

OLM10.4. Historical reflections on the development of the niche concept

Probably, the “Concluding remarks” by Hutchinson (1957) is the most central piece of the decades-long niche discourse. He studied spatial distribution of species along an environmental gradient, as determined by its environmental tolerance (cf. Ch5Toler). He observed that competitive exclusion was expected between species of identical “niches” – assuming single-factor local limitation. Competition of species with partially overlapping niches may shrink their area of distribution (realized niches). The qualitative idea comes from Grinnel (1917). Hutchinson’s contribution is the set theoretical formulation: the niche of a species is a subset of an N dimensional abstract niche space. The dimensions, or niche axes, are the environmental conditions, roughly the variables we considered, as modifying.

Elton (1926, 2001) introduced the notion of ecological niche in a very different sense: it is the functional role of the species in the community. Elton’s sense was incorporated into the concept of niche space via introducing a new kind of niche axis (Hutchinson 1978). It was called “bionomic”, as opposed to the original axis that was referred to, as “scenopoetic”. The bionomic axis had nothing to do with spatial distribution. Meanwhile the concept of niche, as a subset, was refined by the introduction of the resource utilization function (MacArthur & Levins, 1967). They assumed that competition coefficients are determined by the overlap integral of these functions.

Hutchinson’s niche space stirred huge controversies. Most importantly, because food concentration, instead of food quality, was seen as the bionomic equivalent for the scenopoetic, e.g. temperature, axes by many. To alleviate the problem, Leibold (1995) suggested a re-analysis of niche concept in the context of mechanistic/explicit modelling, esp. of Tilman’s model (Figure 9.11), with emphasis on the bidirectionality of the population-environment interaction. Instead of a continuum of the resource types, he considered finitely many ones only. His „requirement”-niche was the subset of the space of regulating variables, where the population survives. It was delimited by the zero net growth isocline (ZNGI). Leibold’s „impact” niche is the consumption vectors of Tilman’s model. These two kinds of niche were identified with Grinnel’s and Elton’s niche, respectively. They jointly determine possibility and stability of coexistence. However, we lose the intuitive picture of coexistence based on partitioning the niche space, if this terminology is used.

The precise concepts are more involved. We discussed in Ch5Toler, how the response function determines the tolerance range and spatial distribution. The response function

depends both on the modifying and the regulation variables, e.g. both on temperature and food concentration, in the same way. (In case of a food-size continuum, it depends on the concentrations of all size, i.e. on infinitely many concentration values – a point we did not emphasize in Ch5Toler, but see OLM 10.1.) In contrast, modifying and regulating variables affect tolerance range differently (TBox 5.1). Modifying variables together with the unloaded (i.e., measured without the population) regulating variables are the environmental conditions determining tolerance range. A population affects the distribution of another one only through the regulating variables.

We learnt in Ch9Coex that robust coexistence is predicated on their difference with respect to the regulating variables. Therefore, the ensemble of the regulating variables is the entity that is partitioned between the species. To follow Hutchinson's terminology, we refer to this set, as niche space. It does not need to be continuous, however. If it does, like in the case of seed-size continuum, then the continuum corresponds to infinitely many regulating variables (Figure 10.5, TBox 10.3). The quantity distinguishing between these regulating variables is the index variable (OLM 10.1): e.g. the size of the food. It should not be confused with the regulating variables itself, which are the e.g. food concentrations. In our terminology, continuous niche space is spanned by the index variable(s) of the regulating variables.

A population becomes a structured one in a spatially heterogeneous environment. Its long-term growth rate depends on the modifying and regulating variables at all locations (TBox 10.3). Therefore, location (or a proxy of it, like temperature) is a quality of the food, just like its size. Competition for resources occurs, when they are limited by the same resource at the same habitat. This is why it was the correct approach by Hutchinson to consider biotic and scenopoetic niche axes on the same footing.

As we discussed in Ch9Coex, the species' relationship towards the regulating variables have to be characterized by impact and sensitivity vectors. Our impact is analogous to Leibold's one, but see OLM 9.3 for details. Sensitivity is the gradient vector of the response function, restricted to the regulating variables. That is, sensitivity is the tangent vector of the boundary of the requirement niche *sensu* Leibold. Impact and sensitivity are the operationalization of the intuitive notion of resource utilization function in the context of Lotka-Volterra modelling.

References

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