER
Damien MONIER
Vitor SOUSA



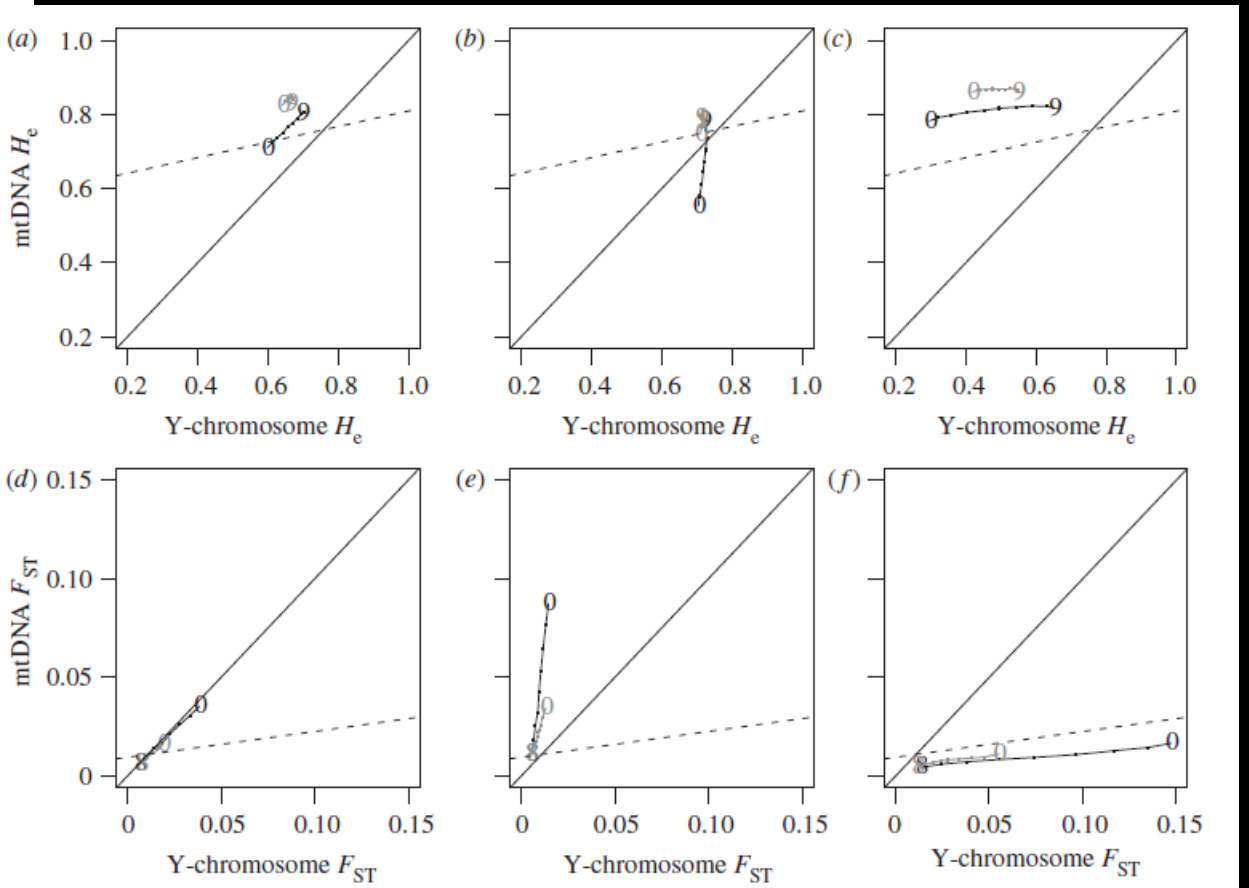
K: carrying capacity
F: friction
m: migration rate
r: growth rate
γ: admixture
Genetic parameters: mutation rates, sequence length, etc

Investigating sex-biased migration during the Neolithic transition in Europe, using an explicit spatial simulation framework

Rita Rasteiro[1,*,†], Pierre-Antoine Bouttier[1,‡], Vítor C. Sousa[1,§] and Lounès Chikhi[1,2,3,*]



bilocality **matrilocality** **patrilocality**

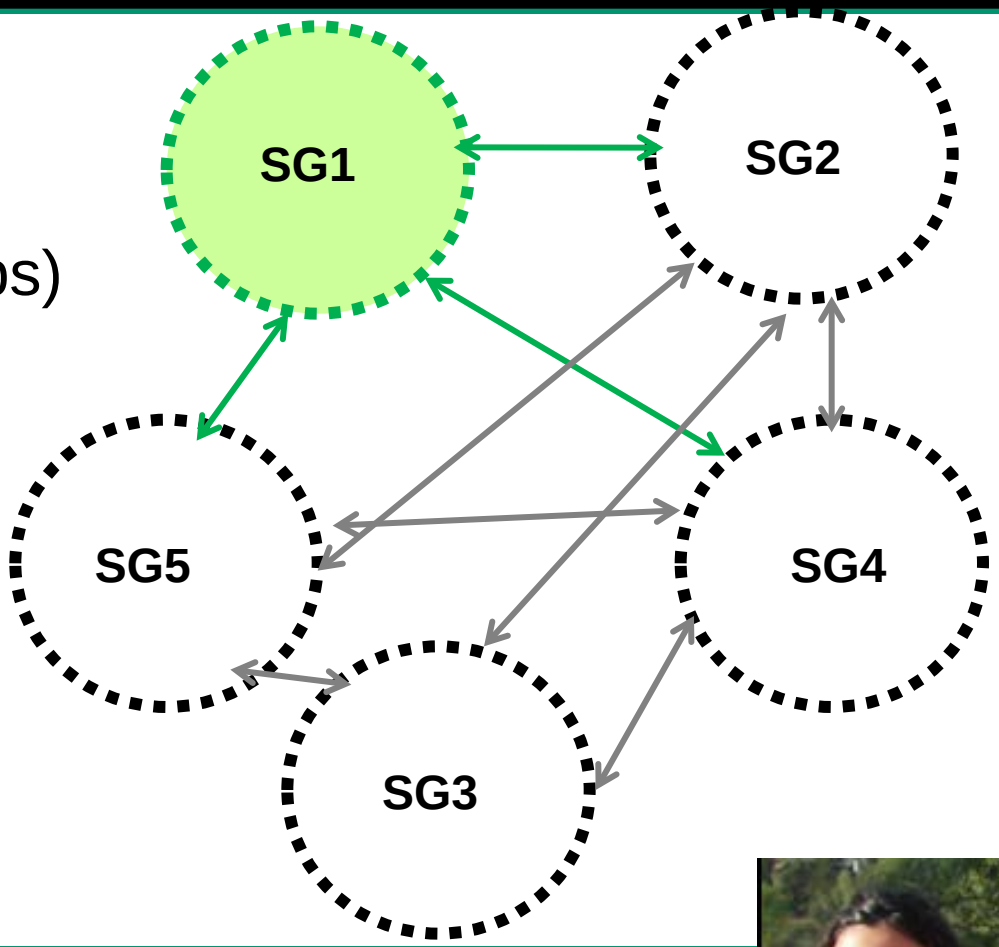


Modelling social structure (is it population structure ?)

MATRIX (ngroups*ngroups)

popstructure.txt

	S1	S2	S3	S4	S5
S1	0	1	0	1	1
S2	1	0	1	1	1
S3	0	1	0	1	1
S4	1	1	1	0	1
S4	1	1	1	1	0

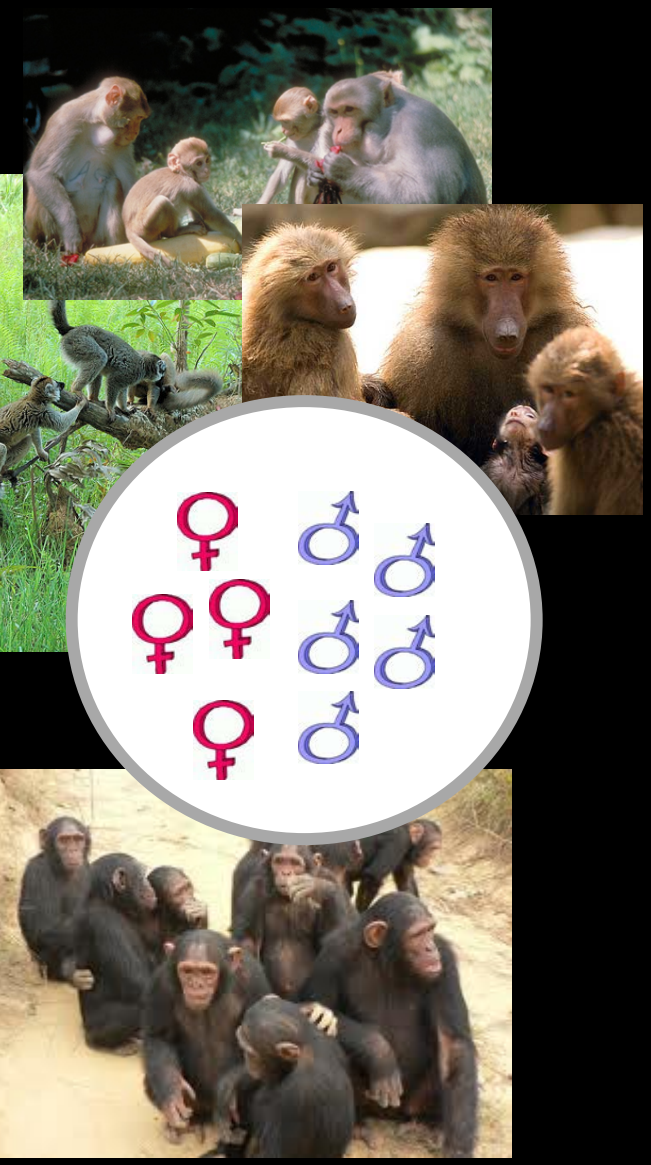


- SG1 is connected to pops 2, 4, 5
- SG3 is connected to pops 2, 4, 5
- SG2, SG4, SG5 are connected to all other SG's

B. Parreira

Types of mating system

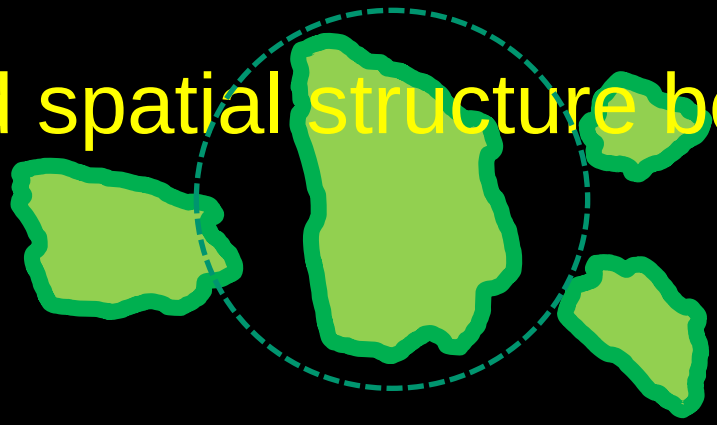
Multi-males; multi-females

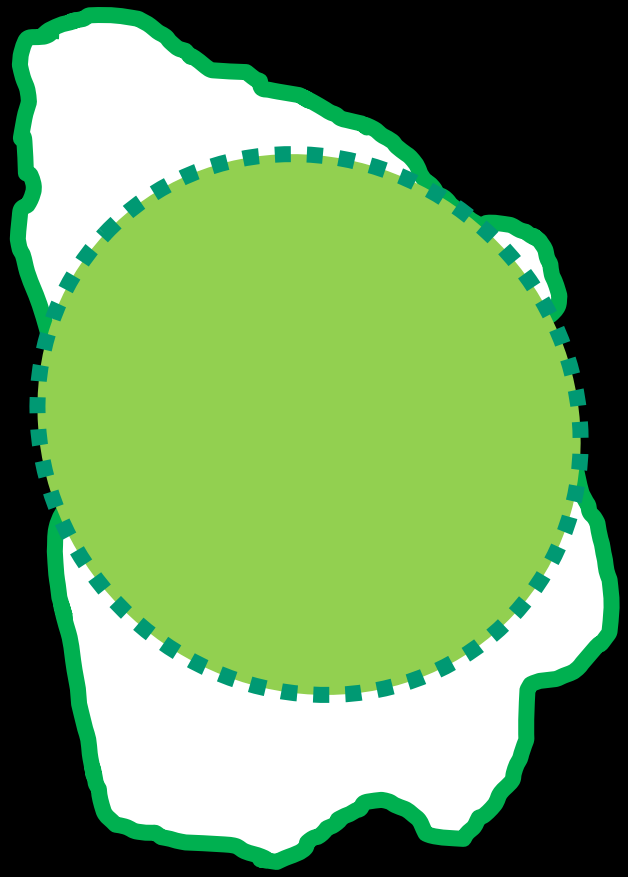


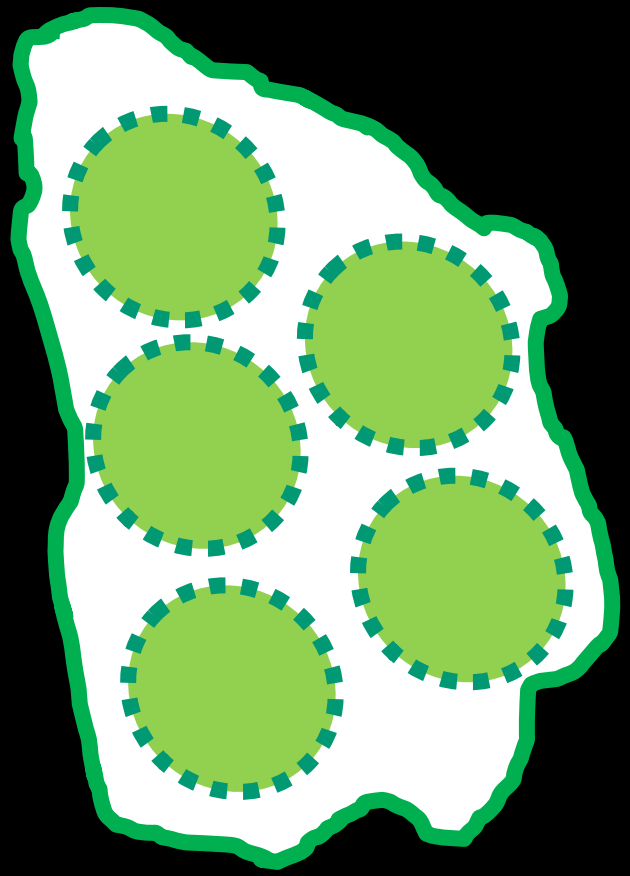
Monogamy

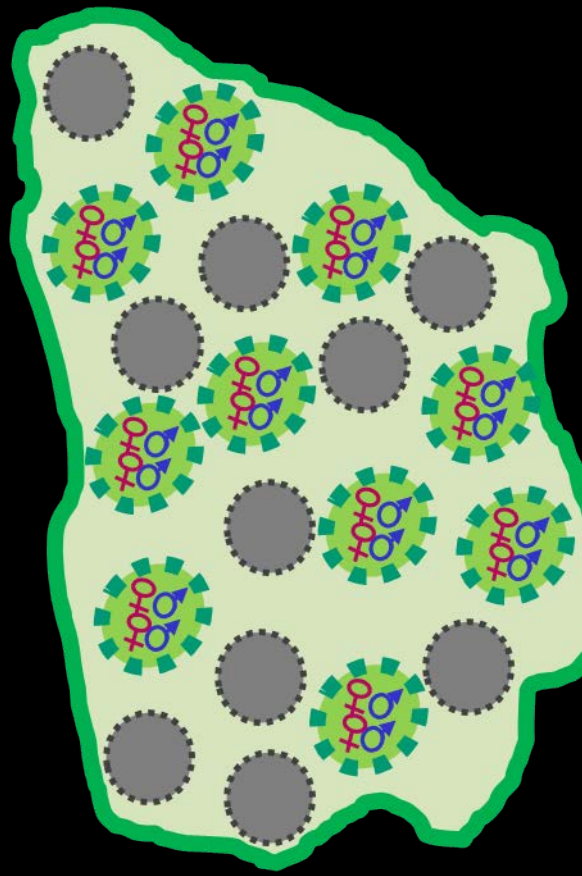
Dominance

How should spatial structure be represented?









PARTIAL CONCLUSION (again)

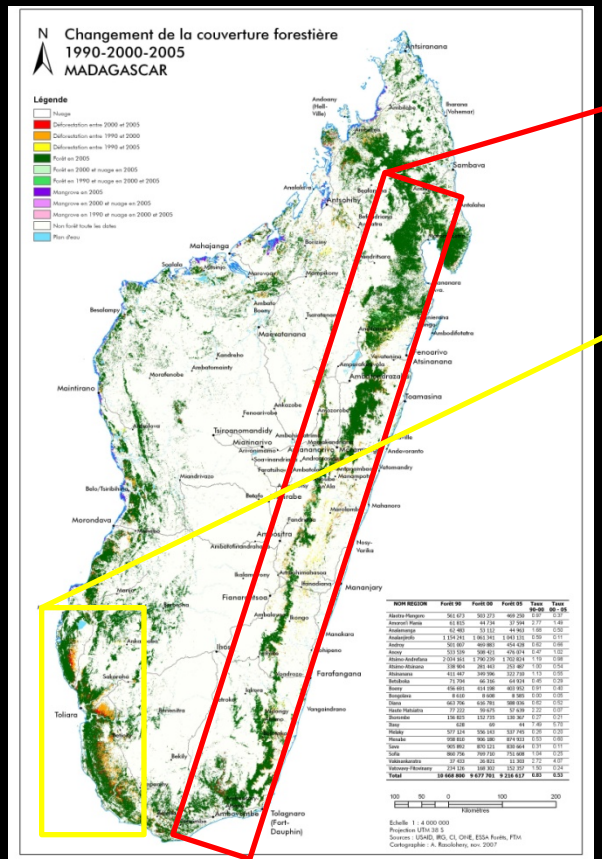
Collaborate with mathematicians/statisticians:

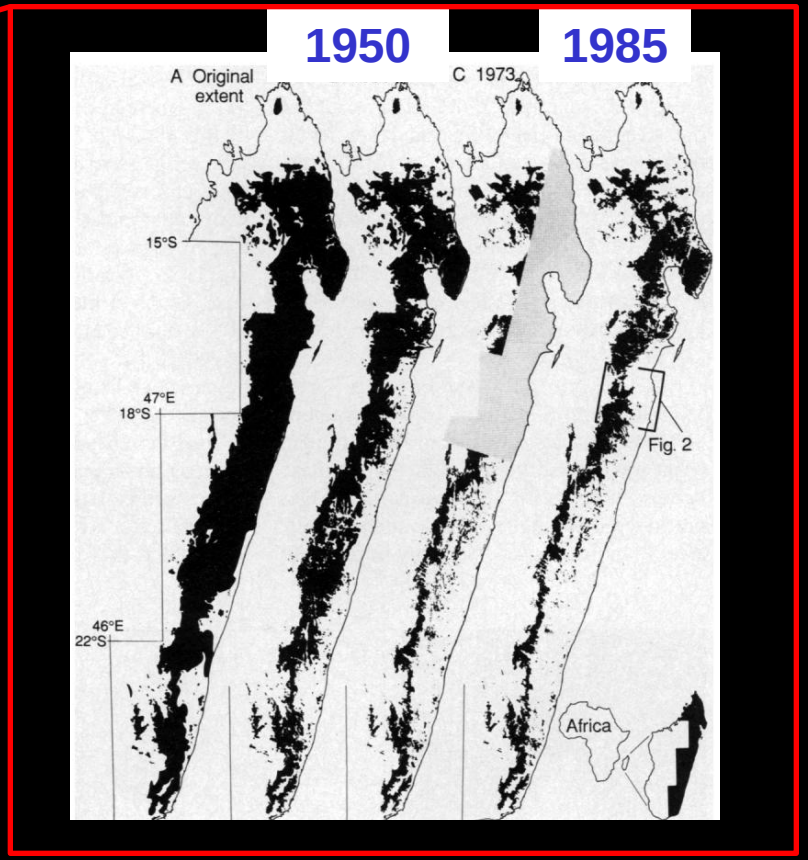
Ongoing work with

- **Simon Boitard (INRA)**
- **Olivier Mazet (INSA, IMT)**
- **Willy Rodriguez (PhD student)**
- **Simona Grusea (INSA, IMT)**
- **Mark Beaumont (Univ. Bristol)**

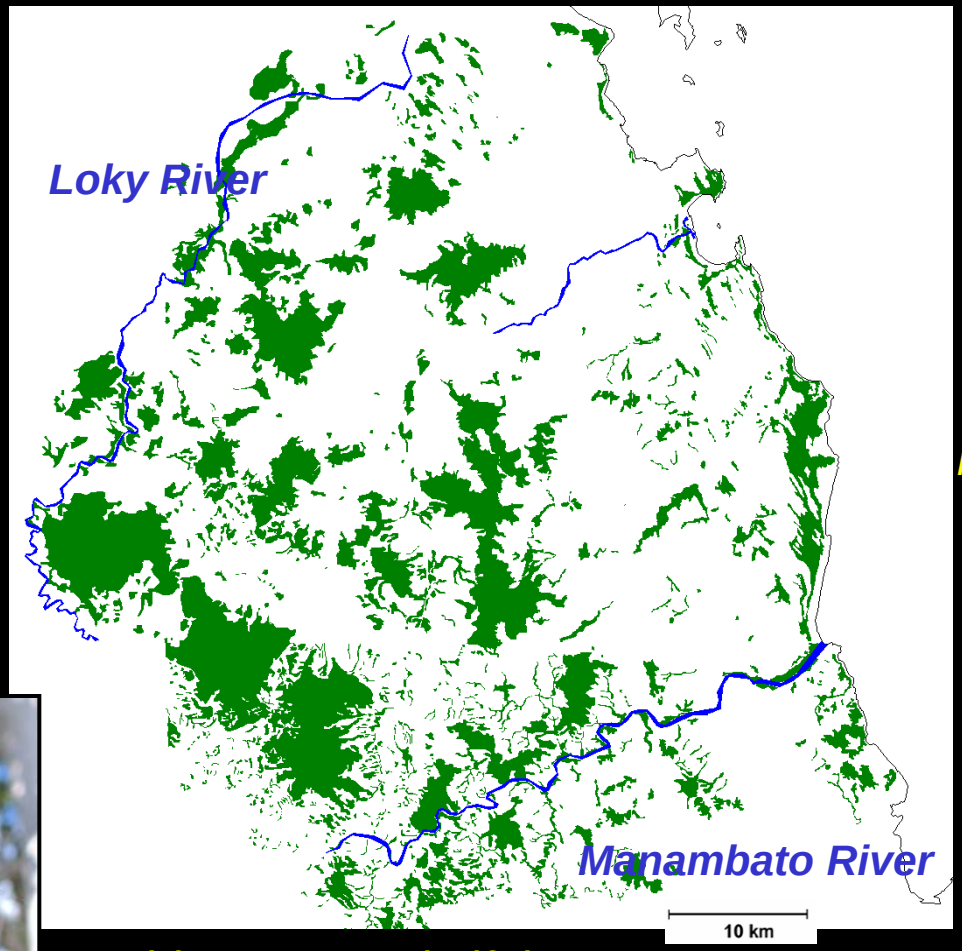
HABITAT LOSS AND FRAGMENTATION IN MADAGASCAR

FOREST HABITATS : 10-20 % TOTAL SURFACE
90% of vertebrates depend on forested habitats
Large size lemurs have disappeared
MOST present-day lemurs are threatened in Madagascar





HABITAT LOSS AND FRAGMENTATION AND SIFAKAS

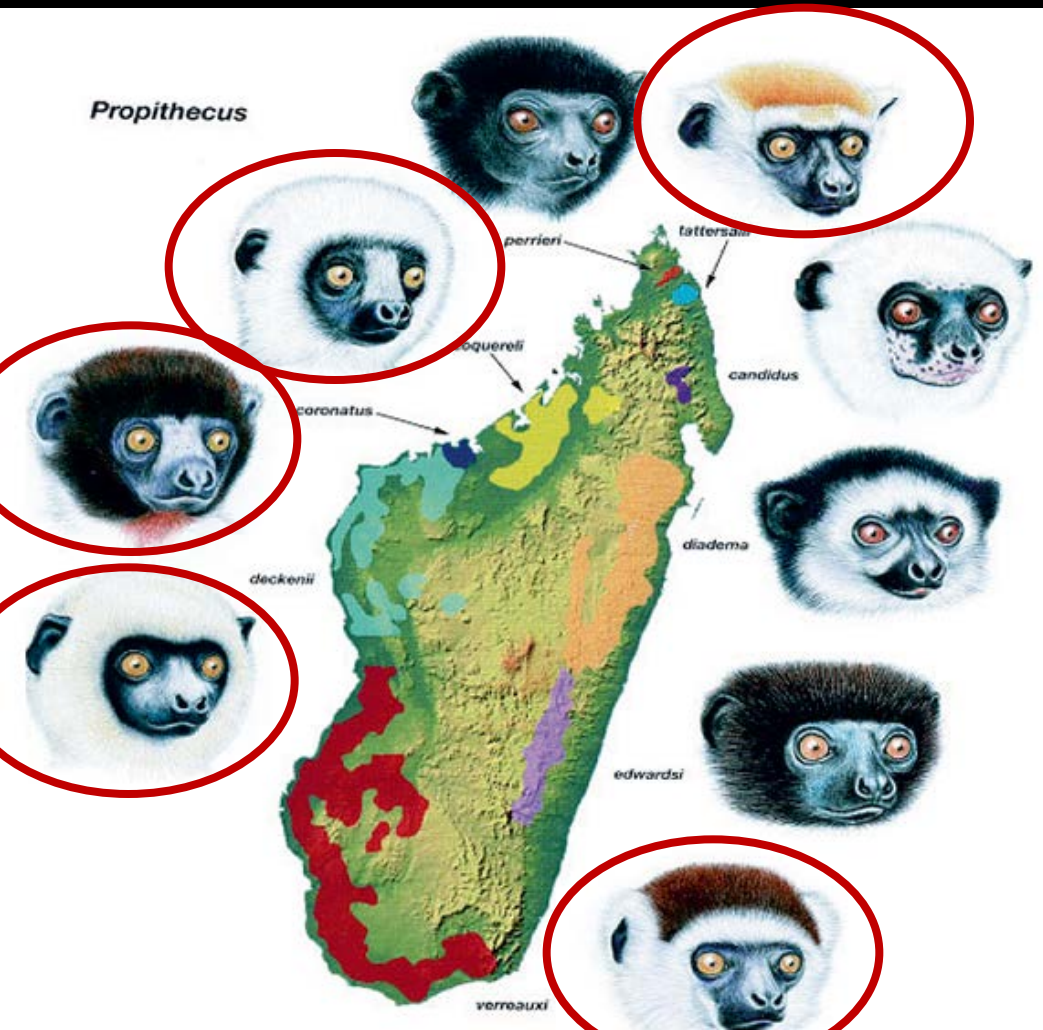


Indian Ocean

Golden-crowned sifaka
Propithecus tattersalli

Erwan Quéméré

SIFAKAS (Propithecus)

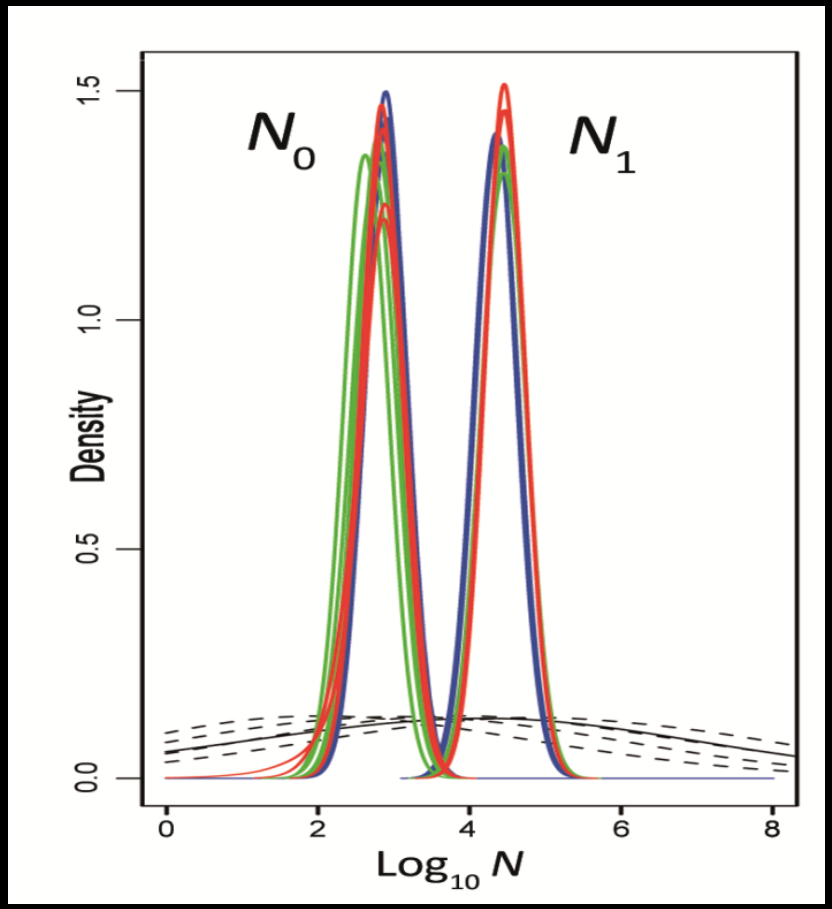


IS HABITAT FRAGMENTATION DUE TO THE ARRIVAL OF HUMANS?

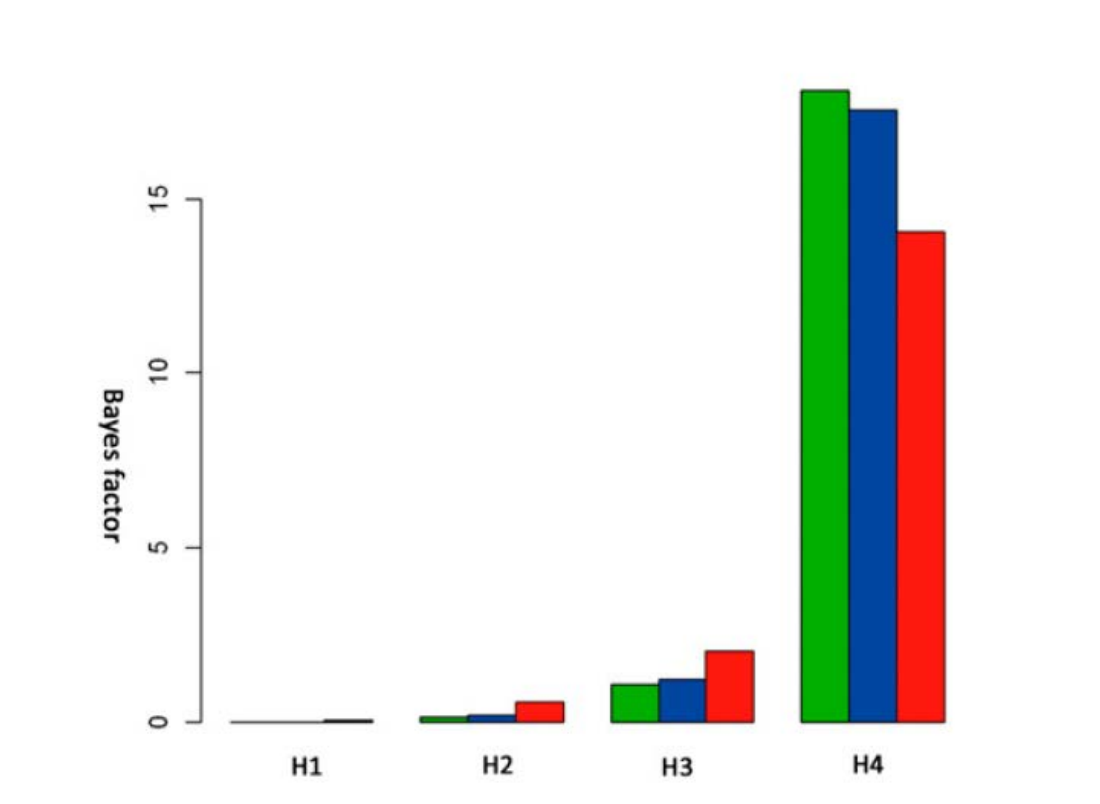
1. Is there a bottleneck signal in golden-crowned sifakas ?

2. When did it happen?
   - H1: in the last 100 years (recent pop increase)
   - H2: between 100 and 1000 years ago (first “real” demographic impact)
   - H3: 1000 - 2000 years ago (human arrival)
   - H4: 2,000 - 10,000 years (Holocene climatic)?

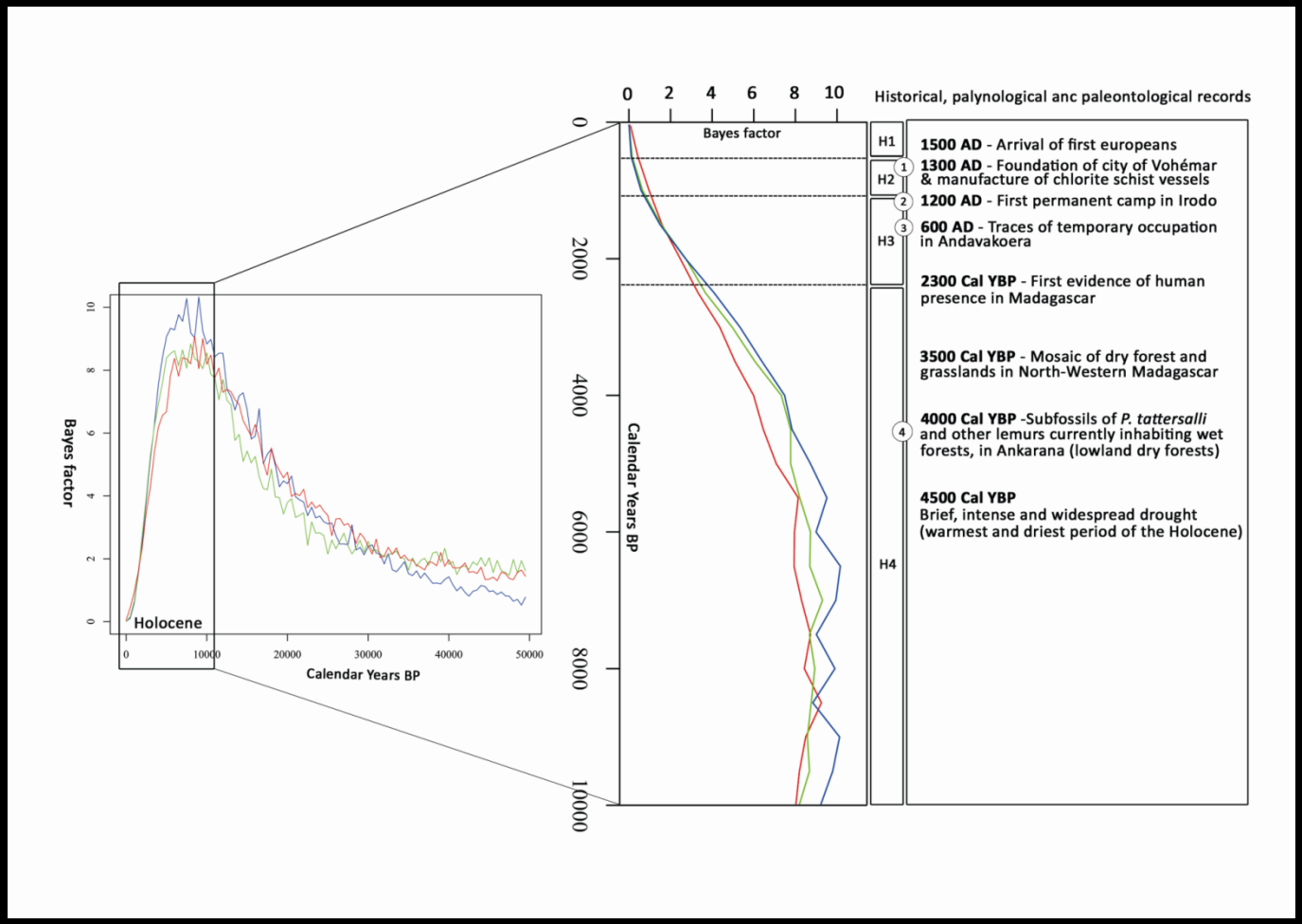
1. Is there a bottleneck signal in golden-crowned sifakas ?



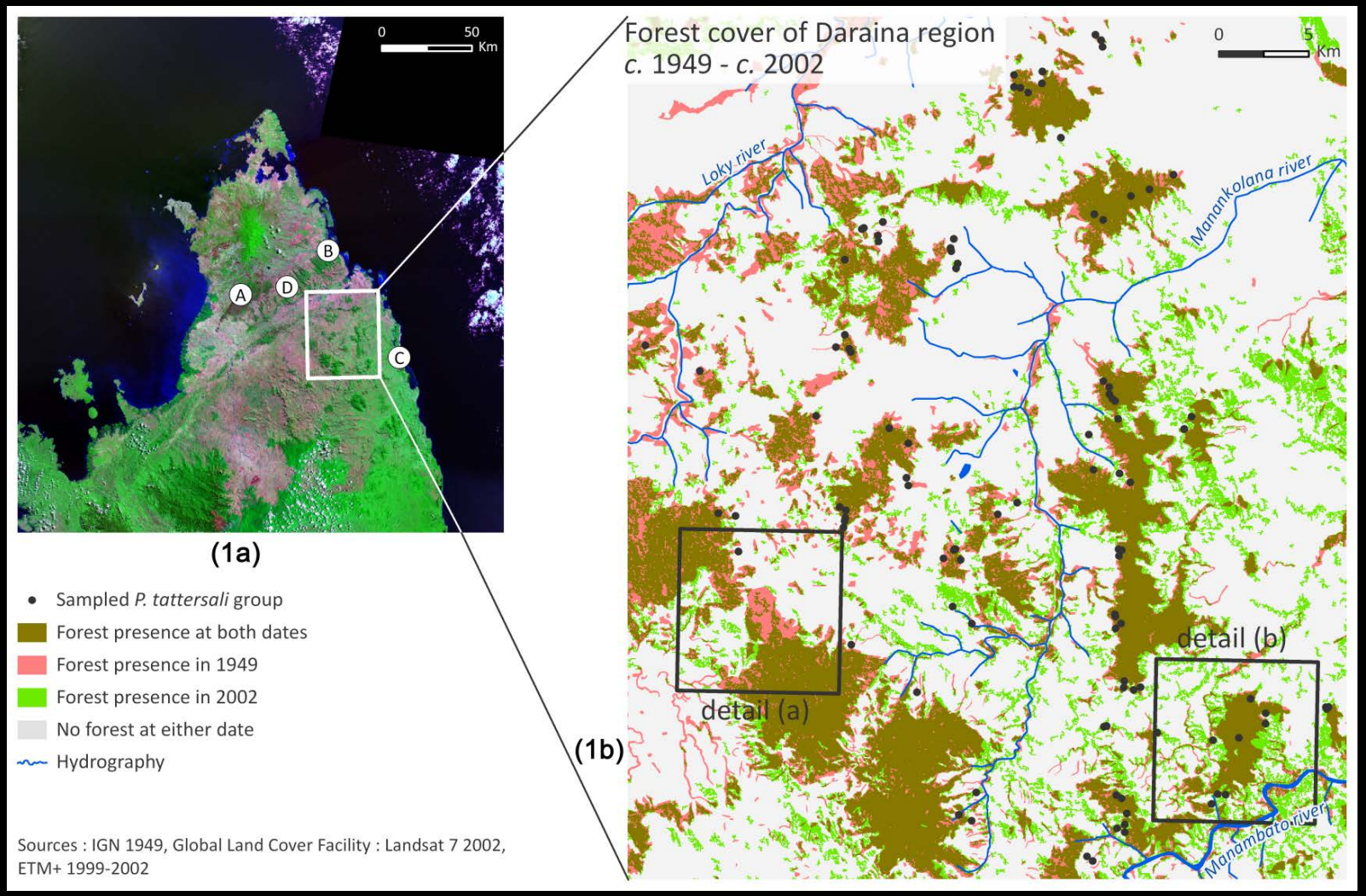
2. When did it happen?
   - H1: in the last 100 years (recent human pop increase)
   - H2: 100 - 1000 years ago (first “real” demographic impact)
   - H3: 1000 - 2000 years (human arrival)
   - H4: 2000 - 10,000 years (Holocene droughts)?



Most likely period for the start of the population decrease

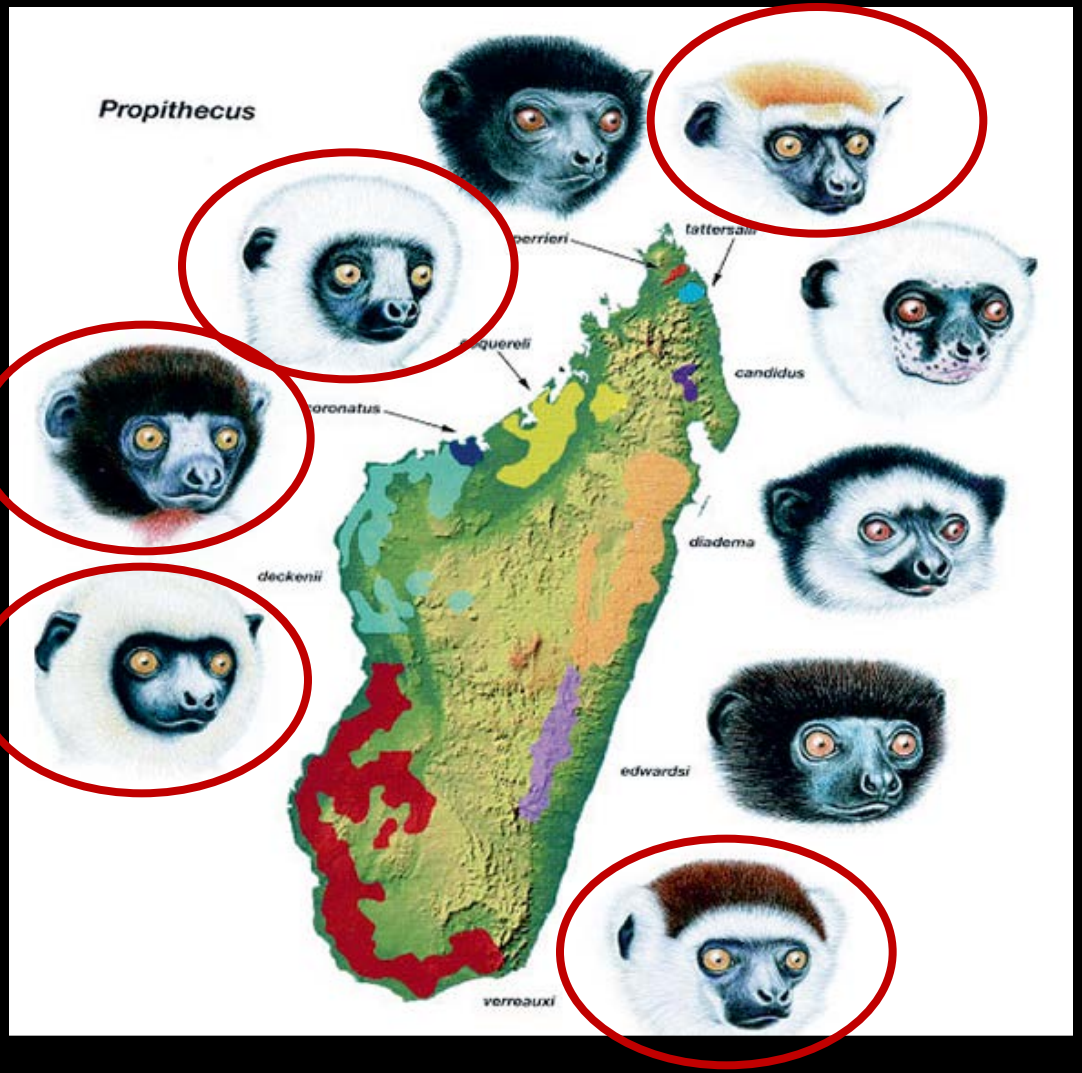


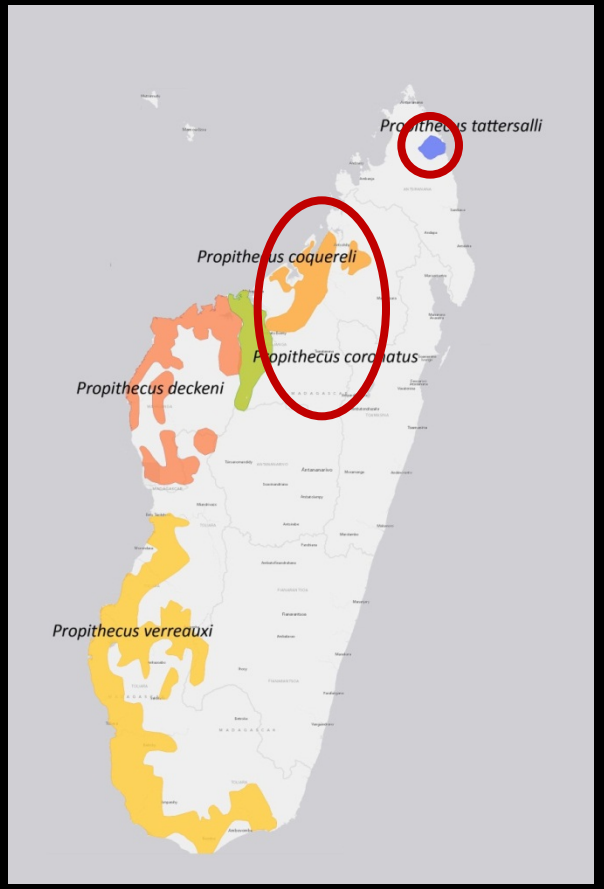
EVOLUTION OF THE FOREST COVER IN DARAINA



Xavier Amelot, Julie Pierson

Why is the golden-crowned sifaka so far away from its sister species ?





CONCLUSIONS AND PERSPECTIVES

- Statistical and simulation-based inference is an active research field.

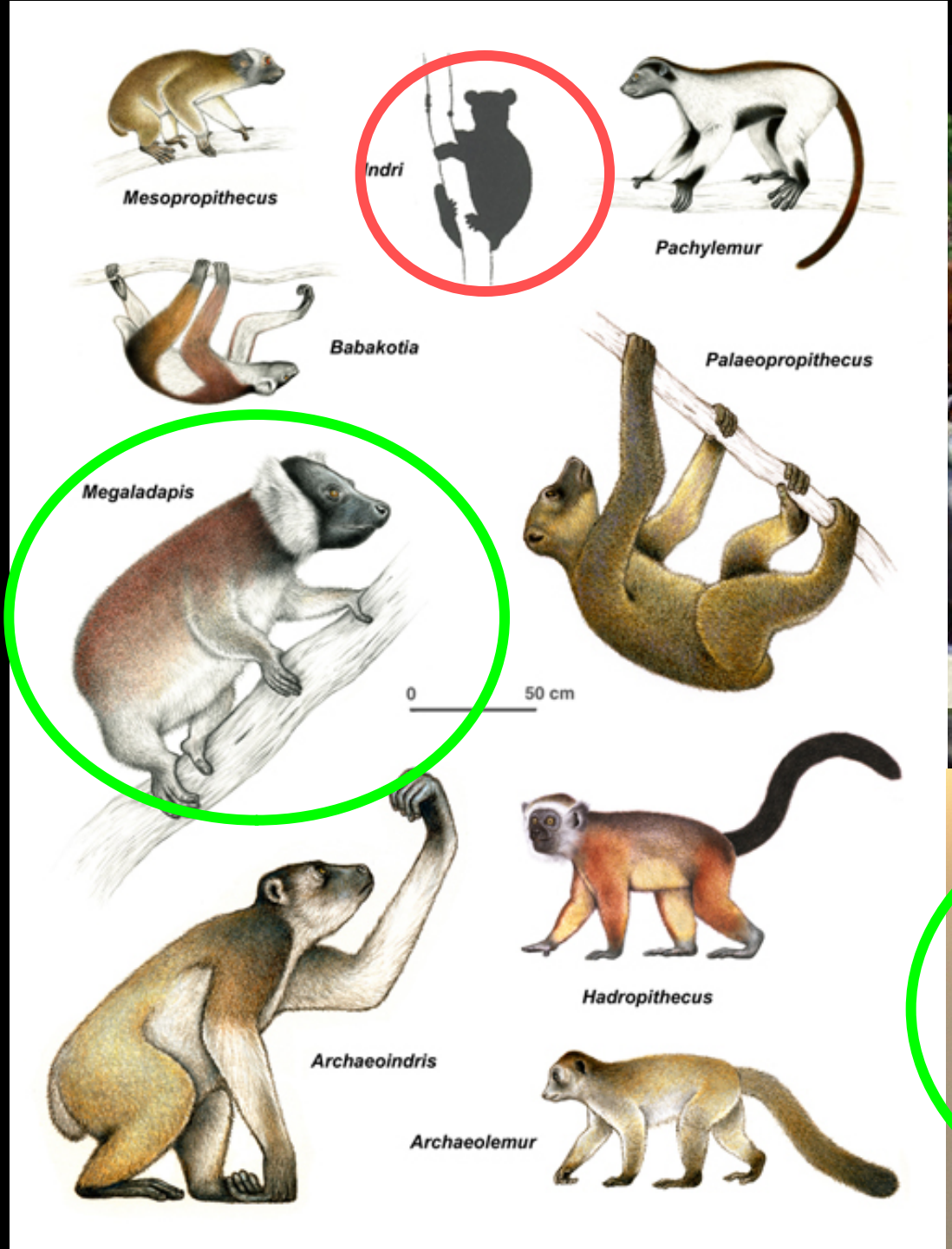
- While population genetics tended to ignore space, spatial appraches originating in ecology tended to ignore time (and evolution)

- How other aspects of population structure (social, spatial, asymetrical gene flow) should be integrated is less studied

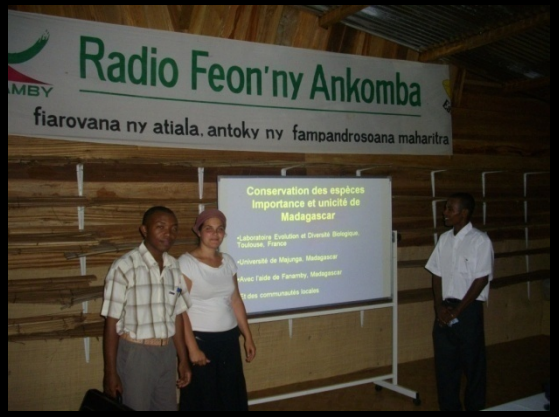
CONCLUSIONS AND PERSPECTIVES

Madagascar is a particularly interesting region:

- Recent human colonisation
- “Independent” evolutionary replicates
- Comparative approaches


Mesopropithecus
Indri
Pachylemur
Babakotia
Palaeopropithecus
Megaladapis
0
50 cm
Hadropithecus
Archaeoindris
Archaeolemur

LEMUR
unite



Anna Rozzi

Mélanie Barnavon, Angelika Beck, Barbara Le Pors, etc.

Brigitte Crouau-Roy Univ. Paul Sabatier, Toulouse, France

Lounes Chikhi CNRS and Univ. Paul Sabatier, Toulouse, France

Instituto Gulbenkian de Ciência, Oeiras, Portugal

Bárbara Parreira, Rita Rasteiro, Vitor Sousa Inst. Gulbenkian de Ciência, Portugal

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Mark Beaumont: Reading Univ., UK

Erwan Quéméré: Univ. Paul Sabatier,Toulouse, France

Pedro Fernandes: Bioinformatics Unit, IGC

Ed Louis: Omaha Zoo

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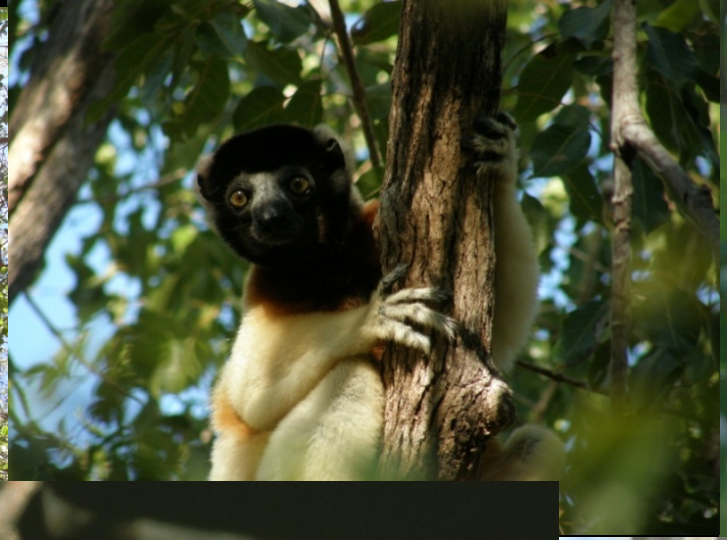
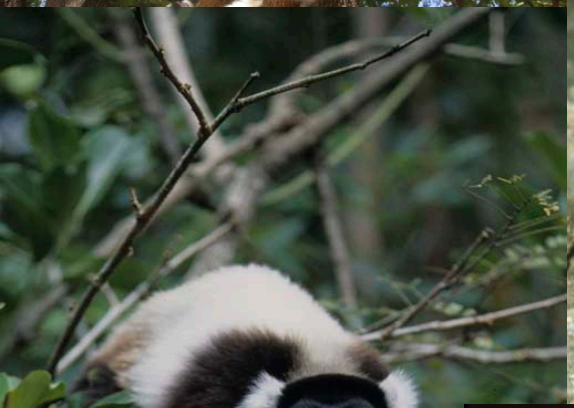
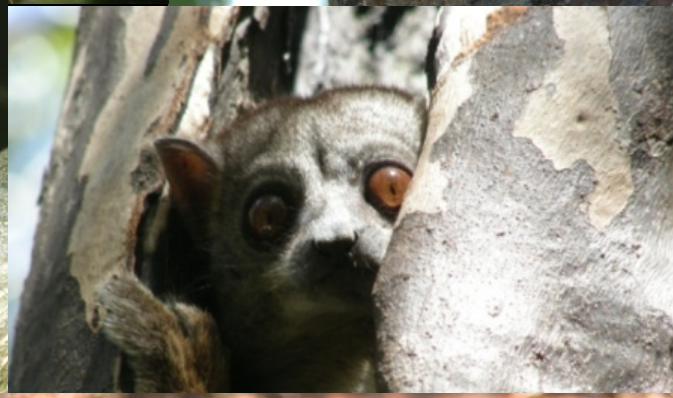


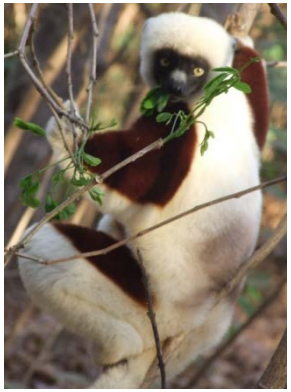




Related study species and corresponding distributions

3 species of sifaka

- *Propithecus tattersalli*
- *P. coquereli*
- *P. coronatus*



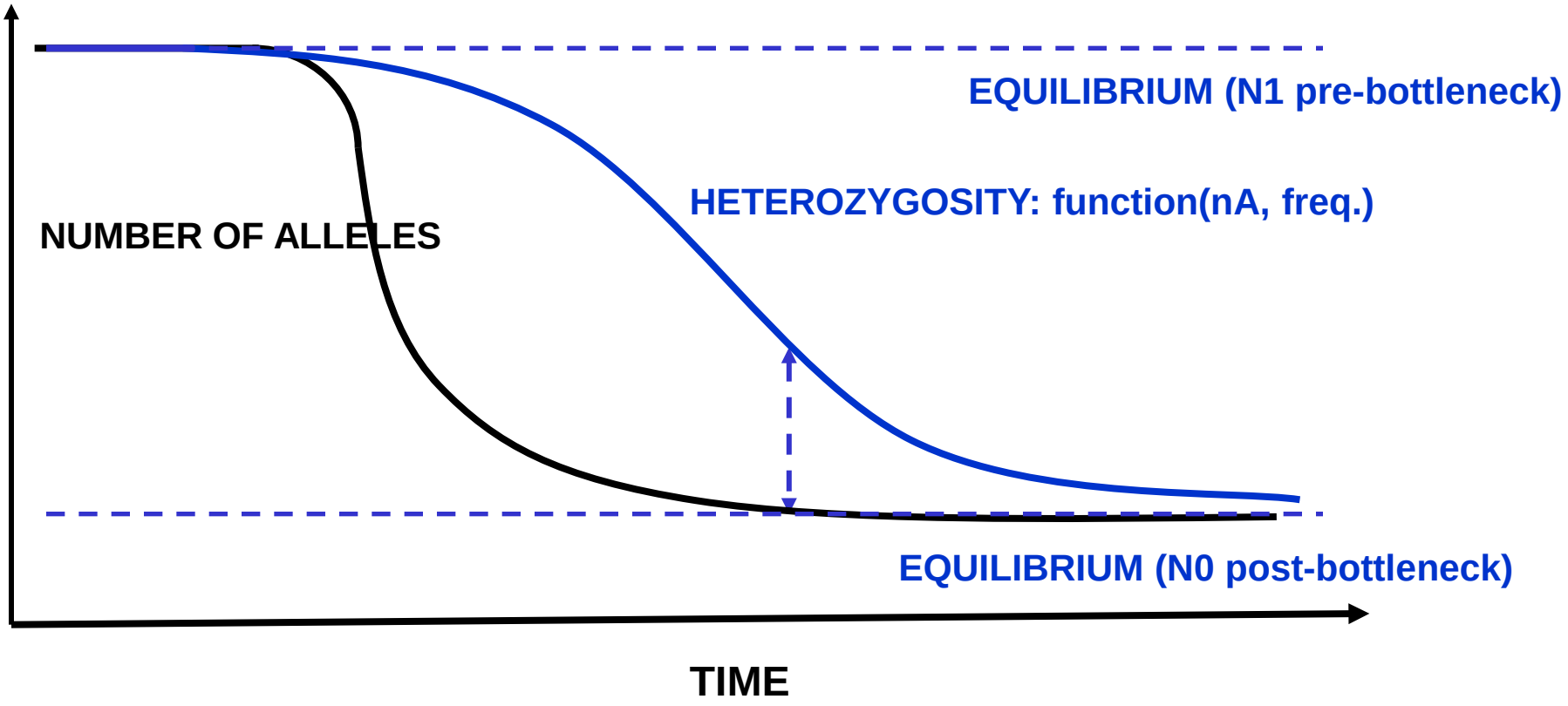
Habitat Fragmentation (and loss ?) in Daraina

44 000 ha of fragmented forest

Pictures: E. Quéméré

...nfluence of forest fragmentation on an endangered large-bodied lemur in northwestern Madagascar
Mathias Craul a,*, Lounes Chikhi b,c, Vitor Sousa c, Gillian L. Olivieri a, Andriatahiana Rabesandratana a,
Elke Zimmermann a, Ute Radespiel a
Genetic structure and signature of population decrease in the critically endangered freshwater cyprinid Chondrostoma lusitanicum
Vítor Sousa · Filipa Penha · Maria J. Collares-Pereira · Lounès Chikhi · Maria M. Coelho
From genetic diversity and structure to conservation: Genetic signature of recent population declines in three mouse lemur species (Microcebus spp.)
Gillian L. Olivieri a, Vitor Sousa b,c, Lounès Chikhi b,d, Ute Radespiel a,*

GENETIC DIVERSITY



DIFFERENT TEMPORAL DYNAMICS OF THE TWO MEASURES