Climate and biodiversity: what modelling and data analysis can tell us

Lisbon, EGI Forum – EUBrazilCloudConnect – May 18th, 2005

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A comprehensive framework for global patterns in biodiversity

Abstract
The present study proposes to reconcile the different spatial and temporal scales of regional species production and local constraint on species richness. Although interactions between populations rapidly achieve equilibrium and limit membership in ecological communities locally, these interactions occur over heterogeneous environments within large regions, where the populations of species are stably regulated through competition and habitat selection. Consequently, exclusion of species from a region depends on long-term regional-scale environmental change or evolutionary change among interacting populations, bringing species production and extinction onto the same scale and establishing a link between local and regional processes.

Keywords
Beta diversity, community, competition, diversity, extinction, habitat breadth, local processes, regional processes, speciation, species richness.
Ecological Niche Modelling

Profile Techniques: BIOCLIM; DOMAIN; Ecological Niche Factor Analysis (ENFA); Mahalanobis distance

Regression-based Techniques: Generalized linear model (GLM); Generalized Additive Model (GAM); Multivariate Adaptive Regression Splines (MARS)

Machine Learning Techniques: MAXENT; Artificial Neural Networks (ANN); Genetic Algorithm for Rule Set Production (GARP); Boosted Regression Trees (BRT)/Gradient Boosting Machines (GBM); Random Forest (RF); Support Vector Machines (SVM)

Most niche modelling algorithms are available in the R packages 'dismo' and 'biomod2'.

The Collaboratory for Adaptation to Climate Change adapt.nd.edu has implemented an online version of openModeller that allows users to design and run openModeller in a high-performance, browser-based environment to allow for multiple parallel experiments without the limitations of local processor power.

From http://en.wikipedia.org/wiki/Environmental_niche_modelling
Usefulness of Bioclimatic Models for Studying Climate Change and Invasive Species

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**BOX 1.** Key assumptions of bioclimatic models

- Biotic interactions are unimportant in determining geographic ranges or are constant over space and time.
- The genetic and phenotypic composition of species is constant over space and time.
- No dispersal limitation: species occur at all locations where climate is favorable and nowhere else.

**BOX 2.** Statistical methods often used for empirical bioclimatic models

- Logistic regression, generalized linear model (GLM)
- Generalized additive model (GAM)
- Climate envelope (e.g., BIOCLIM)
- Classification and regression tree (CART)
- Neural network (NN), genetic algorithm (e.g., GARP)
Figure 1  Global pattern in richness of 172 flowering plant families. Family richness per grid cell was calculated by summing the number of families represented in each grid cell. Richness increases going from blue to red. Relative richness values correspond closely to those estimated by Francis & Currie (2003) based upon a wider sample of angiosperm families, indicating that the subset of families used in the present analysis provide a good surrogate for total angiosperm diversity.
Figure 1 Population features and relevant processes at the leading and the rear edge of species ranges. The width of grey bars shown on the left hand indicates the quantity of features at the corresponding position within the range.

Conserving biodiversity under climate change: the rear edge matters

Abstract

Modern climate change is producing poleward range shifts of numerous taxa, communities and ecosystems worldwide. The response of species to changing environments is likely to be determined largely by population responses at range margins. In contrast to the expanding edge, the low-latitude limit (rear edge) of species ranges remains understudied, and the critical importance of rear edge populations as long-term stores of species’ genetic diversity and foci of speciation has been little acknowledged. We review recent findings from the fossil record, phylogeography and ecology to illustrate that rear edge populations are often disproportionately important for the survival and evolution of biota. Their ecological features, dynamics and conservation requirements differ from those of populations in other parts of the range, and some commonly recommended conservation practices might therefore be of little use or even counterproductive for rear edge populations.
Figure 1. LGM extended coastlines (sea-level drop of 120m) computed from bathymetry (Smith and Sandwell, 1997).

Figure 3. Legend accompanying the maps.

Legend

1. Tropical rainforest
2. Monsoon or dry forest
3. Tropical woodland
4. Tropical thorn scrub and scrub woodland
5. Tropical semi-desert
6. Tropical grassland
7. Tropical extreme desert
8. Savanna
9. Broad-leaved temperate evergreen forest
10. Montane tropical forest
11. Open boreal woodlands
12. Semiarid temperate woodland or scrub
13. Tundra
14. Steppetundra
15. Polar and alpine desert
16. Temperate desert
17. Temperate semi-desert
18. Forest steppe
19. Montane mosaic
20. Alpine tundra
21. Subalpine tundra
22. Dry steppe
23. Temperate steppe grassland
24. Main taiga
25. Lakes and open water
26. Ice sheet and other perennial

A GIS-based Vegetation Map of the World at the Last Glacial Maximum (25,000-15,000 BP).
Amazonia Through Time: Andean Uplift, Climate Change, Landscape Evolution, and Biodiversity

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The Amazonian rainforest is arguably the most species-rich terrestrial ecosystem in the world, yet the timing of the origin and evolutionary causes of this diversity are a matter of debate. We review the geologic and phylogenetic evidence from Amazonia and compare it with uplift records from the Andes. This uplift and its effect on regional climate fundamentally changed the Amazonian landscape by reconfiguring drainage patterns and creating a vast influx of sediments into the basin. On this “Andean” substrate, a region-wide edaphic mosaic developed that became extremely rich in species, particularly in Western Amazonia. We show that Andean uplift was crucial for the evolution of Amazonian landscapes and ecosystems, and that current biodiversity patterns are rooted deep in the pre-Quaternary.
- Angiosperms: lower Cretaceous
- First Angiosperm fossil: China, Barremian (Yixian Fm)
- Major biotic evolution
  Transition in the Mesozoic floras.
- 350,000 Angiosperm species
Why their radiation is so surprising?

- **High** and **rapid** diversification (350,000 species)
- Sustained tempo of speciation
- Dramatic rise to ecological dominance (in 30 Ma)

Friedman, 2009

Crepet & Niklas, 2009

Friis & Crane 2011
Angiosperms localities & climate (1120 ppm – 4x)

120 Myr – 4x

95 Myr – 4x

70 Myr – 4x

120 Myr: Low diversification

95 Myr – 70 Myr: high diversification and migration to higher latitudes
A tool for linking paleoclimate with paleoniches

NetCDF files
- Temperatures
- Precipitations

```
import netCDF4 as nc
dataset4test = '../netcdf_data/70Ma_8x.nc'
data = nc.Dataset(dataset4test, 'r', format='NETCDF4')
```

```
$ ./python-prg -i xxx -args [...] 
```

Project team

Galaxy server
A PCA on temperature and precipitation data
Mapping first two axis of PCA
Climatic regimes in Maastrichtian, -70 My?
Thanks to

Anne-Claire Chaboureau
Pierre Sepulchre
Yannick Donnadieu

LSCE, Saclay

Yec’han Laizet
Philippe Chaumeil
Jeran-Marc Frigerio

BioGeCo, Bordeaux
Pleiade, Bordeaux