INTERNATIONAL CONFERENCE ON
MOUNTAINS AND CLIMATE CHANGE

Alpine butterflies: a challenge to understand the effects of climate change on biodiversity and ecosystems

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Why butterflies?

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- Butterflies are rigorously dependent upon both biotic and abiotic landscape features even at very tiny scales, since their ecology and evolution have been shaped upon their "*coarse-grained*" sensitivity to the environmental heterogeneity.
- Butterflies have short life cycles and thus react quickly to environmental changes. Their limited dispersal ability, larval foodplant specialisation and close-reliance on the weather and climate make many butterfly species sensitive to fine-scale changes.
- These features make butterflies a valuable indicator of biodiversity and provide an early warning system for biodiversity loss and other kinds of ecosystem changes.

As a result, they are now the best-monitored group of insects in the world.

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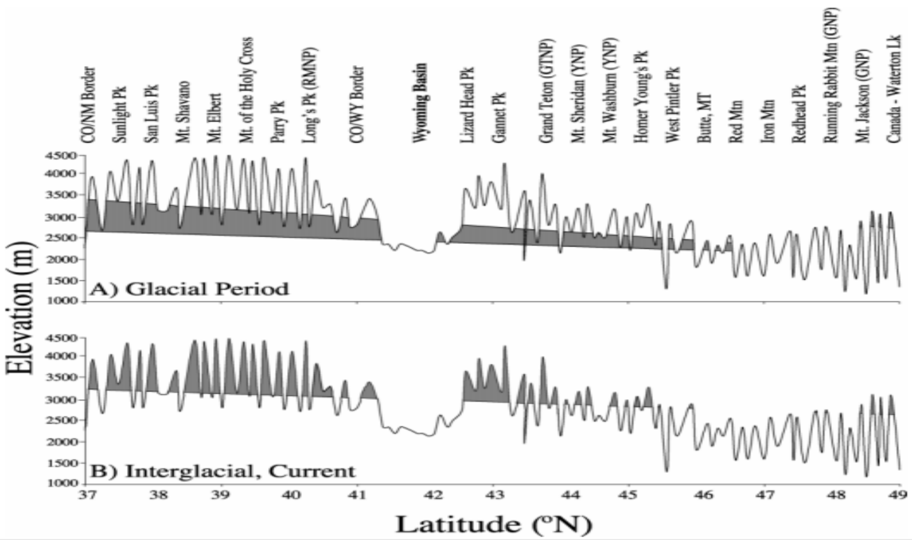
- The Pleistocene glaciations have had a major effect on plants and animals as most species’ distributions shifted in response to climatic fluctuations.

De Chaine & Martin(2005). American Journal of Botany. 92: 477- 486.



- Cold resistant alpine species were probably widely distributed during the last ice age with its cold and dry climatic conditions, and only became disjunct after the climate warmed and their habitats shifted pole-wards and to higher elevations in mountains (sky islands).

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- Many butterfly species inhabit previously glaciated areas in the Alps, Himalaya and other Eurasian mountains, as well as Rocky Mountains, and offer an ideal opportunity to study what effects the climate changes had on their demography and evolution.

Kunlun Shan, Qinghai, China

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- Biogeographical terms like"arctic-alpine" and "boreo-alpine" distributions have been applied to species showing today a disjunct or discontinuous distribution in arctic regions or high mountain areas, probably reflecting wider and more continuous distribution ranges during the cold periods.

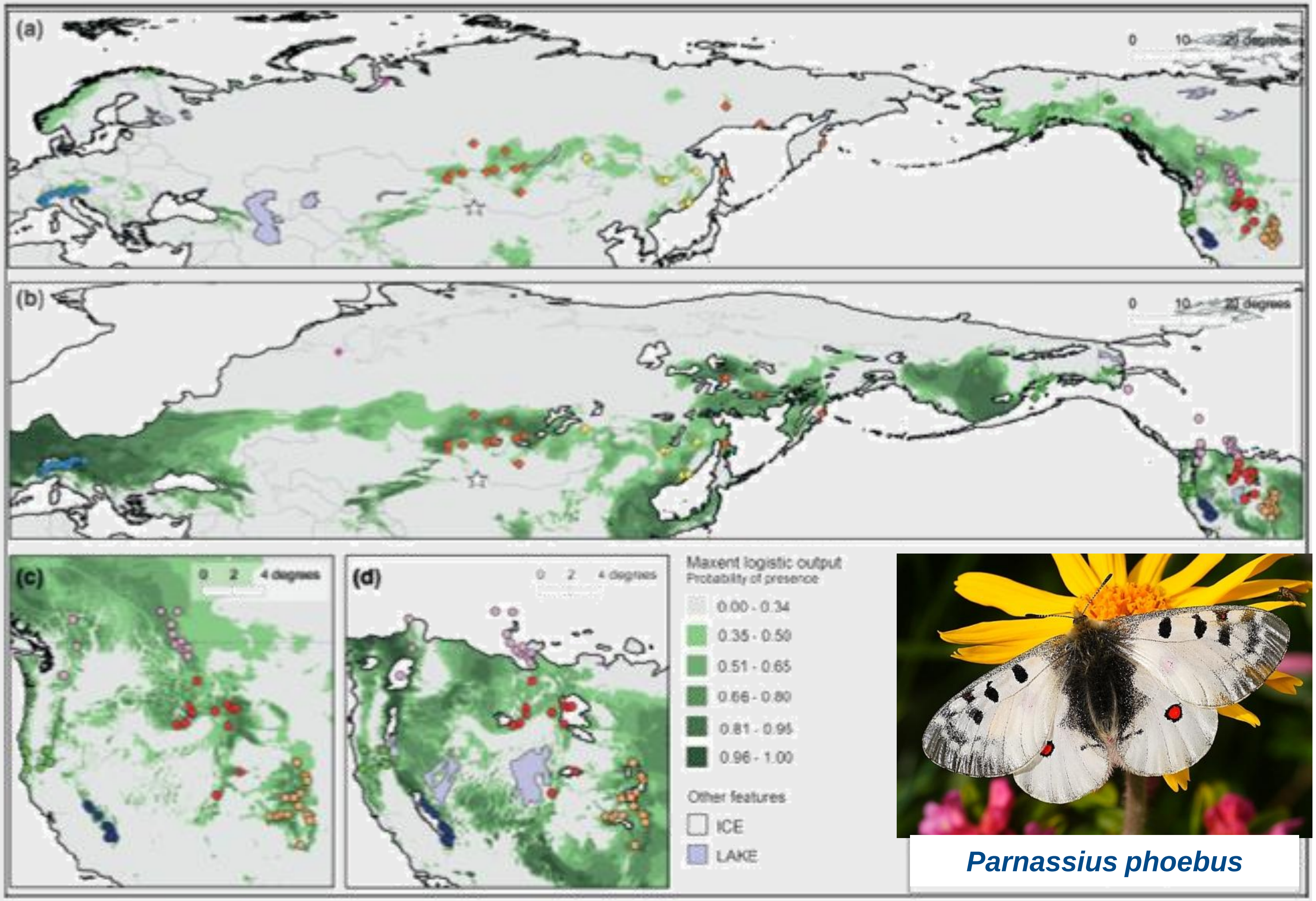
Boloria pales

Erebia epiphron

Parnassius apollo

Parnassius phoebus

- Large datasets of georeferenced occurrence data are available



Parnassius phoebus

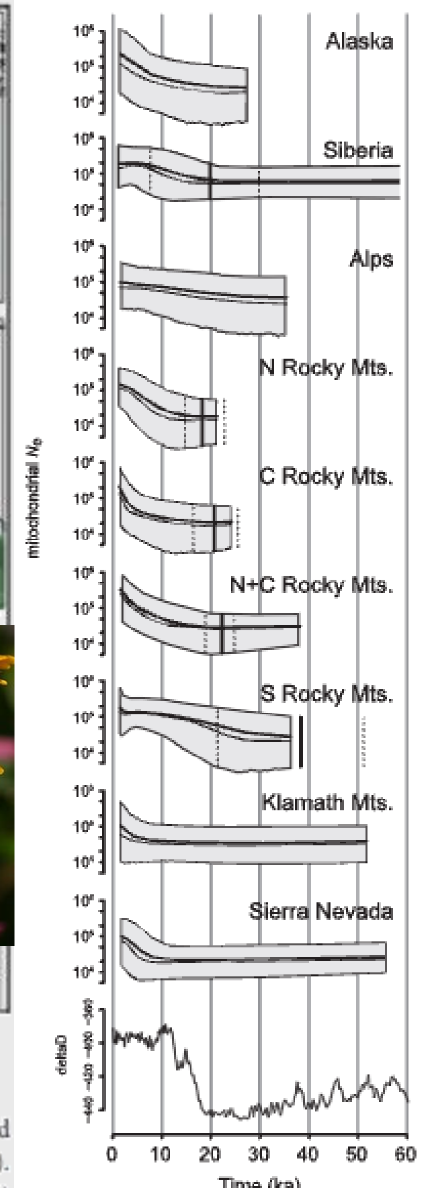


Figure 2 Species distribution models (SDM) and palaeoclimate. Modelled geographical distribution of climatic niche for the Holarctic *Parnassius phoebus* complex obtained by MAXENT analysis under current conditions (a) and community climate system model (CCSM) for 21 ka (b). Western North America is enlarged in panels (c) current conditions and (d) 21 ka. Last Glacial Maximum (LGM) ice sheet and lakes data are from Dyke *et al.* (2003) and CLIMAP (1981). Dots indicate sampling sites for molecular analyses (colour-coding as in Fig. 1). The full list of presence locations used for SDM analyses is available upon request to the authors. Panel (e) reports deuterium excess (deltaD) from Antarctic ice cores (EPICA Community Members, 2004) and percentage of *Quercus* pollen in sediments from Clear Lake, CA (Adam *et al.*, 1981) as indicators of climate through the last 150 ka.

Todisco et al. (2012) J Biogeogr. 39, 1058–1072

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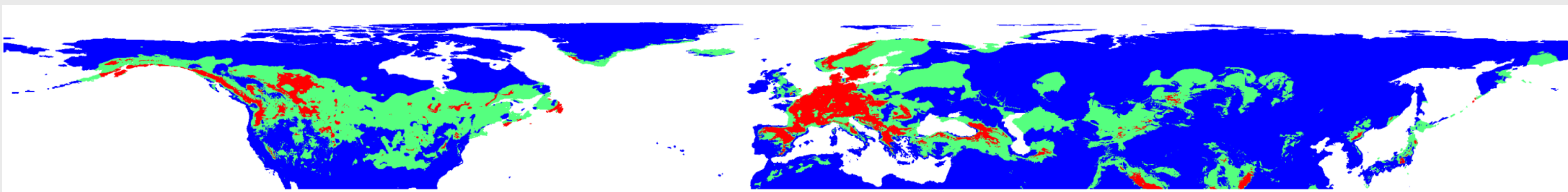
Parnassius phoebus

Legend

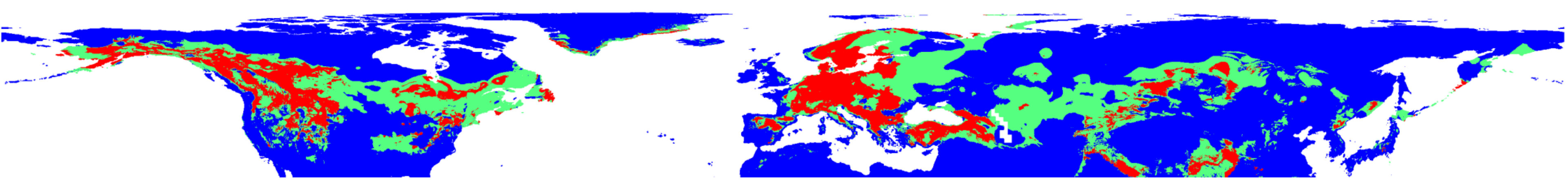
Parnassius

- unsuitable
- 1 - 3 algorithms
- consensus

21K years BP



6K years BP



present

Parnassius apollo

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Do ecology and genetics tell the same history?

- We can model the evolutionary and distributional history of these alpine butterflies in relation to climate changes by means of two independent analytical approaches:

  • ecological niche modelling (ENM)
  • genetics (i.e.: molecular phylogeography)

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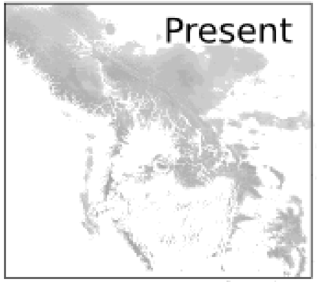
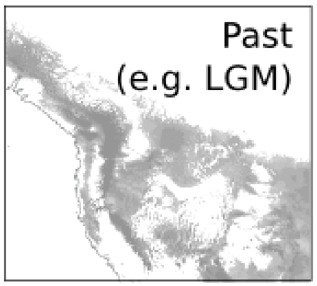
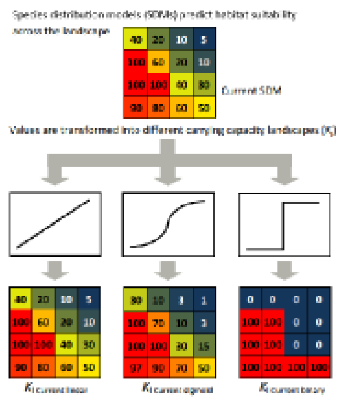
Species distribution models in phylogeography

SDM



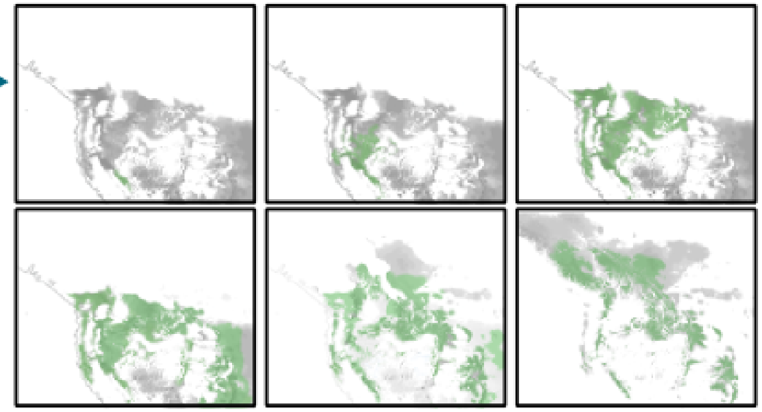


Convert probabilities to carrying capacities

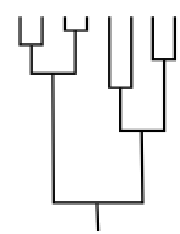


Brown & Knowles, 2012
Mol. Ecol. 21, 3757

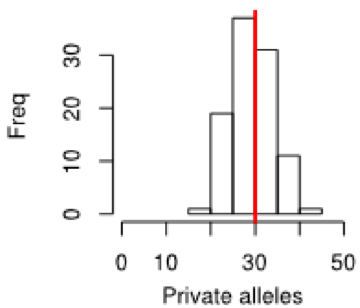
Simulate biogeographic scenarios
in a realistic, changing landscape!



Simulate genetic data



..AGTCGCAT..
..AGTTGCAT..
..AGTCGCTT..
..AGTTGCTT..



compare to observations
test hypotheses and estimate parameters
(e.g. by ABC)

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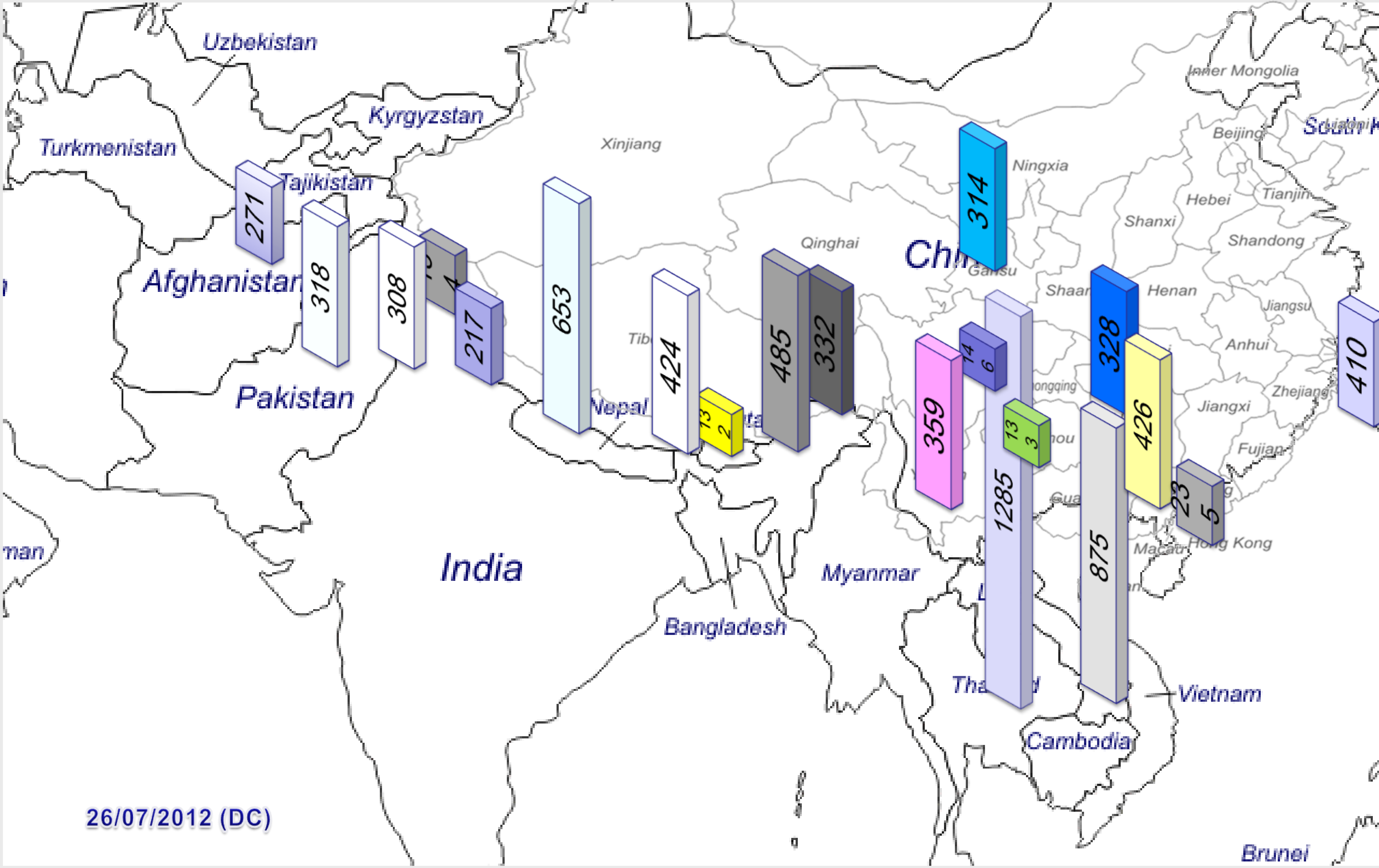

Sino-Himalayan butterflies: geographical trend in number of species

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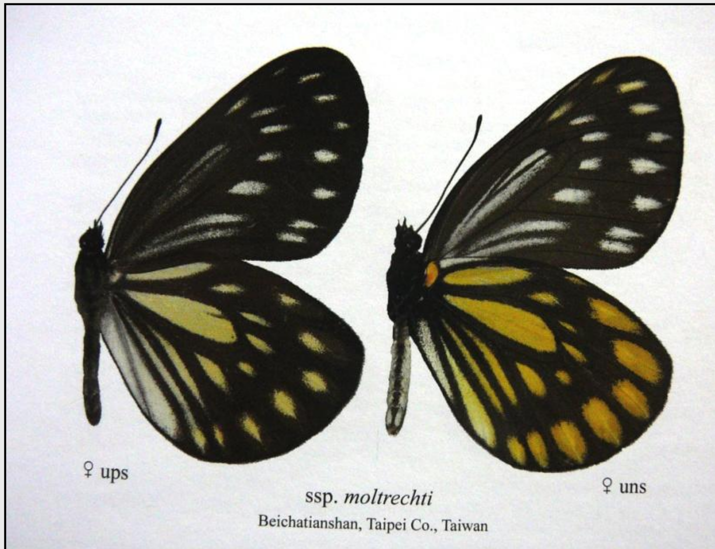
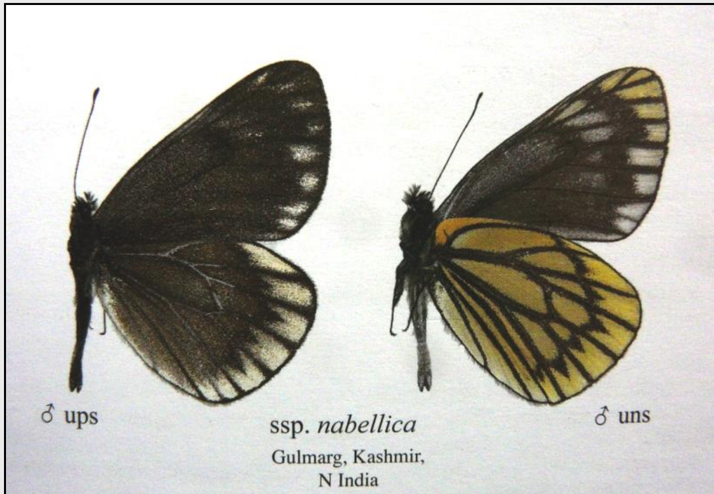
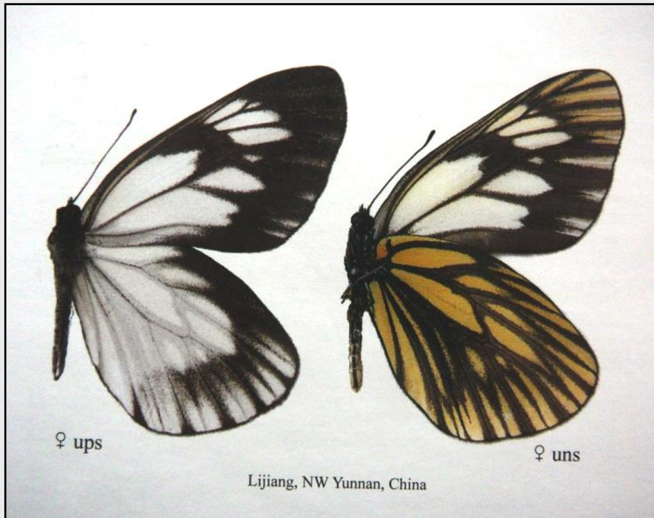


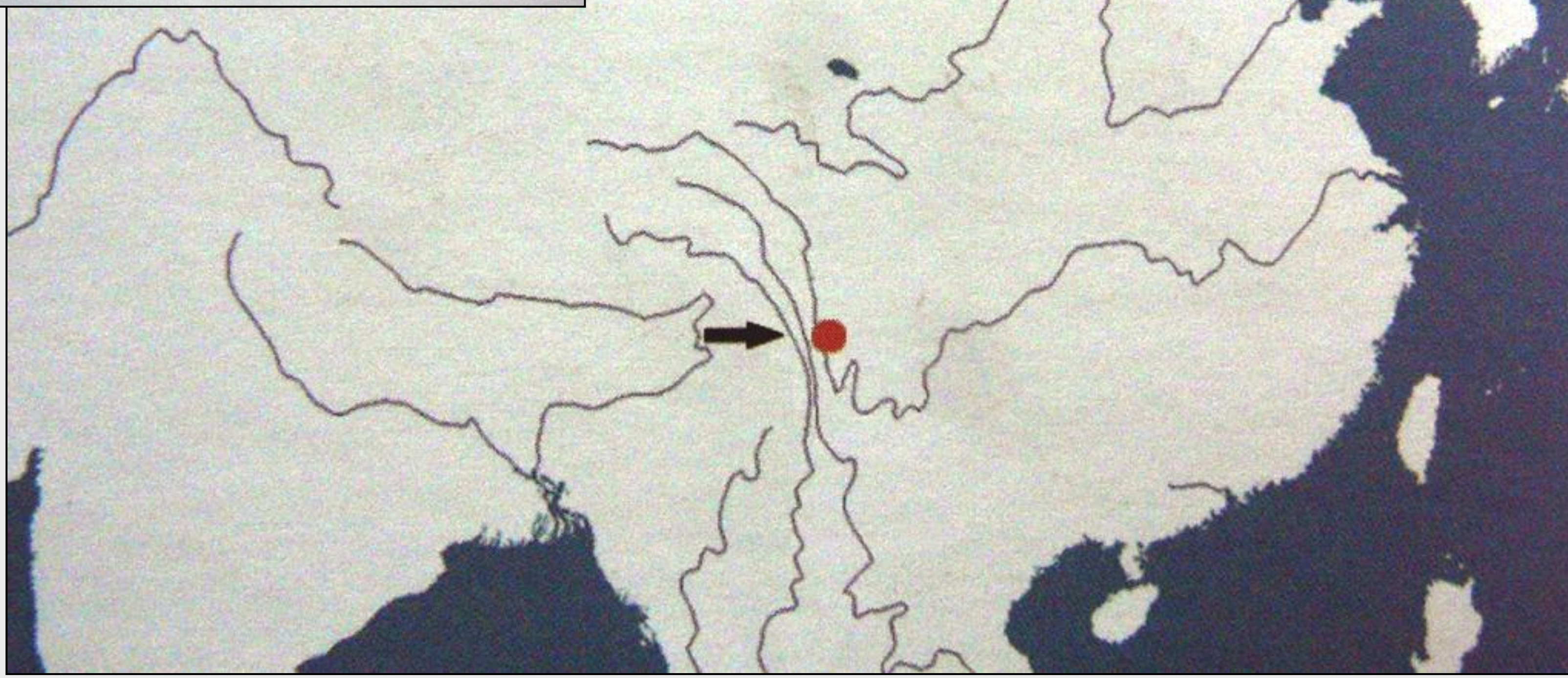
Aporia agathon



Aporia nabellica

Aporia hastata





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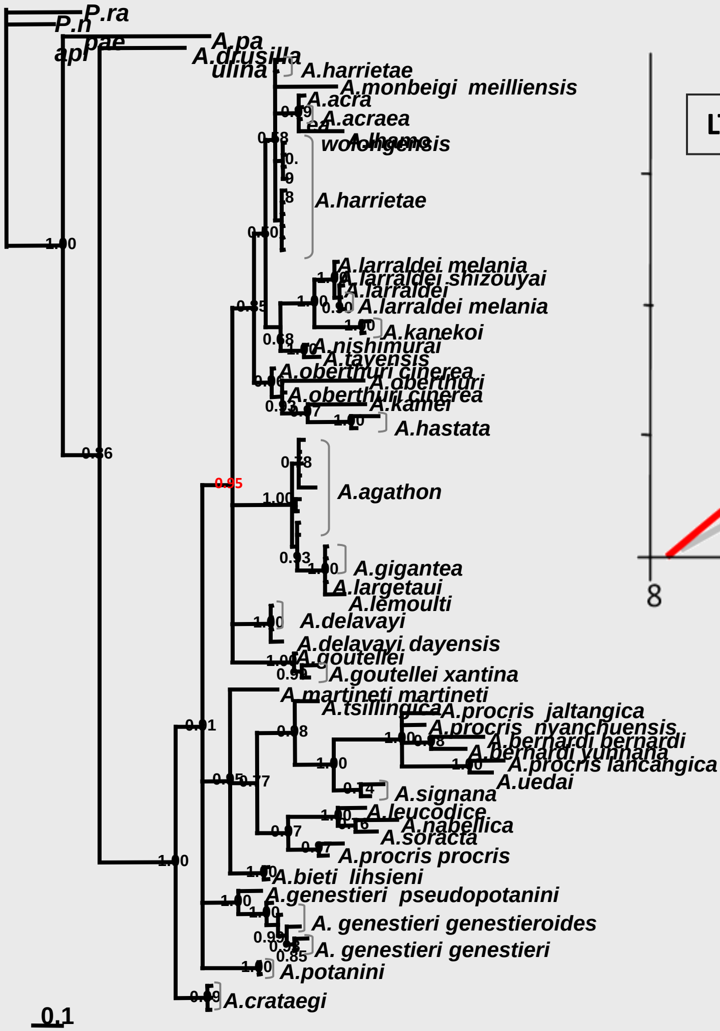
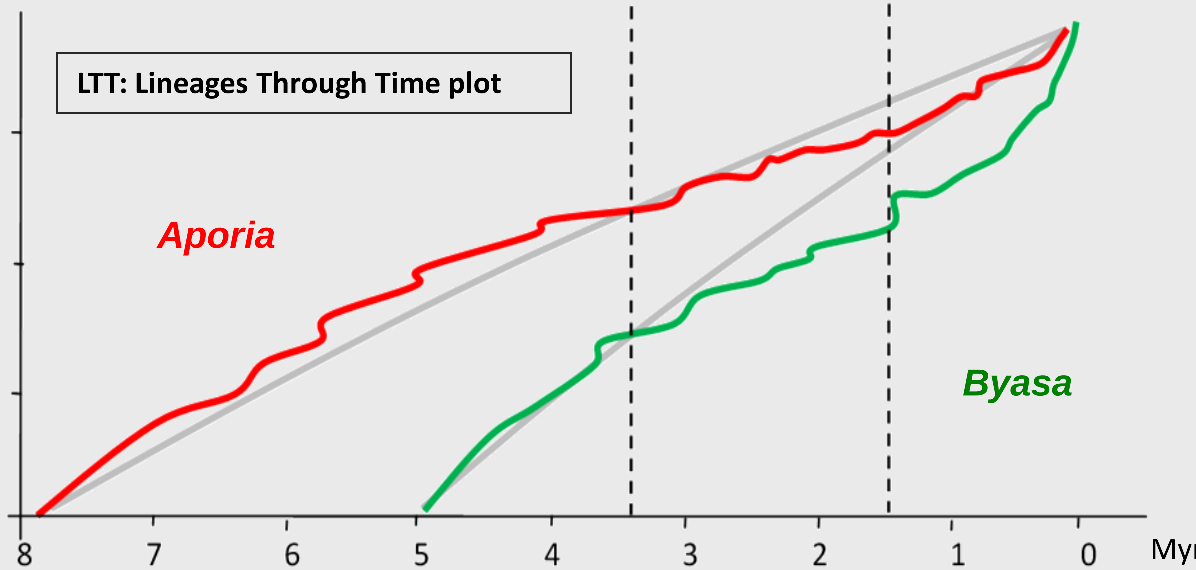
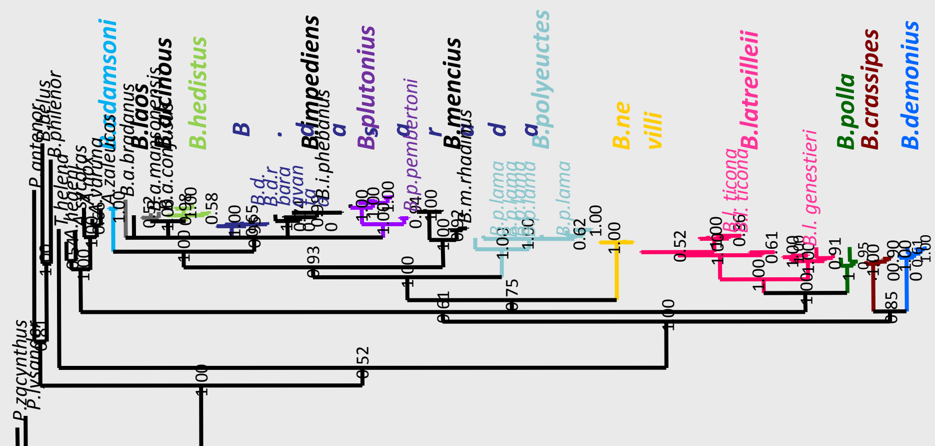
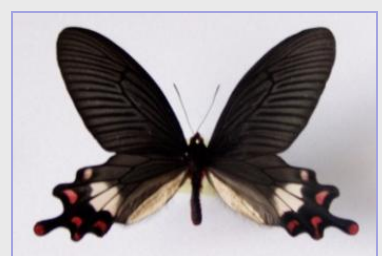






Genus *Aporia*

Genus *Byasa*



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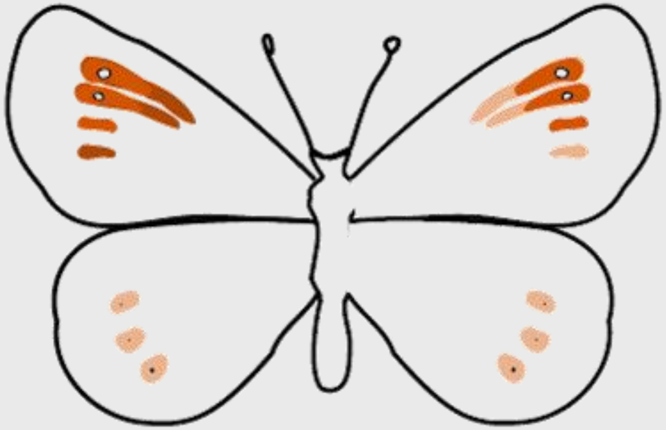
PRIN 2009 - MIUR

Thank you!

Università "Tor Vergata", Roma

A. Trasatti
G. Riccarducci
S. Marta
G. Allegrucci
D. Cesaroni
P. Gratton



CEES
Centre for Ecological and Evolutionary Synthesis

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B. Zakšek

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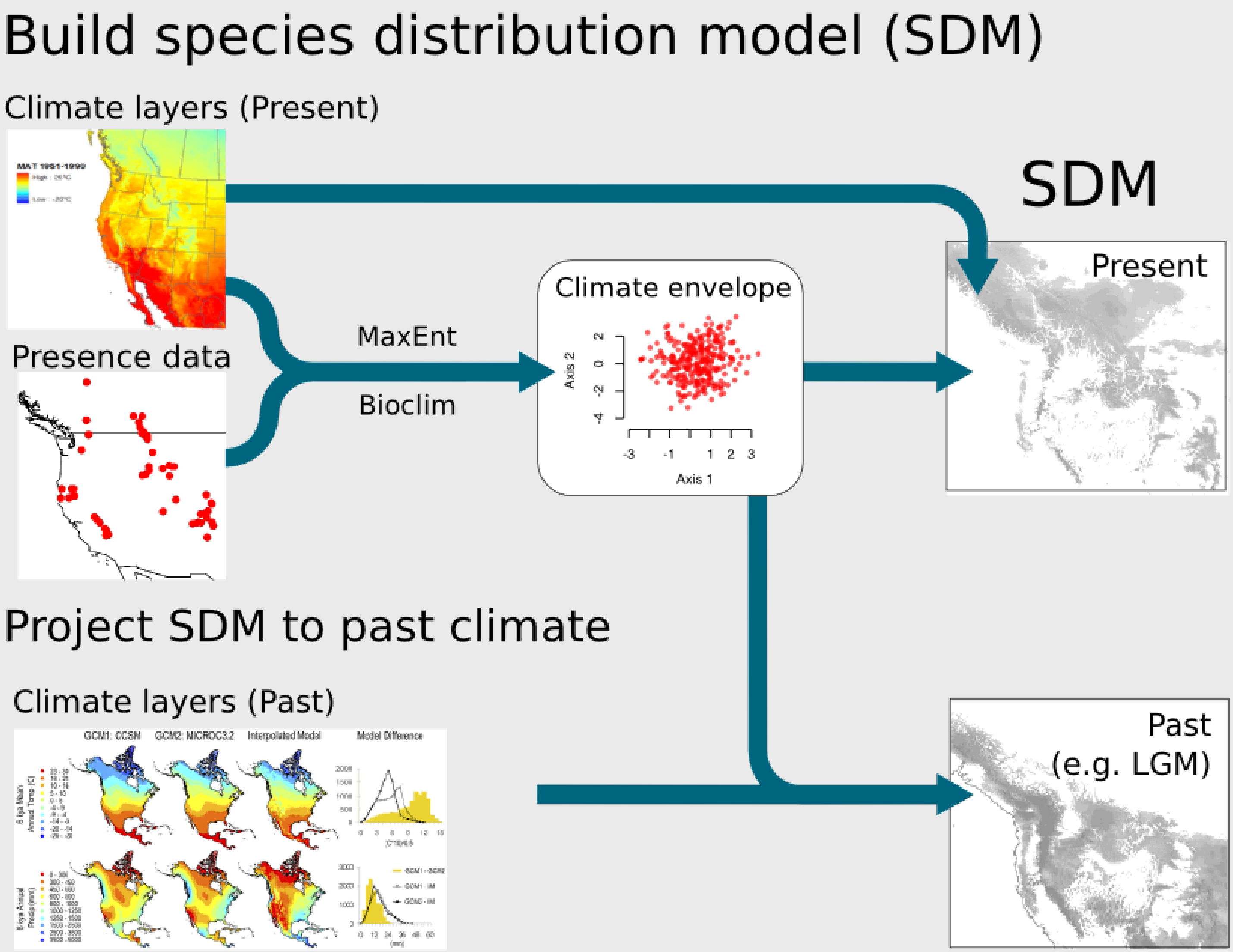
Species distribution models in phylogeography



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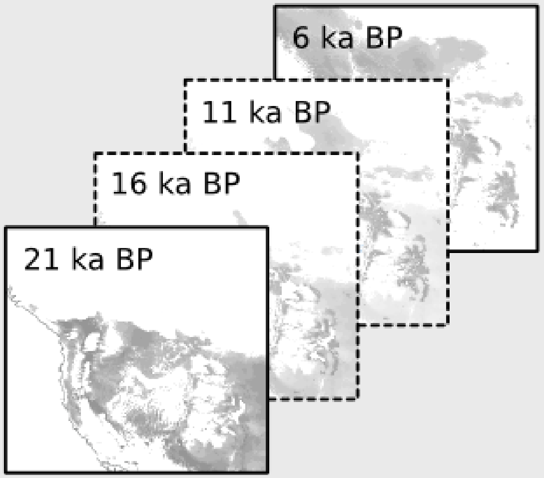
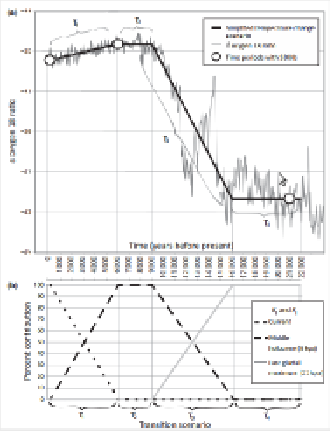
Species distribution models in phylogeography

Interpolate to create 'continuous' landscapes

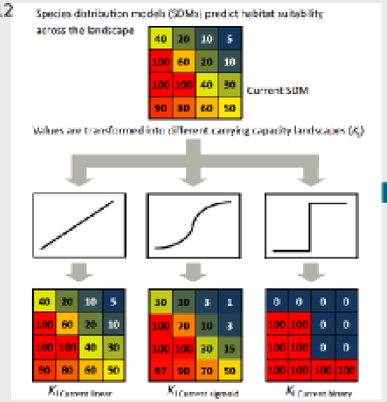


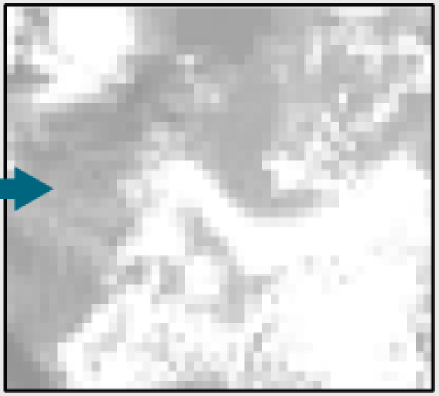


Brown & Knowles, 2012
Mol. Ecol. 21, 3757

Convert probability grids into carrying capacity grid

Brown & Knowles, 2012
Mol. Ecol. 21, 3757





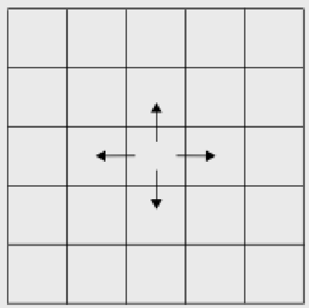
Species distribution models in phylogeography

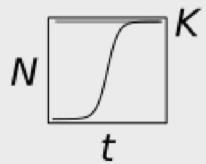
Geographically explicit simulations

demographic

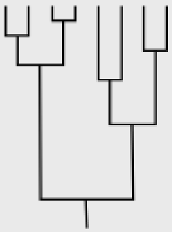
SPLATCHE 2
Ray et al., 2010 Bioinformatics 26, 2993

coalescent

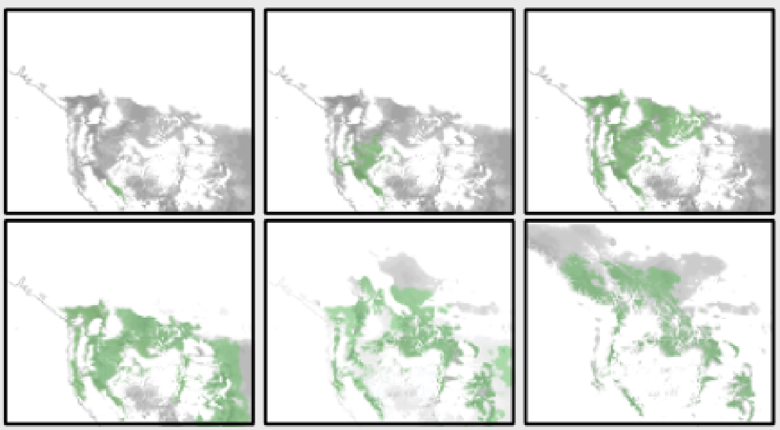




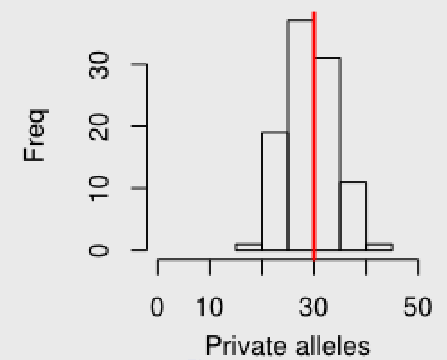
Parameters
carrying capacity (*K*)
friction (*F*)
growth rate (*r*)
migration rate (*m*)



Simulate biogeographic scenarios in a realistic, changing landscape!



Simulate genetic data and compare to observations to **test hypotheses**



Ice Sheet and Nunataks in East Greenland, Photo M. J. Hambrey, 1987.

Why butterflies?

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- Biogeographical terms like”arctic-alpine” and “boreo-alpine” distributions have been applied to species showing today a disjunct or discontinuous distribution in arctic regions or high mountain areas, probably reflecting wider and more continuous distribution ranges during the cold periods.

Erebia pandrose

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