iDigBio Research Spotlight: Using Museum Specimens to Refine Models of Species Distribution

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Using distribution models is crucial for estimating levels of biodiversity at the landscape level. Museum specimens are a significant source of information for these models as they witness current but also past habitats. When coupling this information with historical climate information, museum data become a powerful tool to define a species' niche, infer its potential changes in the historical past, and project the impact of global change on its distribution.

Museum Specimens for Better Models

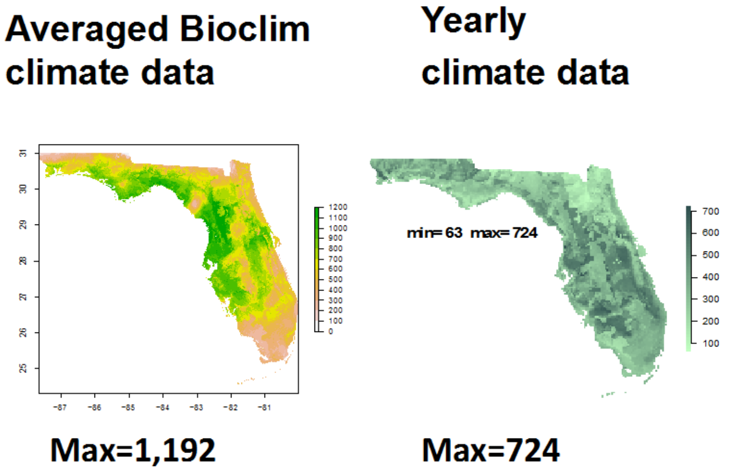

Fig. 1. Comparison of alpha diversity maps from models using the averaged climate data from Bioclim (left) vs. the yearly climate data from PRISM (right). The map on the right has much tighter models and produces a much more realistic picture of our understanding of the flora of Florida.

In my research, I am developing tools that will enable scientists to construct models based on digitized museum specimen data (and other information). My own research focuses on plants in Florida. Using data from herbaria and other observation sources, I gathered enough high-quality data to build distribution models for 1,548 species and create maps of alpha diversity and endemism hotspots. Associating the date of collection of the specimen with the yearly climate data (from PRISM - http://www.prism.oregonstate.edu/) proved very useful, especially for narrow endemics, usually limited by subtle variations in climate variables. These methods are still being refined and tested, and Florida offers an unprecedented source of expert knowledge that we can use to ground proof our models. So far, our models have yielded more realistic alpha diversity maps than the typical modeling based on climate variables averaged over several decades (Bioclim - http://www.worldclim.org/bioclim), and further work will continue to improve the models (Fig. 1.).

The Future of Florida Plants

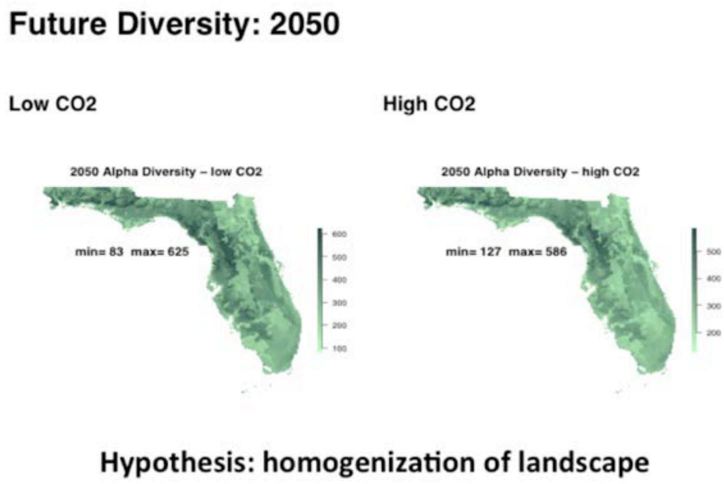

Fig. 2: Maps of alpha diversity of plants in Florida in 2050, with scenarios of low (left) and high (right) CO_2 emissions. Note that increased emissions lead to a decrease in diversity in the most diverse communities, but an increase of diversity in the least diverse ones.

We have projected these models into the future to investigate the impact of climate change on the landscape of Florida plants. The most diverse areas will lose diversity (in terms of species number) while the least diverse areas will gain diversity (Fig. 2). We hypothesize that there will be a homogenization of the landscape, with some species becoming more widespread, while others disappear. The mapping of beta diversity over the landscape seems to confirm this hypothesis, with fewer areas showing high geographic species turnover (Fig. 3).

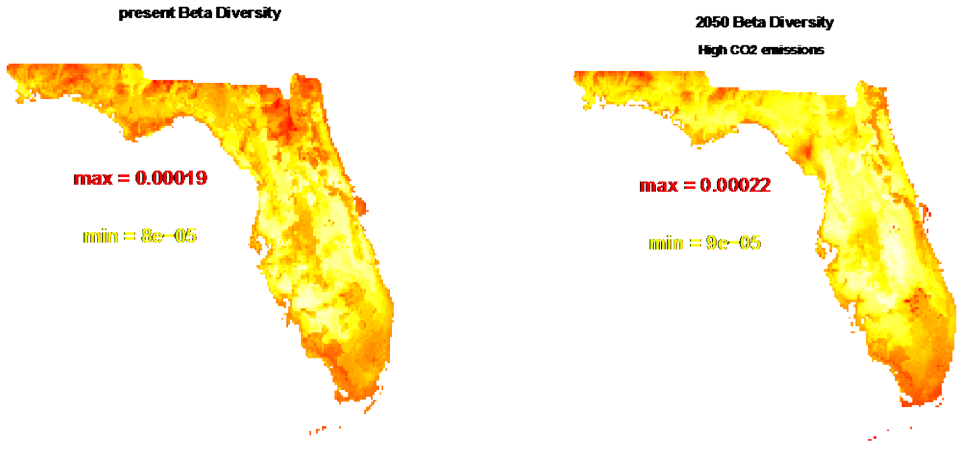

Fig. 3. Beta diversity (geographic turnover of species over the landscape). Areas in red indicate high turnover, where species are different from the rest of the landscape. In the future, the reduction of the red areas means that despite having a high number of species, regions in northern Florida will have less overal diversity, their communities becoming more similar in species composition.

We have also calculated the risk of complete extinction of all species of plants and of endemic species only, using raw models under climate scenarios caused by different levels of CO_2 emissions. Gradually, we added layers of complexity, taking sea level rise, dispersal limitation, and projections of urbanization into consideration (Table 1). The main factor affecting the extinction risk in plants in Florida is the level of CO$_2$ emissions!!! The good news is that it is one factor we can do something about…

Projection conditions	Low CO2 emissions	High CO2 emissions
Unlimited disp., No SLR, No urb.	**115**	**314**
Endemics	11	25
Limited disp., No SLR, No urb.	**144**	**333**
Endemics	11	26
Limited disp., 1m SLR, No urb.	**146**	**340**
Endemics	11	26
Limited disp., 1m SLR, Urb. Best scenario	**146**	**340**
Endemics	11	26
Limited disp., 1mSLR, Urb. Worst scenario	**146**	**340**
Endemics	11	26

Table 1: Risk of complete extinction for 2070 under different CO$_2$ emission scenarios, and at different levels of complexity.

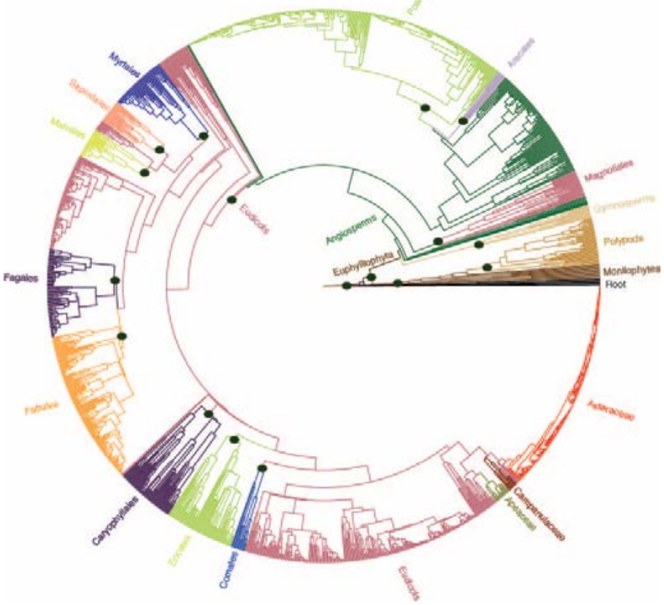

Fig. 4. Phylogenetic tree of Florida, based on the chloroplast genes *matK* and *rbcL*

Biodiversity as a Product of Evolution

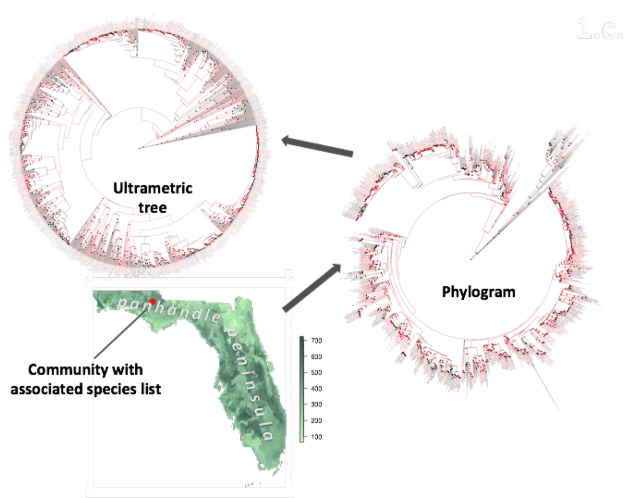

Fig. 5. Calculating Phylogenetic Diversity. For each of the 8,045 communities in Florida, we associated the list of present species with the evolutionary tree, undated (phylogram) or dated (ultrametric tree).

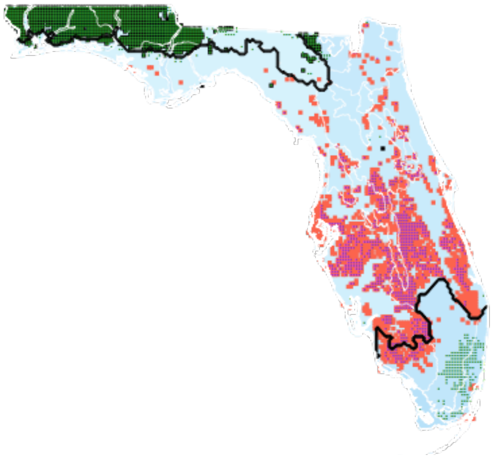

Fig. 6. Map of phylogenetic diversity in Florida. We can see here an overdispersion (green areas) in the northern and southernmost regions, as well as a clear clustering (orange) in the central peninsula. In black, the EPA ecoregion delimitations correspond to these regions of evolutionary diversity patterns.

Preserving species number is not sufficient for effective conservation. IUCN guidelines explicitly state that a community of species should also be assessed as a product of evolution. For the same number of species, is it better to preserve representatives of 5 or 10 different plant families? In order to estimate the evolutionary diversity of plants in Florida, we reconstructed a phylogenetic tree of the same 1,548 species for which we have distribution models. Harvesting approximately half the *matK* + *rcbL* sequences from GenBank and producing the remainder ourselves, we obtained a tree of satisfying resolution and topology (Fig. 4). Combining the information from the species distribution map (e.g., Fig. 1), which encompasses over 8,000 pixels, or communities (list of species), with the phylogenetic tree, we can calculate the accumulated evolutionary history for each pixel (Fig. 5). With a randomization test, we can then evaluate whether each community represents more (overdispersal) or less (clustering) evolutionary history than expected at random, given all species present in all communities of Florida. This approach allows us to reconstruct a map of the evolutionary history of plant communities in Florida (Fig. 6). This map clearly distinguishes the three major EPA ecoregions in Florida, an encouraging sign that this approach successfully reconstructs expert knowledge on biodiversity and can therefore be applied to regions with lesser expert knowledge but important conservation needs.