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Local biodiversity should increase with climate change: case-study for ponds from the Swiss National Park

Véronique Rosset

Keywords

Small waterbodies, predictive models, protected area, climate warming, species richness, sentinel systems

Summary

Climate change is expected to have a significant impact on biodiversity worldwide (THOMAS et al. 2004). Many studies focus on responses to climate change at the regional level, such as species distribution shifts, and evidence that enrichment of regional biodiversity could happen in many areas of the world (HICKLING et al. 2006). Less is known, however, about the consequences of climate change on the species richness in ecosystems (local scale). Alpine areas are particularly sensitive to climate change (BENISTON 2003). Small waterbodies like ponds are abundant and widespread, and because of their small size they shelter simple communities, particularly at high altitude. Therefore, alpine ponds should play an important role as sentinel and early warning systems in the assessment of the future changes in local biodiversity. The Macun ponds of the Swiss National Park are part of a unique and exceptional area for such investigation and monitoring.

The aims of the present study are: (i) to present the observed species richness in the Macun ponds (2002 to 2008), and (ii) to predict the changes expected for 2100 (A2 IPCC emission scenario).

The Macun cirque was added to the Swiss National Park in 2000. This area is situated in the Alps (2'600 m. a.s.l.) in Graubünden, Switzerland. The climatic conditions are extreme, with extended ice cover (9 months).

The cirque covers 3.6 km^2 and includes a hydrographic system (Figure 1) composed of a stream network and more than 35 small waterbodies (area: 24–18,000 m^2).

As part of the National Park, the Macun cirque was identified in Europe as one of the Important Pond Areas of Europe (Minssieux in preparation). and a monitoring program has been put in place since 2002 (ROBINSON & OERTLI 2009). The ongoing research projects include monitoring of stream and pond diversity.

Macun pond diversity, as part of the monitoring project, has been assessed since 2002 with different rhythms according to the ponds. Macroinvertebrates are sampled in nine ponds with a standardized hand net, which is swept through the water intensively for 60 seconds per sample.

113 Swiss lowland to mountain ponds (including some of the Macun ponds), have been used to build predictive models for forecasting the potential impact of climate warming on freshwater biodiversity. Pond diversity was assessed once between 1996 and 2005 using the PLOCH standardized method (OERTLI et al. 2005), which measured the species richness for five taxonomic groups: aquatic vascular plants, aquatic Gastropoda, aquatic Coleoptera (larvae and adults), Odonata adults and Amphibia.

Predictive models were built using Generalized Additive Models (GAM) in order to model the relationship between 15 environmental variables (including mean annual air temperature) and measured species richness for each of the five taxonomic groups. To simulate climate warming, the future temperature increase predicted by the A2 IPCC emission scenario for 2090-2100, +3.4°C (IPCC 2007), was used.

In the Macun cirque, the monitoring between 2002 and 2008 showed that pond communities had presently a taxa richness between six and eleven taxa (Figure 2), values which fall within the range of observations from other alpine ponds but are particularly low compared to ponds from lower altitude (OERTLI et al. 2008). Coleoptera species richness was nevertheless particularly higher (two times higher) than what is usually observed at similar altitudes.

Figure 1: The hydrological system from Macun cirque (Swiss National Park).

For the Macun ponds (n=9), our predictions evidence that warming will lead to the apparition of taxa presently not observed at high altitude, such as Gastropoda, Odonata and Amphibia (Figure 3). A particularly marked increase in richness will occur for vascular plants. For Coleoptera, the slight decrease predicted is a bias due to the exceptional high richness of Macun ponds compared to alpine ponds with similar characteristics.

Analogous predictions for alpine ponds evidence that a temperature increase would enhance pond diversity for the five taxonomic groups: +139% for vascular plants, apparition of Gastropoda, +185% for Coleoptera, +454% for Odonata, and +56% for Amphibia.

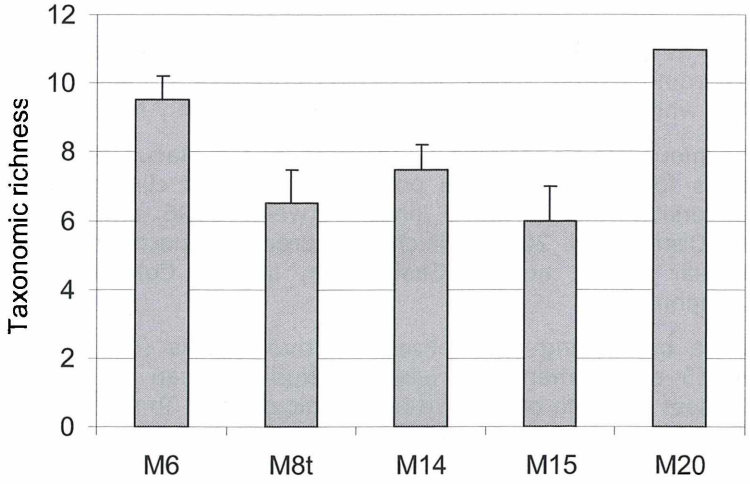

Figure 2: Taxa richness (species level, except for Diptera and Oligochaeta to family level and Chironomidae to subfamily) between 2002 and 2008 in five monitored ponds. Number of years sampled are two (M6, M14), three (M15, M20), or four (M8t).

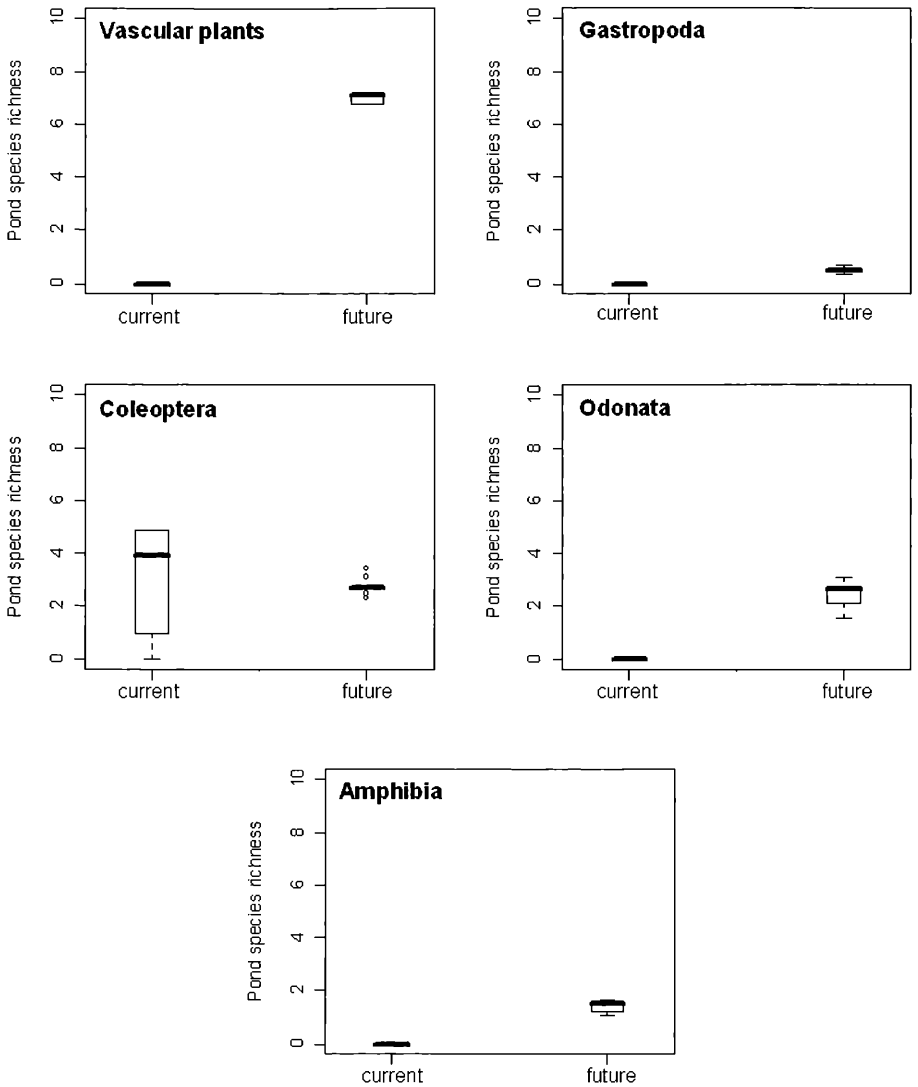

Figure 3: Current species richness ("current") and predicted species richness expected to occur in response to climate warming for 2100 ("future") for nine alpine ponds of the Macun cirque (Swiss National Park).

Alpine ponds located in the Macun cirque have the same range of species richness as other alpine ponds (with the exception of beetles). Because of their high connectivity and low disturbance by human activities, they are important to pond conservation and monitoring.

In Macun ponds, species enrichment is expected for the next century. Nevertheless, this enrichment would be in reality the result of a positive balance between numerous colonization events and sparse extinction events. Species currently inhabiting warmer locations will be able to migrate progressively to areas which are warming up. The majority of species (more than 90%) currently in the Swiss regional species pool are potential candidates for colonizing Macun ponds. Indeed, warming will lead to an apparition of vascular plants, Gastropoda, Odonata and Amphibia, species currently absent in these ponds. No cold stenothermal species, at risk of extinction, were detected from the five taxonomic groups used for predictions. Nevertheless, some other taxa inhabiting Macun ponds (Trichoptera for example) are at risk of extinction.

As the species enrichment predicted in this study represent the potential upper range of the expected changes, many important parameters not included in the predictions are believed to reduce this magnitude and should be considered and investigated in the future: species pools available for colonization, dispersal abilities of species, physical changes due to climate change and biological interactions. Future investigations should also focus on field evidence recorded by long-term monitoring programs. The use of alpine pond ecosystems seems particularly appropriate for such investigations, and this study demonstrates that they constitute an excellent sentinel ecosystem for predicting climate change effects at the local scale.

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Contact

Rosset Véronique
veronique.rosset@hesge.ch

Dpt. of Nature Management
University of Applied Sciences of Western Switzerland
150, route de Presinge
1254 Jussy
Switzerland