Island Biogeography Lab

Aims

The aim of this lab is to make you confident in formulating models that can be used to test important biological hypotheses in a Bayesian setting and then analyze them using Rev and RevBayes.

Background

We will be using discrete-state continuous-time Markov chain models to model the biogeographic evolution of animals and plants inhabiting the Canary Islands. We will code distributions in terms of four area states: Mainland, Eastern Canary Islands, Central Canary Islands, and Western Canary Islands. Data will be provided for you on some animal and some plant groups. Each nexus file contains two data matrices: a molecular character matrix followed by a distribution character matrix. The plant data files will also contain a third dataset specifying the distribution of each terminal with respect to ten different island-habitat types, as specified below:

M1	Mainland - Other
E2	Eastern Islands - Open
C2	Central Islands - Open
W2	Western Islands - Open
C3	Central Islands - Laurel forest
W3	Western Islands - Laurel forest
C4	Central Islands - Pine forest
W4	Western Islands - Pine forest
C5	Central Islands - Alpine vegetation
W5	Western Islands - Alpine vegetation

Hypotheses to Test

We will focus on three hypotheses that have been discussed in the literature. Choose one of them or work with all three, depending on how much time you have.

1. Plants shift between islands more readily than between habitats. For animals, it is the reverse. They tend to radiate into different niches on the same island rather than shifting between islands. Is this correct? If so, how large is the difference?
2. The carrying capacities of islands is partly determined by the area of the island, and partly by other factors, such as geological events and altitudinal and ecological diversity. What is the magnitude of these non-area effects on each island?
3. Similarly, the biotic exchange between islands is partly determined by distance and partly by other factors, such as wind and sea currents etc. What is the magnitude of these non-distance effects on the biotic exchange between each pair of islands?

Hints

For the molecular models, use something simple like GTR + gamma for all sites. Do not overdo it by using more complex models of molecular evolution. To calibrate the trees, you could assume that the age of each tree is drawn independently from a lognormal distribution with mean 2.3 and standard deviation 2.3 on the log scale. This is a very diffuse distribution centered on the age of the oldest islands.

To test the first hypothesis, try coming up with a GTR-type rate matrix that separates the island hopping rate from the niche shifting rate. There are several possible solutions. There are also several ways of modeling the carrying capacities.

To test the second hypothesis, you need to know how the relative carrying capacity is related to area. One possibility is to start from a commonly used model in ecological island biogeography, which states that the number of species S, is related to the area A according to a power law:

$$S = c\,A^{z},$$

where c and z are constants. It turns out that you need to know the value of z but not the value of c. In previous studies, which include the Canary Islands among other systems, it has often been observed that z is in the range (0.22,0.28). You can assume $z = 0.25$ for your analysis (or possibly use a hyperprior for z).

You also need to know the areas of the Canary Islands and the Mainland state. You can use the following values

Mainland	1 028 832.0 km^2
Eastern Islands	2 505.9 km^2
Central Islands	3 963.8 km^2
Western Islands	984.0 km^2

To test the third hypothesis, you need to know something about the relation between distance and biotic exchange intensity. One possibility is to assume that the exchange intensity is inversely proportional to the distance. The shortest distances between the geographic states are:

Mainland – Eastern	110.0 km
Mainland – Central	191.0 km
Mainland – Western	434.0 km
Eastern – Central	181.0 km
Eastern – Western	324.0 km
Central – Western	86.0 km

For both hypotheses two and three, you need to mix two factors together in computing the carrying capacities or the exchange parameters. There are several possibilities. Assume for instance that you have two factors a and b and a mixing proportion p (between 0 and 1). Then you could use a linear mix of the two components, such that the resulting effect x is defined by:

$$x = p\,a + (1 - p)\,a$$

or you could use a power mixture, where x is defined by

$$x = a^{p}\,b^{(1-p)}$$

That should be everything you need. Good luck!