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Securing the Conservation of biodiversity across Administrative Levels and spatial, temporal, and Ecological Scales

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Methods for cross-scale species distribution modelling

Summary

Knowledge of how to combine information about environmental factors that determine species distributions across spatial scales is indispensable for effective conservation and management. Researchers have tested three methodological approaches to combine distributional and environmental data for Finnish butterflies. They found that using the best information available at each spatial scale for the development of species distribution models and combining the results by simple multiplication significantly increases the predictive ability. This study highlights the notable potential of multi-scale approaches and demonstrates that the search for environmental correlates with species' distributions must not only be addressed at an appropriate spatial scale, but also should be combined across the spatial scales due to the inherent hierarchy of processes where the higher levels constrain the lower levels.

Key words

Climate envelope, cross-scale modelling, Europe, Finland, global change, species distribution modelling

Relevance to legislation

Habitats Directive 92/43/EEC

Relevance to actual environmental problems

Biodiversity loss, climate change, land-use change, Natura 2000 network

Description of the problem

Why do species occur where they are?

The question why a species occurs at one particular location and not at another is everlasting in ecology. Knowledge about the environmental factors that determine the distribution of the species is thus crucial for both basic and applied ecology. Moreover, our ability to predict species distributions across time and space is an indispensable precondition for the development of adequate policy and management strategies and is particularly relevant in the face of global change. Statistical species distribution models are a powerful tool to achieve these aims. They set up mathematical relationships among current distributions of species and environmental factors and use this information to make predictions for less

Figure 1: **The butterfly species *Anthocharis cardamine* and a landscape where it occurs (Photos: Janne Heliölä)**

well studies areas and for projections to future conditions. The common view in exploring such ecological patterns is that they should be studied on an 'appropriate' scale, while on the other hand some species modellers highlight the importance of hierarchy in the influences of the environment on species distributions. Yet, species distributions are often, if not always, affected by abiotic and biotic factors operating at different spatial scales, and the relative importance of these factors varies across scales. Despite the broad general knowledge of species-environment relationships from many parts of the world, and the recent advancements in species distribution modelling, the understanding of how to best deal with scale issues and scale disparities when fitting statistical species distribution models is still insufficient.

Combining information from different scales

We investigated three approaches to combine information from three different spatial scales (0.05 km, 0.5 km, 10 km) to improve local and regional statistical species distribution models using distribution data of Finnish butterflies. The three approaches were (i) agreements of predicted occurrences among the three scales, (ii) multiplying occurrence probabilities across the three scales, and (iii) developing a single hierarchically nested combinatory model across all three scales. Further, we investigated potential differences in the suitability for cross-scale modelling of three commonly used modelling methods: (i) generalised linear models (GLMs), (ii) generalised additive models (GAMs), and (iii) boosted regression trees (BRTs). Predictive performance of the cross-scale models was tested on an external data set with two methods: area under curve (AUC), which is a threshold-independent measure of the reliability of the model, and error rates of predicting presences and absences, i.e. the frequency with which actual observations are falsely predicted as absences and actually unoccupied areas are falsely predicted as being occupied. We found that while agreements of predicted occurrences among the three spatial scales were definitely unsuitable to improve model prediction, multiplying occurrence probabilities obtained by boosted regression trees across the three scales were best suited to improve predictive performance of the models. In cases when the modelled species are not too rare, generalised linear models can also be used with both approaches multiplying occurrence probabilities and developing one hierarchically nested combinatory model across all different scales at once. Since generalised linear models and boosted regression trees, as well as both approaches to combine the information across the scales, have their pros and cons, one can select the appropriate method and approach according to the particular preconditions of the data.

Recommendations

Processes are important

Our study highlights the utility of multi-scale approaches for understanding and predicting environmental limitations to species' distributions. It also demonstrates that the search for environmental correlates with species' distributions must not only be addressed at an appropriate spatial scale, but also be combined across the spatial scales due to a system-inherent hierarchy of processes where the higher levels constrain the lower levels to various degrees. Thus, conservation policies, which consider an integrated approach across spatial scales rather than species- or habitat-based policies, are required.

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Sources

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Figure 2: **The butterfly species *Aporia crataegi* and a landscape where it occurs (Photos: Janne Heliölä)**