

Adapting to global change

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INTRODUCTION

A lot of effort has been spent in the last few decades demonstrating that the climate is changing more rapidly now than it did through history and prehistory, and that the reason for this rapid change is anthropogenic action. In addition to climate changes, habitats are being directly modified, and organisms are being directly acted upon. Some species are shifting ranges on a global scale resulting in invasions, causing habitat modifications, impacting interspecific interactions, and generating diseases. Other species are being directly persecuted or overharvested to the point that they are no longer able to function in their communities the way they did historically (Jackson, 2008). This has caused many species to become endangered or even go extinct. The future prospects for many species and habitats are in question. Will species be able to survive such rapid environmental changes? Are they flexible enough to adapt to changes of such magnitude? Can we predict which species are at increased risk of extinction?

These questions are complex and require a deep understanding of how ecology and evolution work, and a detailed knowledge of the changes taking place (Dawson *et al.*, 2011). To address these questions, the Estación Biológica de Doñana hosted an international conference entitled ‘Adapting to Global Change’ in Seville, Spain in the fall of 2013. There were nearly 50 invited speakers in nine symposia that conveyed a wide variety of points of view on the ecological and evolutionary effects of the currently ongoing rapid changes in the environment. This special issue of *Evolutionary Ecology Research* comes out of that congress, and likewise reflects many points of view. The papers here provide hints as to how these fundamental questions about the interaction between species and communities and the changing environment will be transformed in the near future.

PREDICTING EFFECTS OF ENVIRONMENTAL CHANGE

Forecasting the effects of ongoing environmental change is fundamental for future preservation and management of natural resources. Anticipating how species will respond to change is difficult anyway but even more complicated given that the details of how the environment will change are unknown. Predictions for entire communities rely on a large number of assumptions. In this special issue, many different tools, from models based on

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theoretical data to model systems are employed to address basic issues, especially connectivity and response capacity.

Connectivity is a recurring theme in these discussions. One theme is the connection between communities that may allow dispersal and rescue in cases of local extinctions. Thompson *et al.* (2014) explore the theoretical consequences of different patterns of changes in connectivity for communities and show that metacommunities are much more sensitive to habitat loss when highly connected patches are lost. Observations of an actual species, the grey wolf, also support the importance of connectivity between habitats for long-term survival and adaptation (Leonard, 2014).

High connectivity appears to facilitate rescue of populations or communities by dispersing individuals from other patches of habitat. High connectivity can also have unintended side-effects. An increase in connectivity can be caused by a wide variety of anthropomorphic actions, including the removal of barriers, the removal of competitors, and even direct transport of individuals to new places (either on purpose or by accident). This can lead to hybridization between species, and invasions of species to areas far outside their range. These are complex situations that can have potentially positive as well as negative consequences for the species or communities involved. Brennan *et al.* (2014) treat the philosophical issues of hybridization in general, whereas Sanchez-Donoso *et al.* (2014) look at a specific case of hybridization between a native species and introduced relatives, and the possible effect of a change in migratory behaviour.

Most populations, species, and communities have at least some capacity to change in response to environmental conditions. This is expected since many species have a natural distribution encompassing multiple different habitats (see Geerts *et al.*, 2014; Leonard, 2014; Sanchez-Donoso *et al.*, 2014). Populations of the same species in different environments may have different environmental tolerances as a result of local adaptation, which could affect their ability to adapt to changing conditions. An environmental feature that is currently changing rapidly is temperature. Geerts *et al.* (2014) test for differences in heat tolerance between populations of the water flea (*Daphnia magna*) from different latitudes in their natural distribution, and find that thermal tolerance, as well as the tightly correlated character of body size vary along a latitudinal gradient. Common garden experiments are one way to test alternative hypotheses and better understand the nature of this capacity to adapt. Molofsky and Collins (2014) test the hypothesis that invasive species are more adaptable than native species with a common garden experiment. They compare native and invasive populations of the same plant species from different latitudes in a series of different habitats, and find that some populations have more evolutionary potential to adapt to a warming environment than others.

Documenting changes in the environment, including abiotic factors such as temperature, as well as biotic factors such as the distributions of native and invasive species, is a fundamental check on how predictions based on theory and model systems work in nature. Collecting such data on a sufficiently detailed scale, both in time and space, is a logistical challenge, which is being met with increasingly sophisticated, remotely controlled technology (Ustin *et al.*, 2014). The effects of this change may be different at different scales, and is explored at both the species and community levels here.

DISCUSSION

Throughout the many sessions in the congress and in the papers presented here, some common themes have emerged. These include the interrelated issues of invasive species, hybridization, and connectivity. Each of these issues is complex, may have different patterns at different scales, and have both positive and negative aspects in terms of species' and communities' ability to adapt to changing environmental conditions. In some cases, experimental results supported initial hypotheses based on theory (Geerts *et al.*, 2014), but in other cases proved more complicated (Molofsky and Collins, 2014; Sanchez-Donoso *et al.*, 2014).

No doubt a lot remains to be understood. Changes in the environment and in communities are happening rapidly. It will be important to incorporate new models and new technologies to better understand what is happening in nature. On a more practical note, it is important to document changes and predict future trends in order to preserve biodiversity and ecosystem function and services.

The maintenance of large populations of native organisms in large, connected habitats without artificially introduced species appears to be the safest route forward, where the species have the most opportunity to adapt to changing conditions. In the vast majority of situations, this is not an option, many habitats and populations having already been fragmented and reduced in size, and invasions, both accidental and planned, continuing at an alarming rate. The environment, communities, and species are changing. Only by putting together many different kinds of data and perspectives will we be able to understand and protect them.

I hope you enjoy reading this special issue as much as I did.

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