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Qualitative models about metapopulation dynamics.

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Abstract

Facing habitat fragmentation, how populations behave? Habitat destruction poses the greatest threat to the long-term survival of species on Earth. Fragmentation means that the remaining habitat for a species is located in smaller and more isolated discrete fragments (patches) of the original area. The consequences of habitat fragmentation on habitat quality may influence population dynamics via effects on effective patch areas and hence on extinction rate, on colonization rate and by creating source-sink dynamics. These are ideas on the realm of metapopulation dynamics.
To assess the consequences of habitat loss and fragmentation is a complex task due to phenomena happening at different scales and to environmental heterogeneity, for which there will never be enough data to support rigorous empirical analyses. A general theoretical framework is needed, based on a clear conceptual understanding of metapopulations' behavior. This is an urgent task due to accelerating changes and modification of natural landscapes imposed by human activities.
Following current theory on education that advocates learning by doing, modelling is considered fundamental to human cognition and scientific inquiry. Qualitative Reasoning captures human interpretation of reality, and provides a conceptual account that explains why a system presents certain behavior. The Qualitative Reasoning vocabulary used in the model (in fact a symbolic logic-based vocabulary) mimics the way humans understand and explain observable behaviors. So learners can formulate their insights on how systems behave in an appropriate qualitative and causal way.
In order to support secondary school and undergraduate students in learning by modeling, a set of qualitative models about metapopulations was developed in the Qualitative Reasoning engine Garp3 (www.Garp3.org) and in the learning spaces with different levels of complexity of the workbench DynaLearn (www.DynaLearn.eu). The models capture and formalize knowledge and the main principles of conservation biology involved in the metapopulation theory for application in educational settings. In fact, we emphasized the importance of conservation biology principles recommended by the Education Committee of the Society for Conservation Biology.
The main goals to be achieved with these metapopulation models are:
a) to address the problem of habitat fragmentation and the effects of conservation biology measures on the metapopulation dynamics;
b) to formalize causal explanations about the source-sink metapopulation approach;

c) to predict differences between the behaviour of populations depending on their size and carrying capacity;
d) to investigate the use of fundamental laws from physics and chemistry, such as diffusion and osmosis, to explain metapopulation behaviour;
These models are related to the simplified view on how the processes of colonization and extinction influence fragments of population in a metapopulation. Some of the simulation scenarios intend to show how is the behavior of the 'suitable patches' and then of the 'fragments of population' from 'metapopulation' face to the changes caused in the landscape due to human population influences.
In one of the models, for instance, landscape modification can be induced by the process of land use by human population, and reduced by environmental restoration process that control and restore the effects of land use. The human population modifies the habitat, and the landscape modification has a negative influence on the suitable patches on the habitat. These suitable patches positively influence the colonization rate and negatively influence the extinction rate of a metapopulation that lives in the fragment.
The main processes influencing the fragments of population (that is, the population that lives in a fragment) are colonization and extinction. Colonization process increases the fragment of population size, while the extinction process reduces it. Simultaneously, the fragment of population size has a negative influence on the colonization rate, establishing a feedback mechanism that acts as a saturation control – colonization is no longer successful after a threshold population size in the fragment.
Another aspect of great importance is the representation of the conservation effort that is the effect of the environmental restoration rate that can diminish the negative aspects of human population impacts on habitat loss and fragmentation.
Qualitative Reasoning modeling has been considered as a tool for integration and exploration of conceptual knowledge in ecological systems and population dynamics (see the special issue on Qualitative Reasoning of *Ecological Informatics* **Volume 4, Issues 5-6, pages 261-412, November-December 2009**) and the work described here confirms such expectations.
This study indicates that Qualitative Reasoning modeling may be a valuable tool for exploring population dynamics and to provide better understanding of complex scenarios dealing with landscape modification, habitat loss and conservation efforts on fragmented areas. This challenge is of great importance, mainly when conservation efforts are needed in a changing planet.

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