Island biogeography in the context of climate change

Biogeography

What is biogeography?

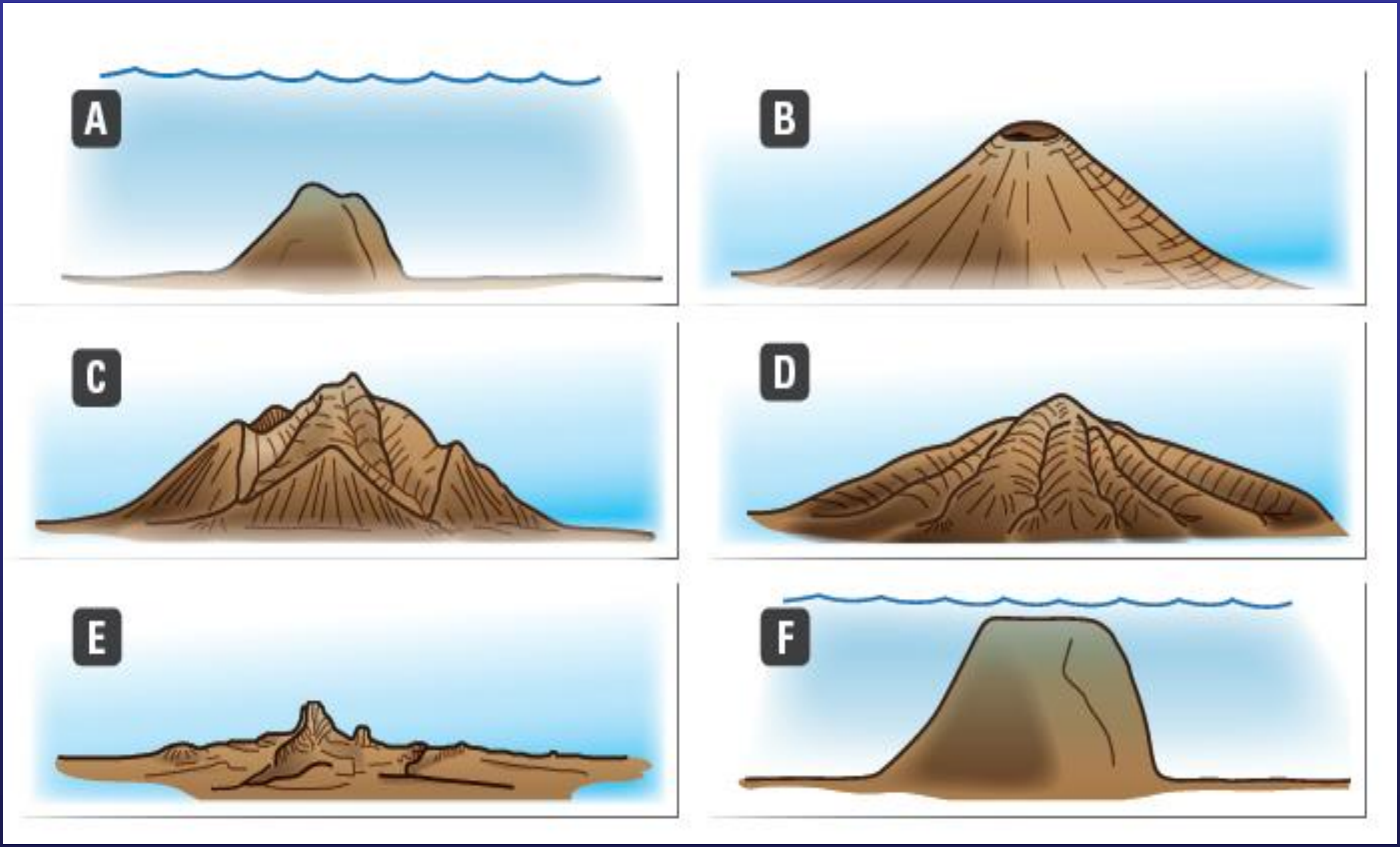
Science that study the distribution of species and ecosystems in geographic space through time:

- What ecological and evolutionary factors shape species distributions?
- How human activities have affected these distributions?

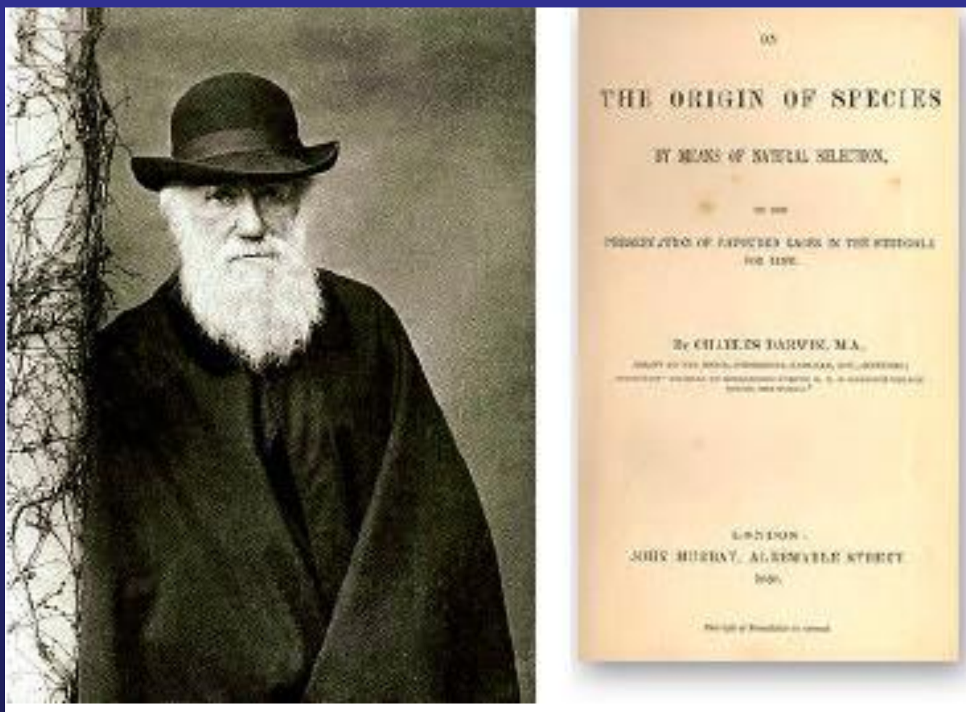
→Link with many other discpilines, including genetics, evolutionary biology, ecology, geography, geology, paleontology, and conservation biology

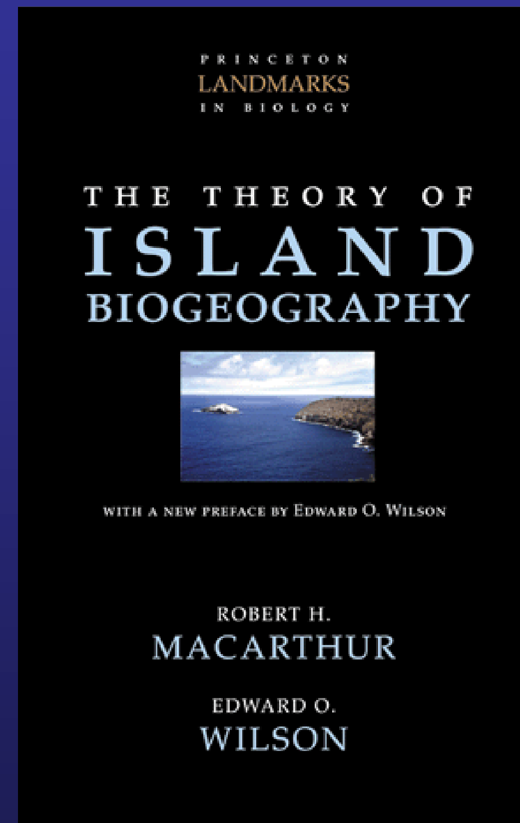
Island biogeography

Island biogeography



Oceanic islands are natural laboratories were some of the prominent theories in ecology and evolutionary biology have been developed

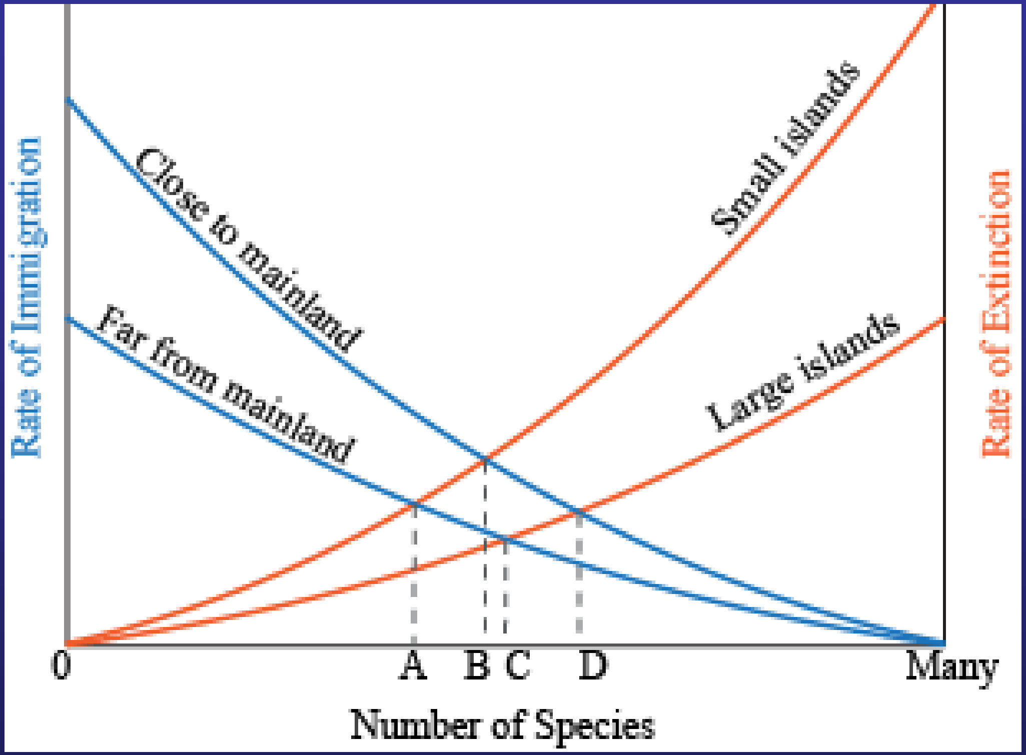




Darwin's theory: speciation and natural selection

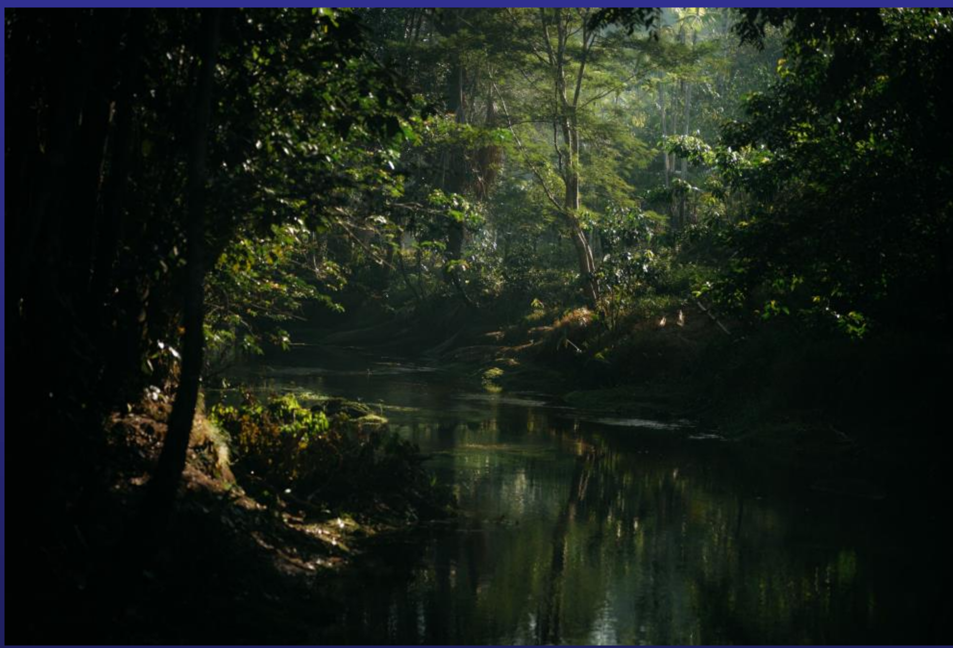
McArthur & Wilson: assembly of biological communities

Oceanic islands are natural laboratories were some of the prominent theories in ecology and evolutionary biology have been developed



The equilibrium theory of island biogeography (ETIB): species richness on islands reaches a balance between immigration and extinction (MacArthur and Wilson 1967)

General application of the island theory: metapopulation theory, fragmentation, and conservation



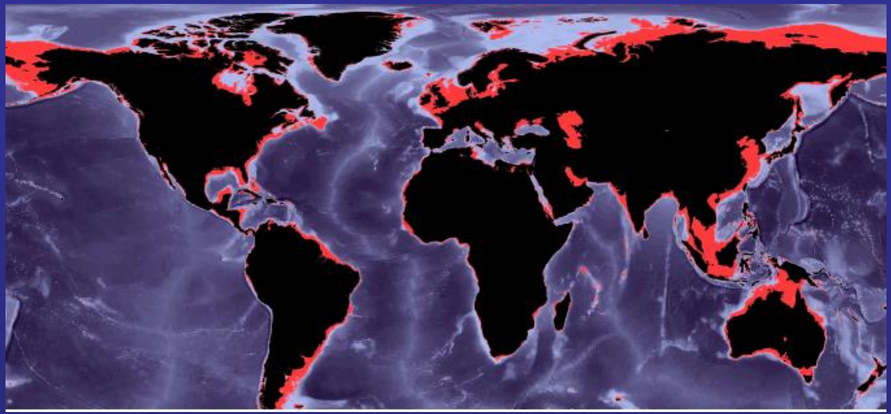
Fragmented landscapes as continental islands

Island and climate change

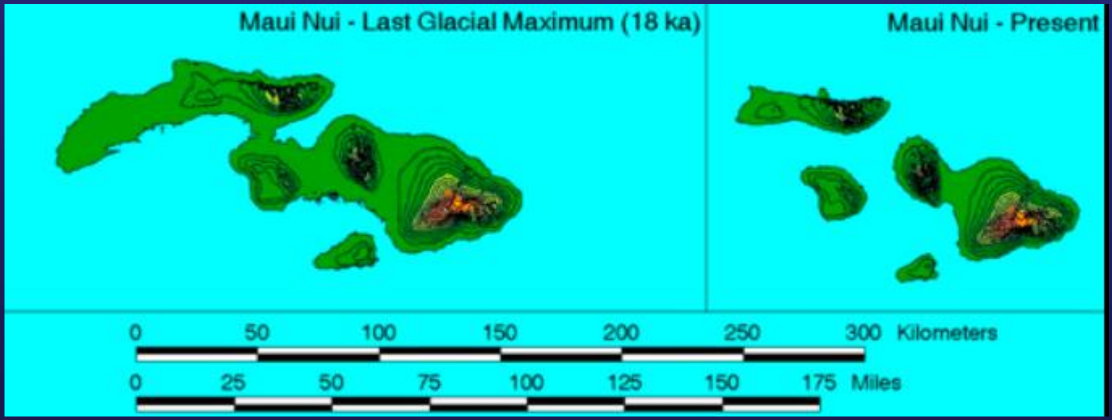
➔ ecological point of vue

How do the properties of the General Dynamic Model vary with climate change?

(Fernandez-Palacios et al. 2015. Global Ecol. Biogeogr.)



Outlines of emerged land at the last glacial maximum



Hawaii, outlines of the archipelago at the LGM and at present

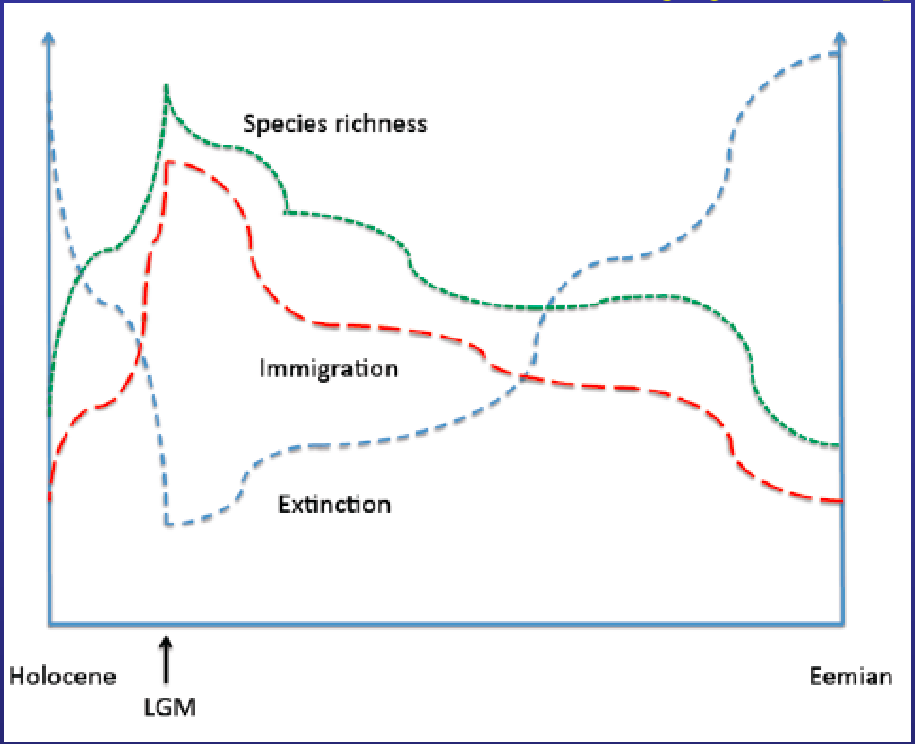
➔ Substantial increase of island area during glacial maxima

Increase in area on oceanic islands in a glaciated world

Island or island group	Present area (sq. km)	LGM island	Aproximate LGM area (sq. km)	Times larger
Isabela, St. Cruz Fernandina, islets	*6270*	*Large Isabela*	*10 000*	*1.6*
Fuerteventura, Lanzarote, islets	*2500*	*Mahan*	*5000*	*2*
Maui, Lanai, Molokai (Hawaii)	*2884*	*Maui Nui*	*6000*	*2.1*
Boavista (Cape Verde)	*600*	*Boavista Bank*	*2700*	*4.5*
Porto Santo (Madeira)	*65*	*Porto Santo Bank*	*250*	*5*
Rodrigues (Mascarenes)	*109*	*LGM Rodrigues*	*1200*	*11*
St. Martin, Anguilla, St. Barthelemy (Lesser Antilles)	*200*	*St. Martin Bank*	*6000*	*30*
Seychelles	*220*	*Granitic Seychelles*	*40 000*	*180*

➔ Increased carrying capacity and immigration rates (target area effect) and decreased extinction rates (ETIB)

Key properties of oceanic islands during glacial periods



Expected variation of immigration, extinction and species richness on oceanic islands since the late Pleistocene

Glacial periods: 🡅 area 🡇 isolation:
- 🡇 Extinction (EMIB and rescue effect)
- 🡅 Immigration (EMIB and target area effect)

Inter-glacial: 🡇 area 🡅 isolation
- 🡅 Extinction (EMIB and rescue effect)
- 🡇 Immigration (EMIB and target area effect)

➔ The island biogeography theory projected into the past suggests that islands might have played key roles as refugia during the Ice Ages (Fernandez-Palacios et al. Global Ecol. Biogeogr. 2015)

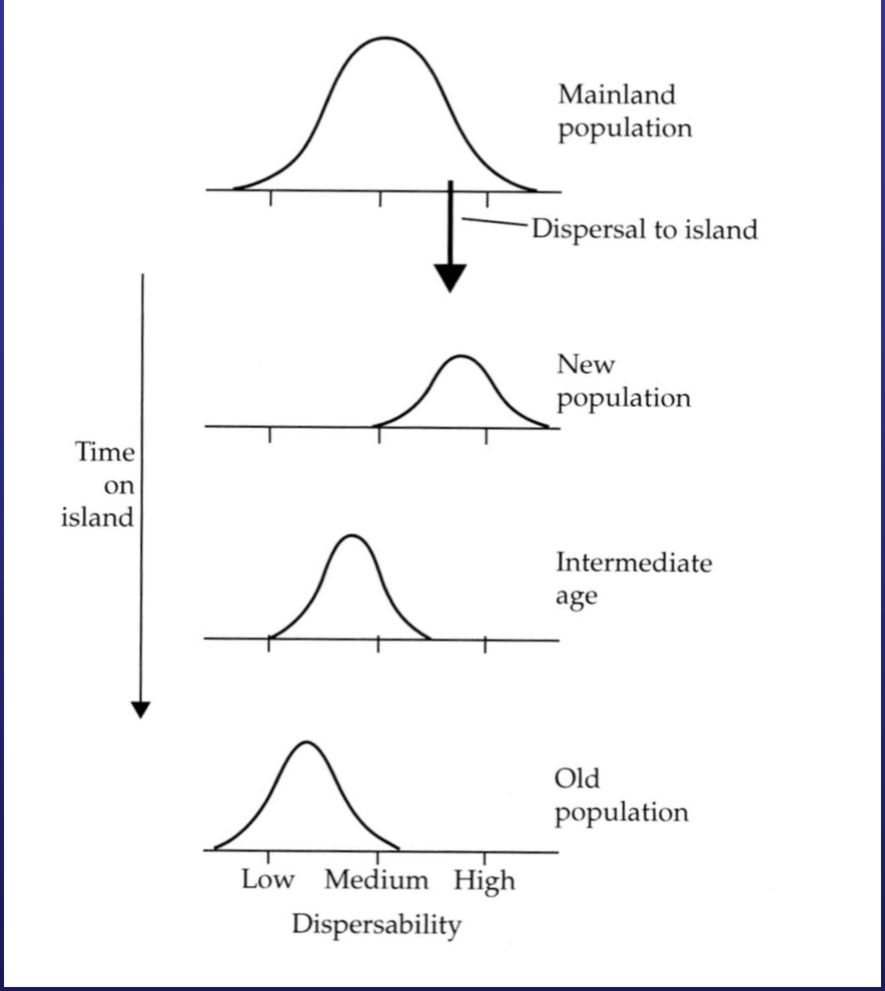
Island syndromes

➔ evolutionary point of vue

Is this dynamic perception of oceanic islands compatible with the characteristics of island species?

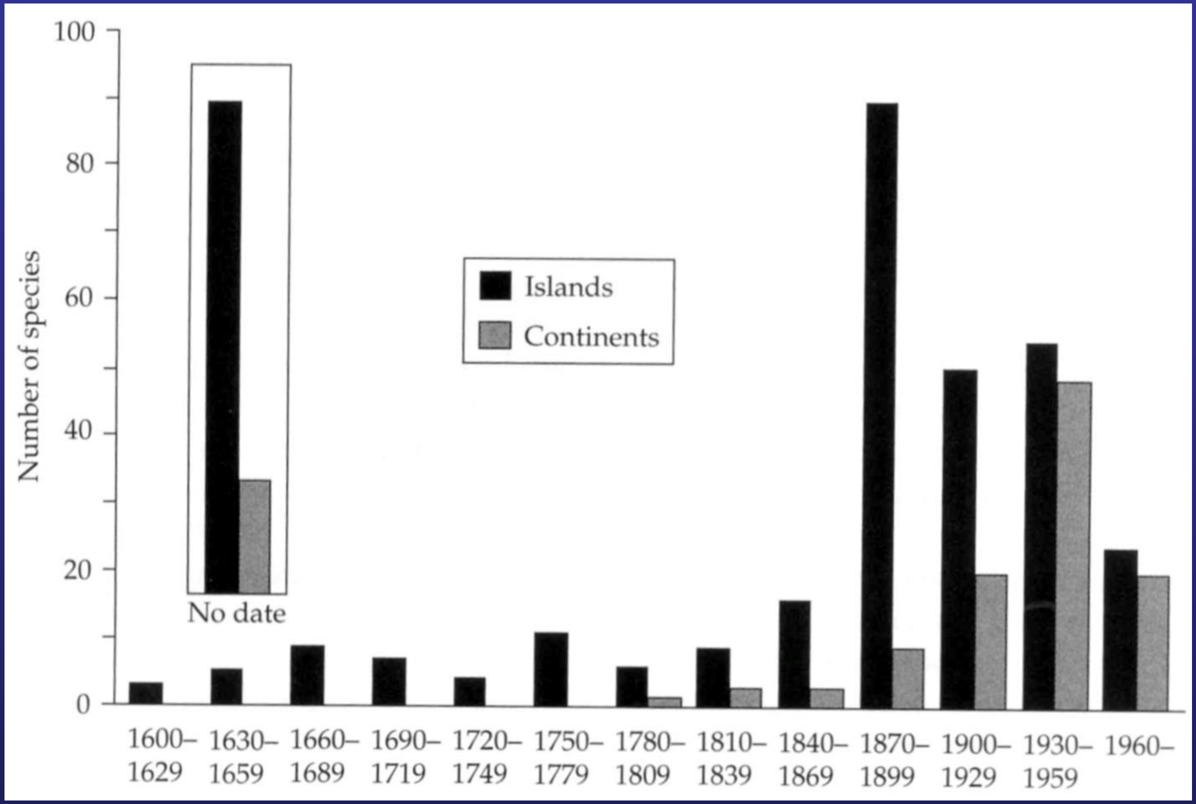
Geographic isolation and absence of competition and predation: the loss of defensive and dispersal capacities on oceanic islands

Theory predicts that oceanic island species progressively lose their dispersal power



Theoretical evolution of dispersal ability in island-colonizing populations

- **Loss of dispersal ability**
- **low adaptive potential associated with the low genetic diversity owing to the founding event**



Extinction series of mollusc, bird, and mammal species on islands vs continents (Whittaker & Fernández-Palacios 2007. Island Biogeography, 2nd ed.)

➔ **Increased sensitivity to human disturbance and associated extinction rates**

Oceanic islands have therefore been considered as evolutionary dead-ends

"*taxon can undergo alternate expansion and contraction, with or without speciation, for an indefinite period of time; it can shift its headquarters from a large land mass to a smaller one but not in the opposite direction*" (Wilson, 1969)

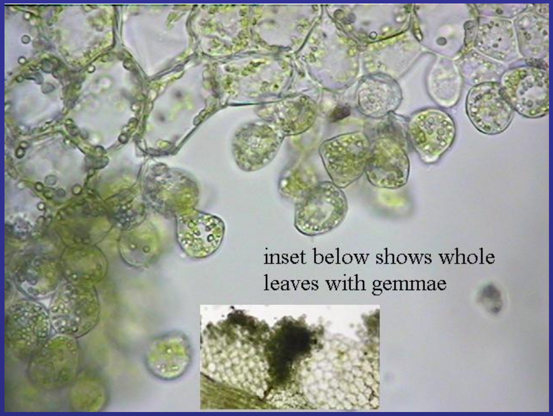
A paradigm that has been recently challenged (Bellemain & Ricklefs 2008 Trends Ecol. Evol.) and may not apply to organisms with high dispersal capacities

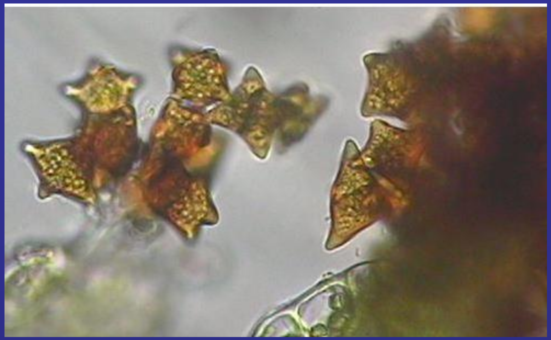
Our case of study

➔ reconciliate ecological and evolutionary point of vue

Using bryophytes for testing the expectations of the island biogeography model in the context of climate change

Whitaker & Edwards 2010 Science (http://) www.sciencemag.org/content/suppl/2010/07/20/329.5990.406.DC1/1190179s2.mov

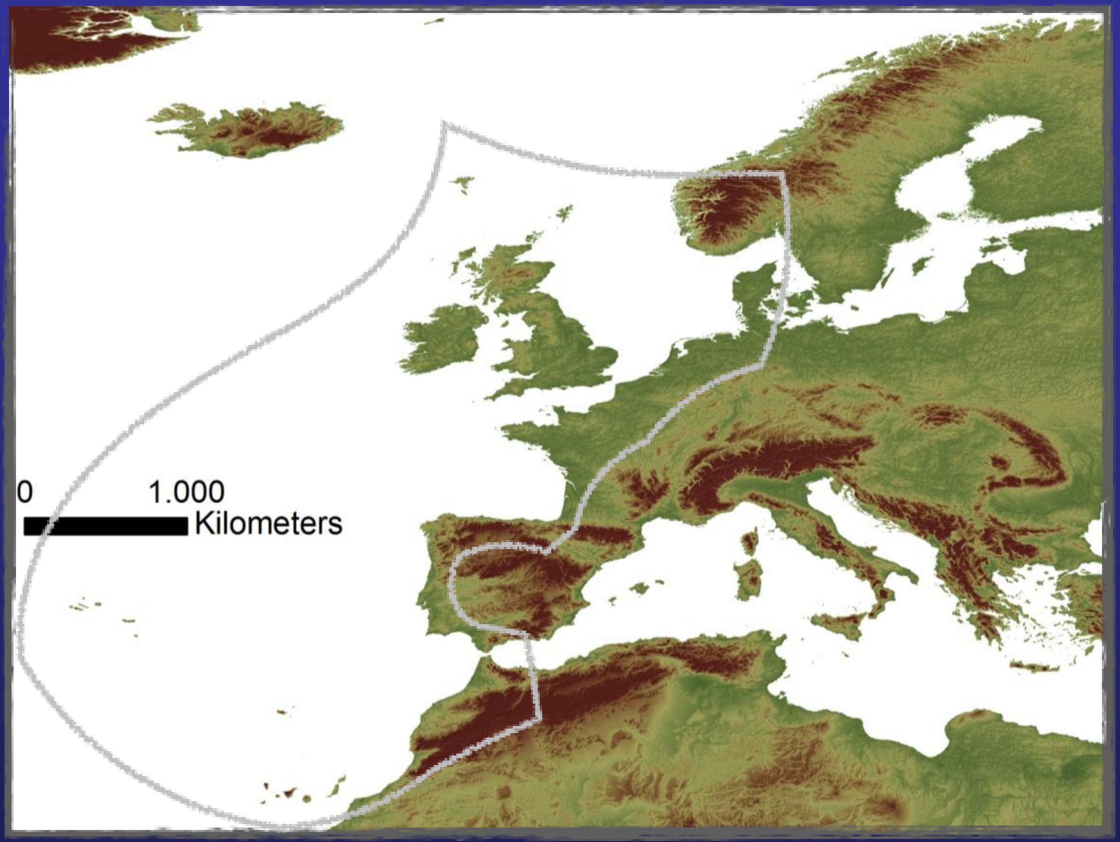




Dispersal by spores and a wide range of vegetative gemmae unparalleled in other land plants

- Spores can be deposited over extensive areas, at rates high enough to drive colonization patterns (Lönnell et al. 2014 Ecography)
- 1% of the regional spore rain has a trans- or intercontinental origin (Sundberg 2013 Ecography)
- Bryophytes are expected to migrate quickly as a response to global change, and hence, benefit from the enhanced conditions on islands during the LGM

Testing the role of oceanic islands for continental biodiversity

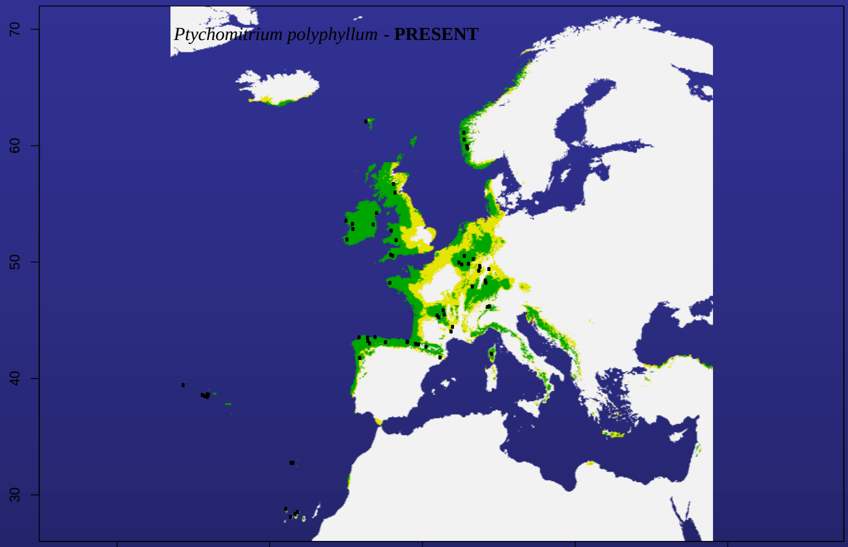


The Atlantic fringe of Europe and the North Atlantic islands

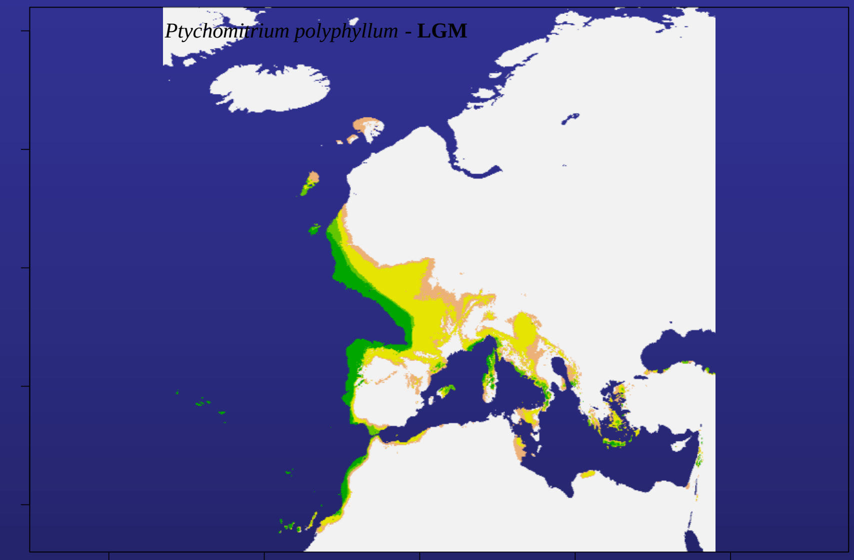
First study

➔ ecology

Using Species Distribution Models to test the glacial refugium hypothesis



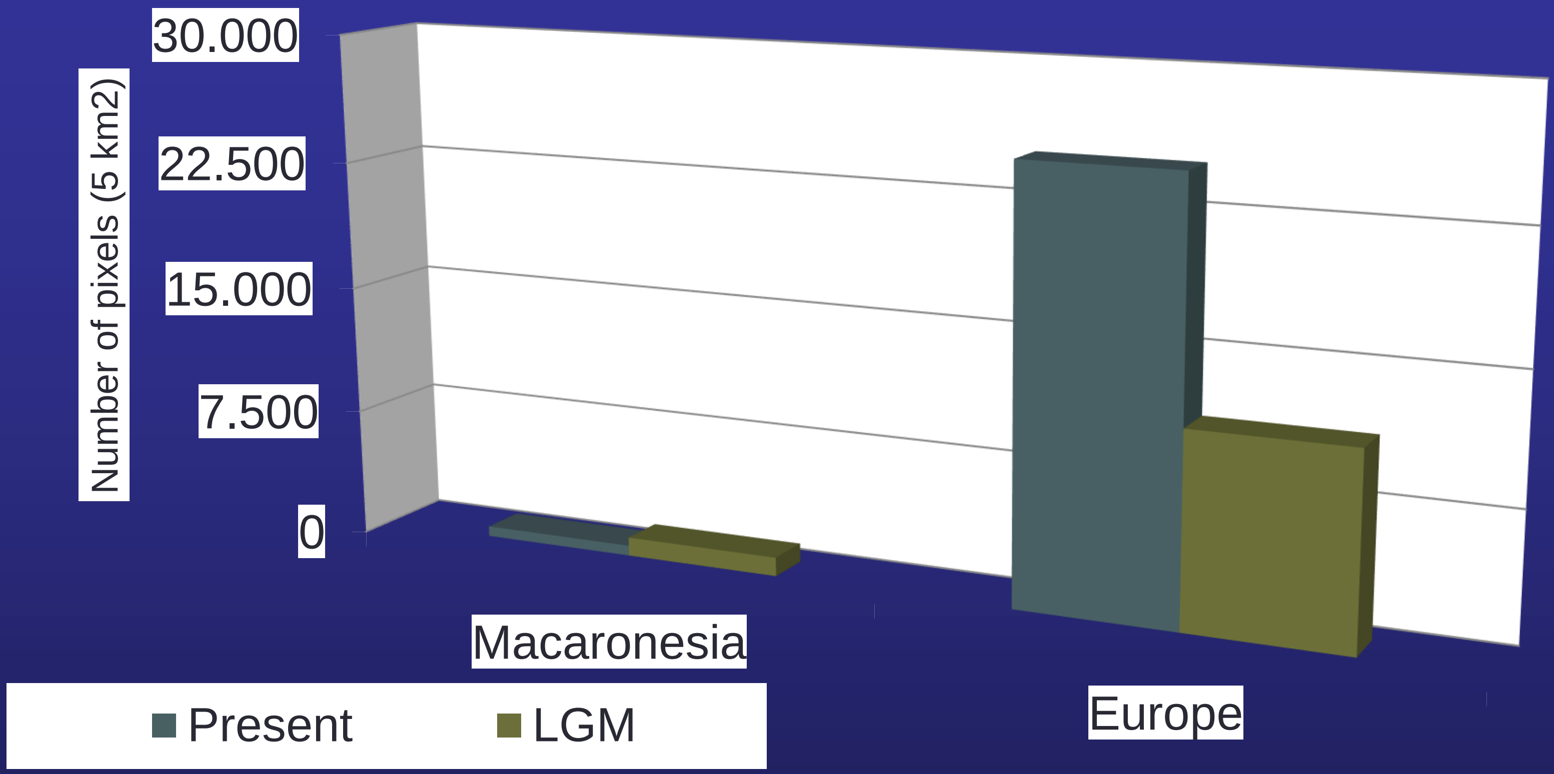
Calibrating SDMs from species distributions under extant climate conditions



Projecting the model onto LGM climate layers

Decreasing suitability

Using Species Distribution Models to infer the extant of suitable areas on islands and on continents at the LGM and at present time



Average number of climatically suitable pixels of 5 sq.km in continental Europe and NE Atlantic islands at the LGM and at present

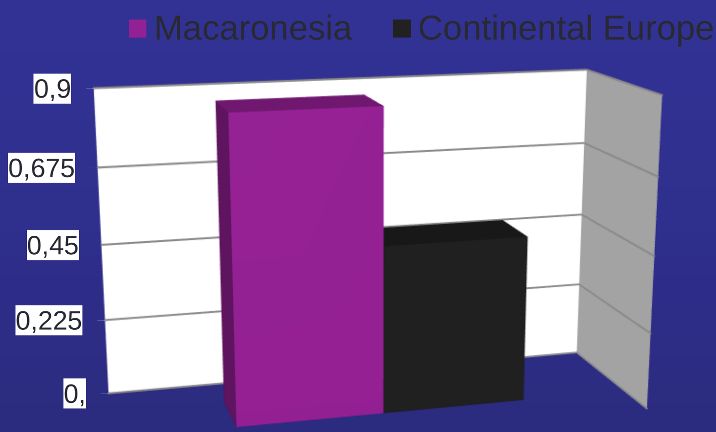
➔ Although the extent of suitable climate at the LGM was larger than today on islands, areas with a suitable climate were much larger on continents

➔ Expecting higher genetic diversity on continents than on islands

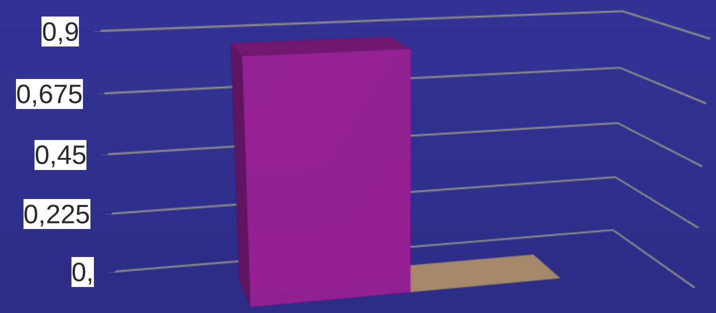
Second study

➔ genetics

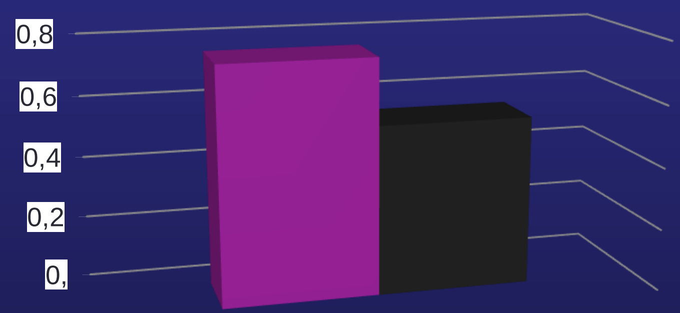
Patterns of genetic diversity on islands and continents



Sematophyllum demissum



Ptychomitrium polyphyllum



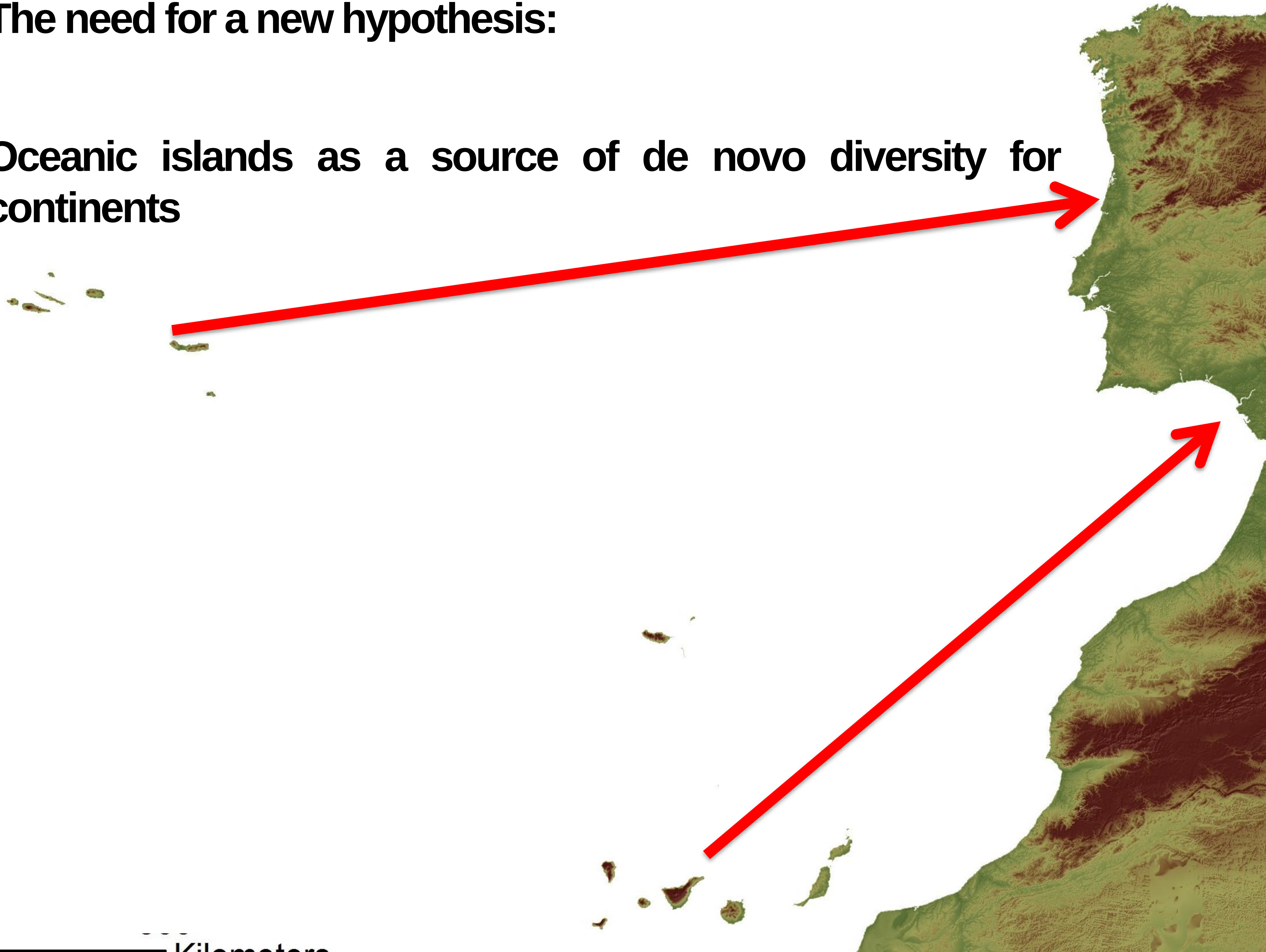
Saccogyna viticulosa

Expected heterozygosity in NE Atlantic islands and continental Europe

➔Conflicting signal between ecological estimates of climatically suitable areas and patterns of genetic diversity on islands and on continents

The need for a new hypothesis:

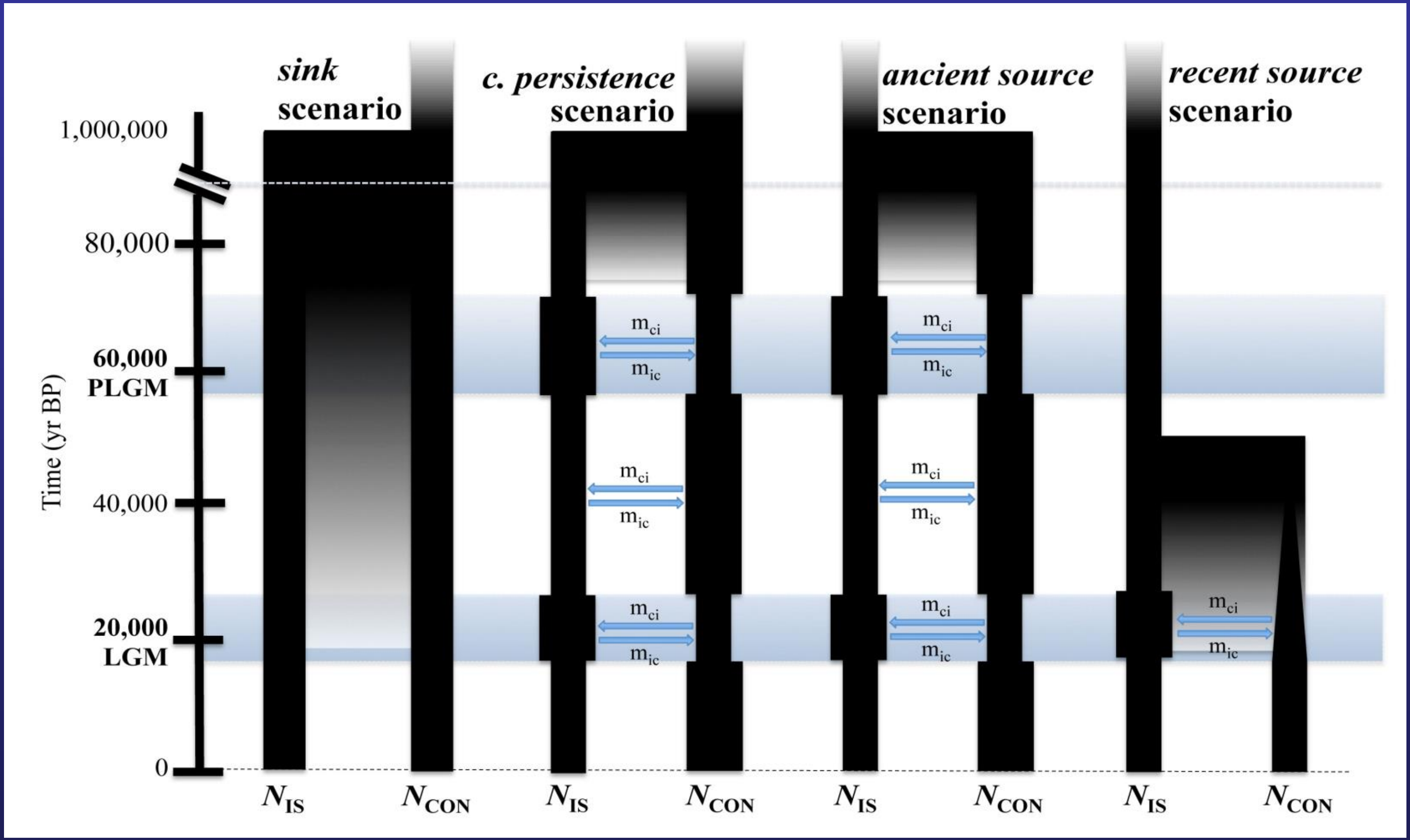
Oceanic islands as a source of de novo diversity for continents



Third study

➔ molecular phylogeography

Did oceanic islands play the role of sinks, refugia for back colonization, or source of *de novo* biodiversity?



Contrasting four demographic scenarios

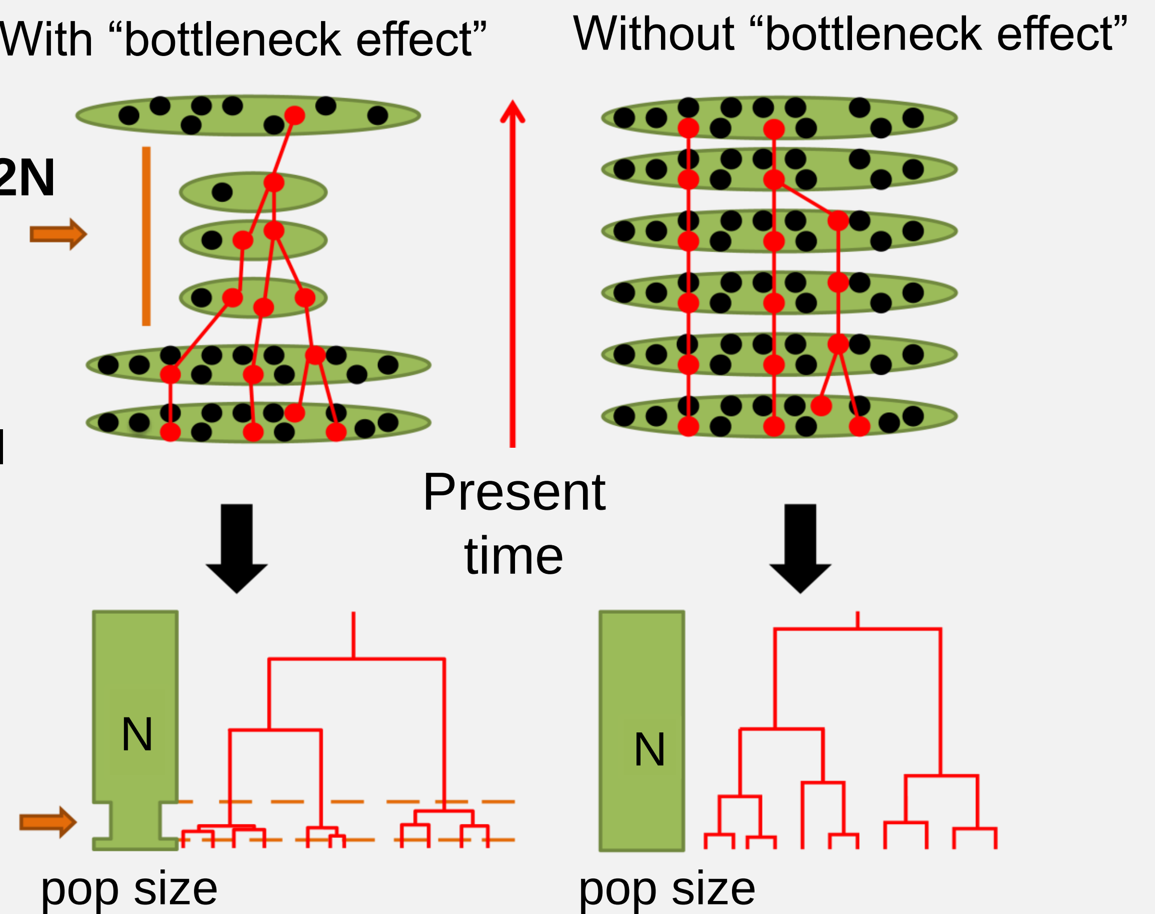
An Approximate Bayesian Computation (ABC) approach based on the coalescent model

A quick primer on the ABC

1. Generating genealogies under the constraint of different scenarios by coalescence

Demographic scenarios influence tree topology

Proba_coal (n, N) ≈ n(n-1)/2N



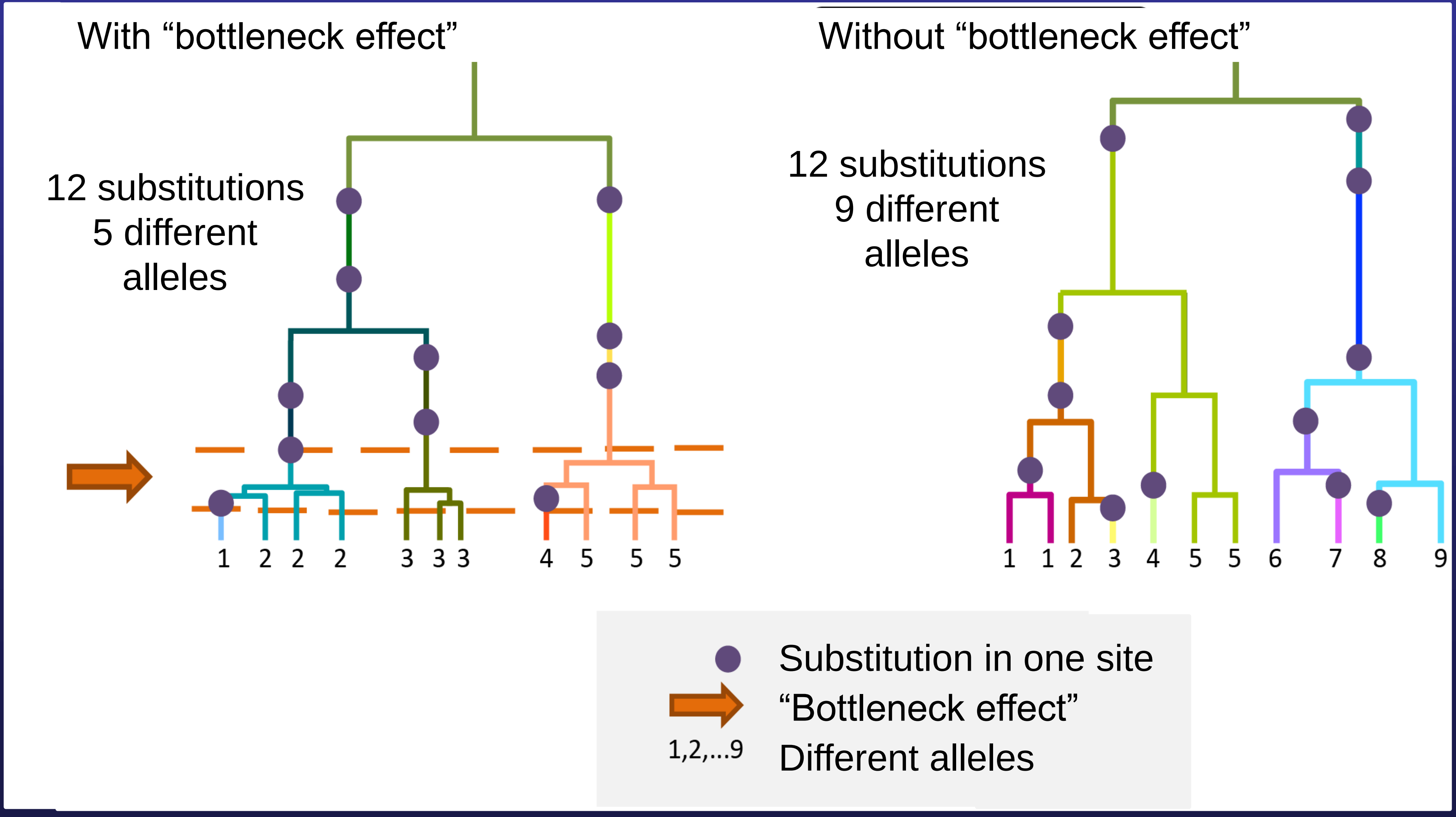
Non-sampled individual

Sampled individual

“Bottleneck effect”

2. Mapping mutations on the genealogies using substitution models and simulating DNA sequence data that fit with the demographic scenarios

Tree topology influence sequences

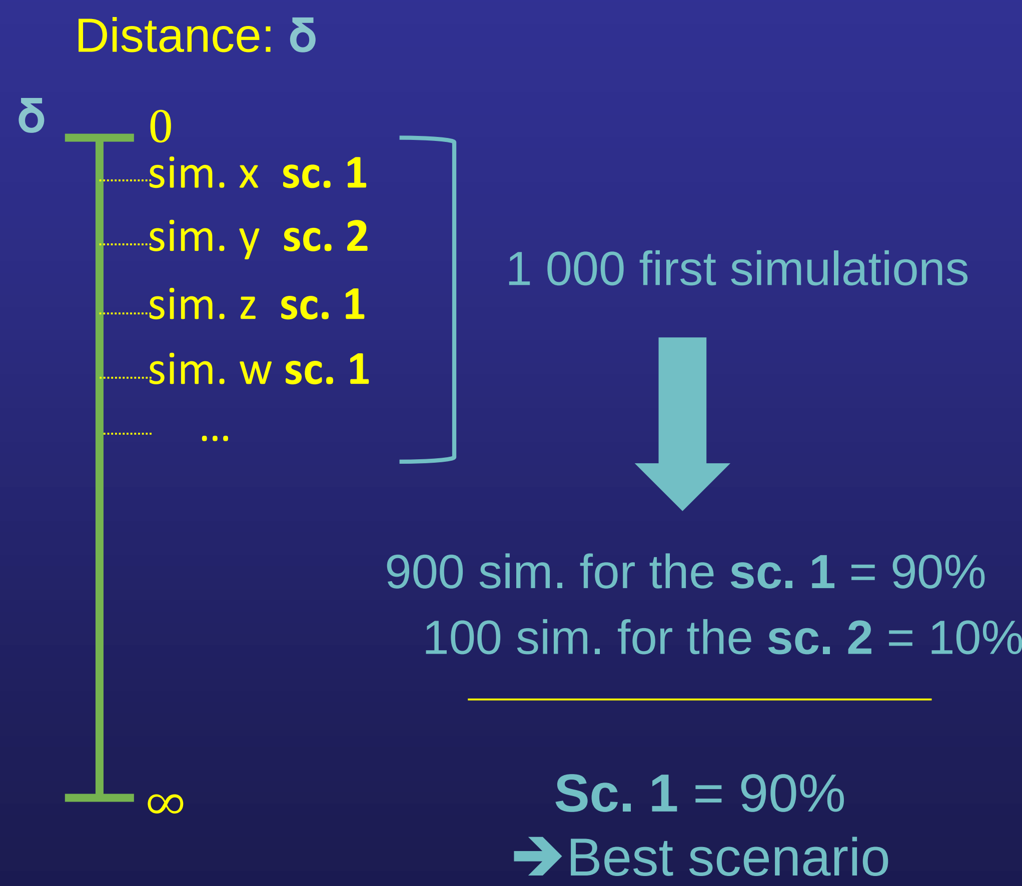


3. Contrasting the simulated data with the observed data

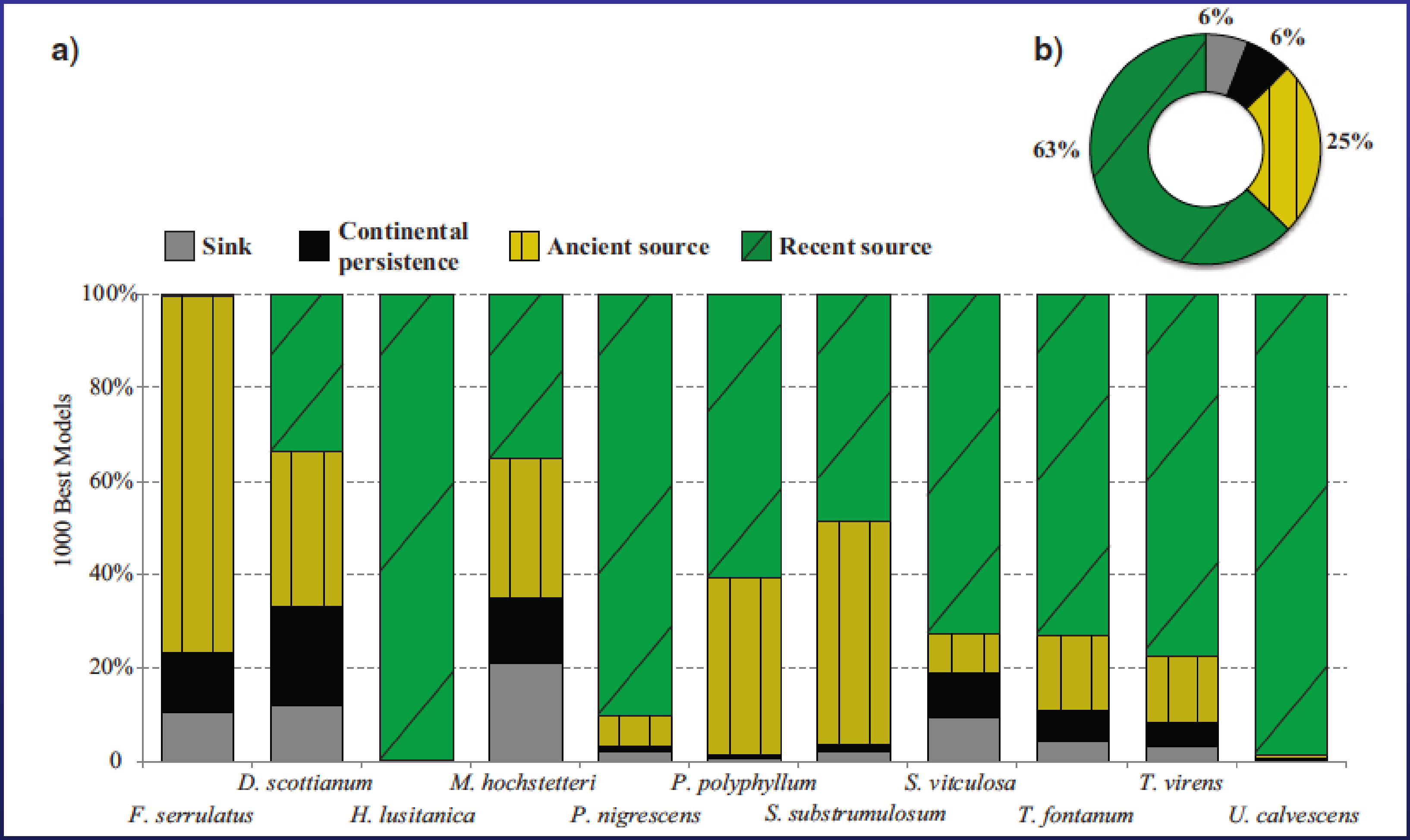
- **Computing the distance between each theroretical simulation and the observed data using summary statistics**

- **Determining, among the 1,000 best simulations, the proportion of simulations produced by each demographic model**

- **Select the best scenario**

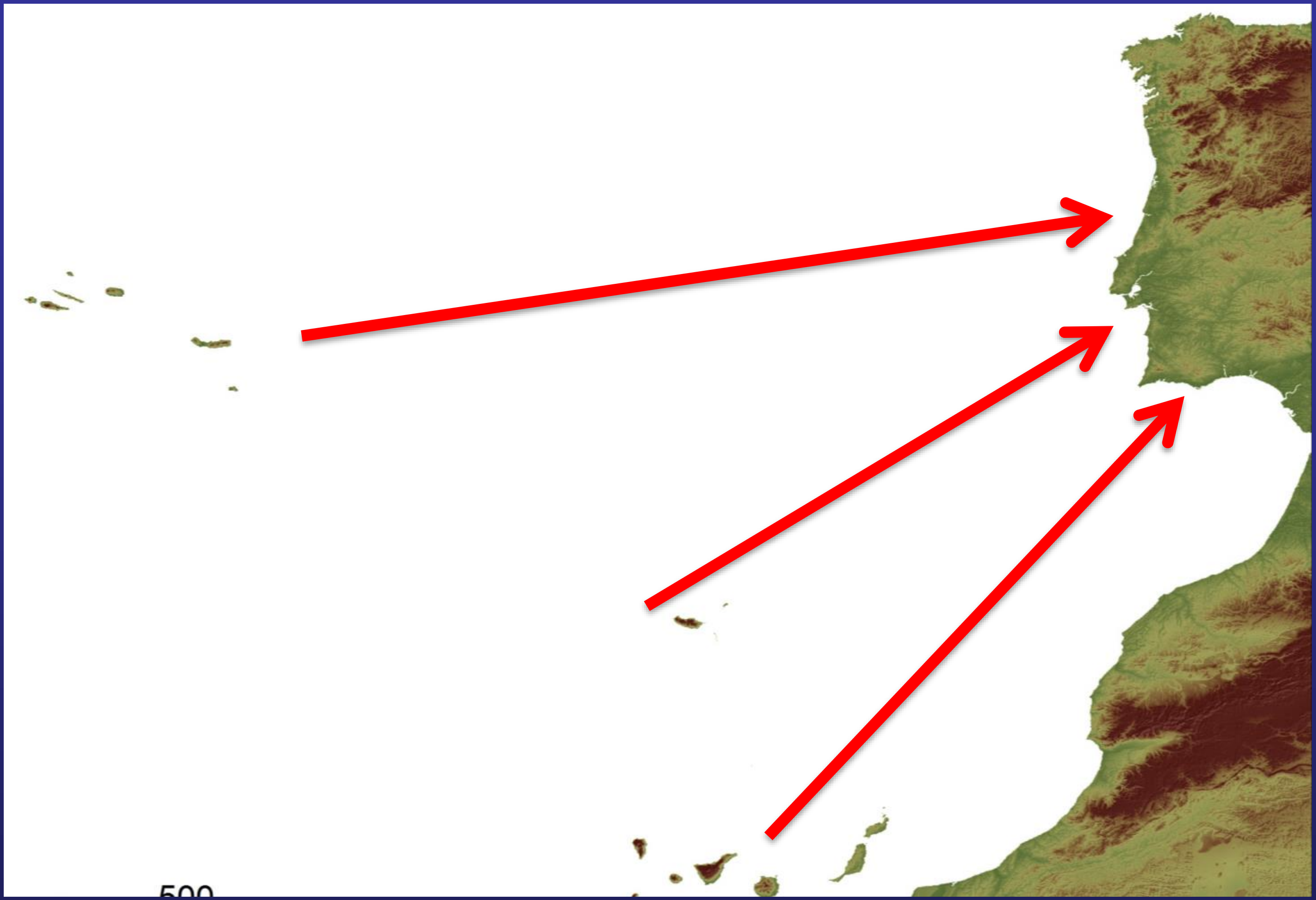


Support for demographic models inferred by ABC in the Atlantic bryophyte flora



Partitioning of the 1,000 best simulations

➔ The summary statistics observed in the 11 species are closer to those derived from simulated data that fit with the source scenario (88% of 11,000 simulations), and in particular, the recent source scenario (Patiño et al. Syst. Biol. 2015)

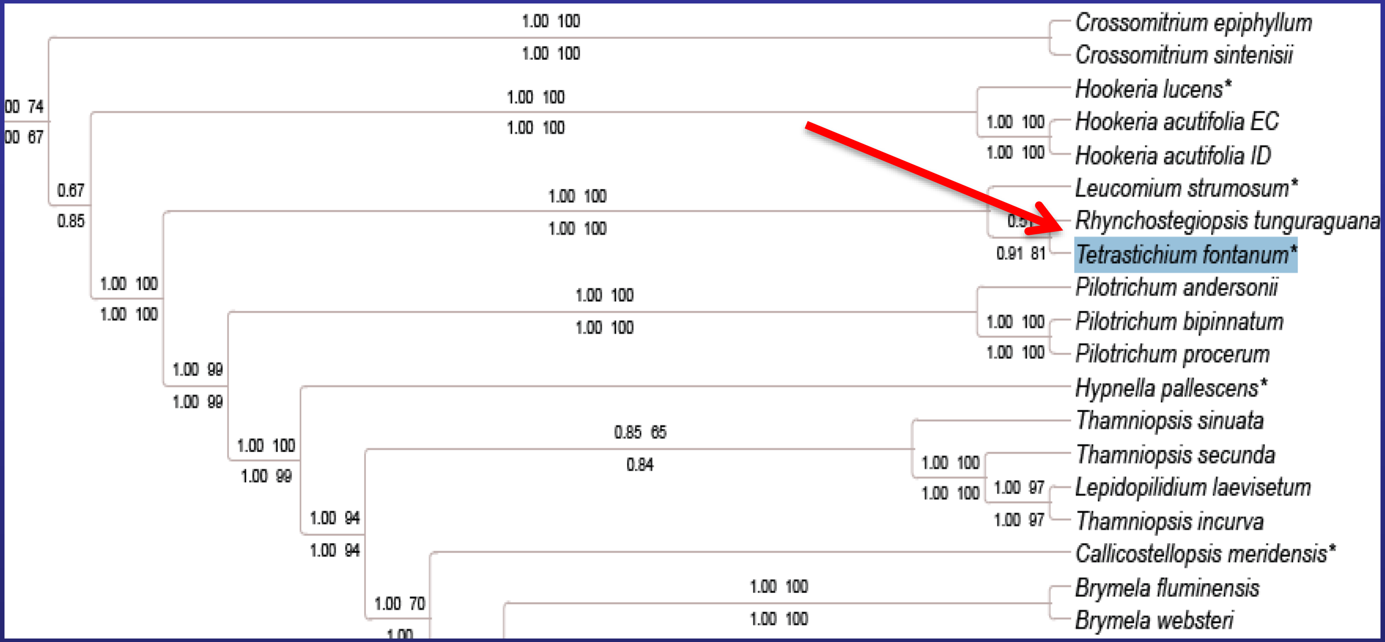


- ➔ In complete contrast with the view of oceanic islands as dead-ends, they instead display a role as reservoirs of novel biodiversity for continents.
- ➔ The bulk of the European Atlantic fringe flora was recently (≈ 18,000 yrs) colonized from islands, taking advantage of empty niche space following the glaciations

Fourth study

➔ phylogenetics

What happened before and what is the origin of the island flora?



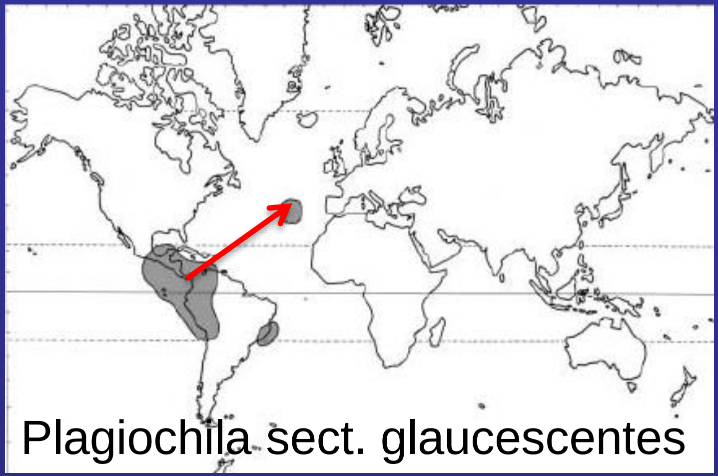
Neotropical clade

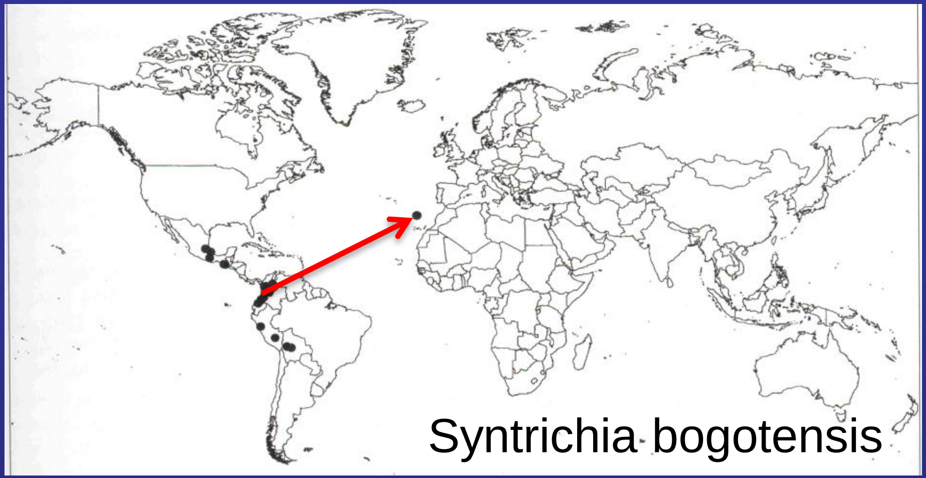
Neotropical clade

Focus on the phylogenetic position of *Tetrastichium* in the Moss Tree of Life, nested within a Neotropical clade of Hookeriales

➔ A (Neo)tropical origin of the western European flora following a stepping-stone on islands

Consistency of the stepping-stone model with the existence of disjunct distribution patterns between the Neotropics and the NE Atlantic islands





3.4% of the moss flora and 7.9% of the liverwort flora of NE Atlantic islands are disjunct with tropical areas

… all candidates for immigration in Europe: Macaronesia is a gigantic custom office for tropical bryophytes in transit towards western Europe

Why is Macaronesia a mandatory stop-over for immigrants into western Europe?

- Niche pre-emption hypothesis
- Pre-adaptation of a tropical flora

Thank you for your attention