This is a <u>video transcript</u> of Module 2 of the Online Open Course in Species Distribution Modelling. To access the full suite of videos click [here](#).

Online Open Course - Species Distribution Modelling

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Module 2 Ecological theory of species distribution models

In the first module of this online open course about species distribution modelling, we had a quick look at what species distribution modelling is. In this second module, I am going to explain the theoretical background of these models.

To understand species distribution models, we need to understand the difference between geographical and environmental space.

Let's start with species distributions in geographical space. This is how we usually think about species occurrences: plotted on a map. We can also visualize this in a graph, in which the occurrence records are defined by the values of the longitudinal coordinates on the x-axis and the latitudinal coordinates on the y-axis.

When we talk about environmental space, we refer to the environmental niche that a species occupies. A species' environmental niche is the set of environmental conditions in which a species can survive and persist. This concept was defined by the ecologist George Hutchinson in 1957.

Let's look at this environmental niche step by step. If you would look at only one environmental condition, and plot the probability of a species to occur in relation to that condition, you usually get a bell-shaped curve. This curve shows the optimum value of the environmental variable for a species to survive. For example, if your species is affected by temperature, the probability of occurrence is highest at the optimum temperature, with decreasing probabilities towards the minimum and maximum values that the species can tolerate. When we add another environmental condition that is relevant for the species, we get a two-dimensional graph, with one environmental variable on each axis. Each of these variables has its own optimum curve. The model will find the area where the combination of both variables results in the most optimum conditions for a species to occur. The center of the circle represents the combination of environmental variables with the highest suitability for a species to survive. The gradient

colour visualizes a decrease in suitability of the environment from the center of the circle outwards.
Tolerances for three different environmental conditions can be plotted in three-dimensional space in which the suitability of the environmental conditions is then represented by a sphere or a cube of which the edges correspond to the minimum and maximum tolerable values of each environmental condition. However, a realistic species distribution model takes into account all environmental variables that are relevant for a species, and this results in an n-dimensional hyperspace that defines the environmental space of a species. Unfortunately, we cannot visualize such a multidimensional space.

Within the environmental niche concept, there are a few things to keep in mind. I will visualise these with a simple two-dimensional graph in which species occurrence is defined by temperature and rainfall.
The crosses in this graph represent occurrences of the species, and the minuses represent absences. The green area is the fundamental niche of the species, which refers to the environmental conditions where a species can occur, and assumes that the species only occurs there and nowhere else. So in this example, a species was found to occur in places where it was not too hot and not too cold, and not too wet or too dry. However, a species is not necessarily found in every location that has suitable environmental conditions. This is because the distribution of a species is also influenced by biotic factors, and can thus be limited by the presence of a predator, or the absence of food. The area that is actually occupied by a species is referred to as the realized niche. In geographical space, we refer to the realized niche as a species' actual distribution, whereas the fundamental niche is referred to as its potential distribution.

And then there are two other factors that you should keep in mind. The first one is the concept of source-sink dynamics. Individuals of a species might move from the area of the fundamental niche, which is the source, to sink areas outside the fundamental niche. This is likely to occur for species with high dispersal abilities. For example, if the fundamental niche of a migrating species is defined based on the environmental conditions of areas where the animals breed, it is likely that this does not include areas where the species moves to outside the breeding season.
The other factor to keep in mind is dispersal barriers, such as mountains, rivers or oceans. Such barriers might prevent a species from occurring in areas that have suitable conditions, just because the species cannot reach those areas.

In modules 5, 6 and 7, we will look at specific algorithms that you can use to model species distributions, and most of these function in environmental space. The only exception are the geographic models, which are not based on the environmental conditions of occurrence locations and therefore only work in geographical space. All other algorithms, however, are designed to link the places of occurrences to the environmental conditions of those places, and thus function in environmental space.

These models follow three steps. First, we take the occurrence data out of the geographical space and we use this data to calibrate the model in the environmental space. The next step is to project the model back into geographical space. Geographical space models do not use environmental variables and as such the second step is skipped.
If you overlay the actual occurrence points with the modelled distribution on a map, you can identify areas where the species likely occurs but just has not been found yet. This can be a starting point for new surveys to find a species in those places. And you will also be able to identify areas where a species is not occurring, but where the environment is suitable for it to survive. This is useful, for example, if you want to prevent an invasive species from spreading to an area where it has not been observed yet.

It is important to realize that it is unlikely that the occurrence records that you have for a species reflect the entire range of environmental conditions that a species can occupy. The species distribution model that you are going to built only uses the data that you put in, and is thus only calibrated with the environmental niche that is represented by the occurrence records. The outcome of the model should thus always be viewed with caution and might not represent the full extent of the actual or potential distribution of a species. This is a general drawback of a modeling approach, as a model is always a representation of the real world.

Hopefully this module has helped you understanding the ecological underpinnings of species distribution models a bit better. In the next module, we will look at the data that you need to run a model. I hope to see you back there.

Attribution

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