Patterns and maintenance of biodiversity

Climate change, human activities and landscape changes influence biodiversity in multiple ways, leading to species loss and dramatic ecosystem changes[1]. Maintaining biodiversity is essential for human well-being, both physically and mentally[2]. Not only do diverse ecosystems provide important services such as clean drinking water, they might also be the source of novel drugs, biological pest-control agents and ecosystem engineers[3]. Yet, our understanding of many fundamental aspects of biodiversity remains insufficient. Numerous basic research questions remain unanswered. Why do individuals of a species live here but not there? How many of each species can coexist locally? Do rules for the local assembly of biodiversity exist and, if so, how flexible are they? How can high biodiversity and its associated roles, such as seed and pollen dispersal, be restored?

ARCHETYPAL INDICATORS

Species, as part of ecosystems, form intricate webs of interdependence. To investigate such ecological and environmental dependencies, it is useful to start where most knowledge is already available. The study of birds — of which around 9,800 species are known — offers a superb opportunity to gain insight into the evolution and maintenance of biodiversity on a global scale[4]. Knowledge about the evolutionary history of birds and their interactions with other species is unparalleled[5]. It is now possible to map the entire, global diversity of birds (Fig. 1) as well as, for example, population densities, dynamics and life-history traits[6], and to link projected patterns of anthropogenic change to single species distributions on a global scale, allowing projections of future bio-diversity[7] (Fig. 2).

above | A keel-billed toucan in the tropical rainforests of Panama, which temporarily carries a 'black-box' logger recording acceleration and location data.

ANSWERING QUESTIONS

Addressing the numerous unanswered questions might shed light on the reasons for the relative successes and failures of species in invading new habitats, and in coping with changes in their surroundings. Scaling up from individual species, the nature and strength of interactions between organisms provides insights into how individuals share and partition their ecological niches — in other words, how they survive given the resources in their environment and the community of which they are a part.

Environmental change offers an unprecedented opportunity to analyse and to better understand the basic rules of biodiversity — the conventions that govern communities, such as whether certain species can co live in proximity. This will allow better predictions of whether biodiversity responses to global change will be gradual or discontinuous, and how they will affect ecosystem and, ultimately, human health. Once an ecosystem is degraded, biodiversity is usually vastly diminished, typically through a cascade effect that involves all taxonomic groups. By understanding the species-assembly rules that support biodiversity, we will be in a better situation to bioengineer the rapid recovery of habitats — if not to their original state, then at least as close to their original functionality in terms of providing essential ecosystem services[8].

Biodiversity research does not stop at the species level — perhaps even more interesting are the rules governing variability in life histories within species or populations. Why are some individuals as possible migrating and others staying, or some monogamous and others promiscuous?

FORGING NEW GROUND

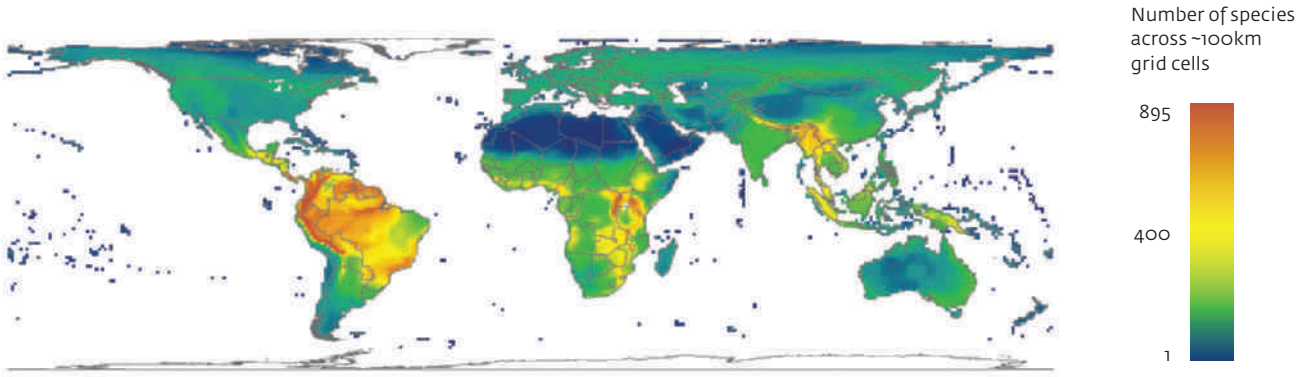
Synthesizing global information. Research efforts could focus on avian biodiversity, about which there is a wealth of published life-history and ecological data. Available information should be collated into an accessible database network. Novel technologies, such as 'black-box' data loggers attached to animals, allow continuous surveillance of behaviour[8]. They can be used to track individuals over time and, as such, to map species' shifts in distribution. It is possible to record an individual's physiology as it moves throughout its environment, and these data can be used to link internal (for example, heart rate) and external (for example, temperature) parameters (see image above).

Data on distributional changes can be shared with the scientific community, conservationists and educators, using the nascent Movebank database (www.movebank.org). A future genomic mapping of bird traits (see *Ecological genomics*, p26–27) should be spatially explicit to enable linkage between GenBank (www.ncbi.nlm.nih.gov/genbank/) and Movebank information.

The maintenance of tropical rainforest diversity is one of the enigmas in ecology, and globally affects both carbon balance and climate. Key observations made by the Max Planck Institute for Ornithology at Radolfzell unexpectedly showed that oilbirds are essential players in the long-distance dispersal of seeds in the Amazonian foothill rainforests of South America. This study also pioneers a new era of remote bio-logging of animal movements (Holland, R. A. *et al*. *PLoS ONE* **4**, e8264, 2009).

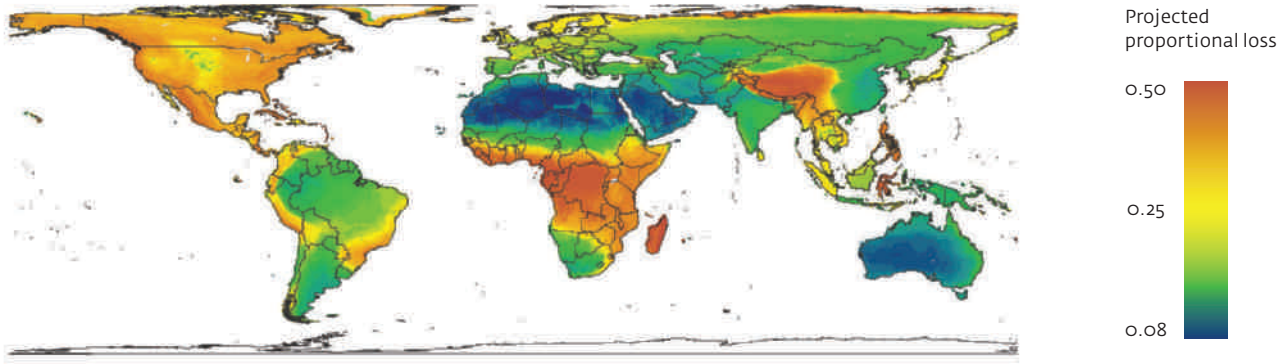
- Biodiversity is essential for ecosystems to function well and to provide services that are critical for human health, yet it is threatened globally, largely by anthropogenic activity.
- Knowledge about the origin and maintenance of global biodiversity is increasing rapidly, providing opportunity for basic and applied research.
- The study of higher vertebrates — and birds in particular — offers a unique opportunity to improve our understanding of all diversity.

Fig. 1 | Geographic variation in bird species richness



Source: Walter Jetz lab, Yale University, adapted from Jetz et al. 2007, 2008

Fig. 2 | Estimated average proportional loss of geographic range for birds, given regionally projected alterations in vegetation owing to climate and land-use change by 2100



Source: Walter Jetz lab, Yale University, adapted from Jetz et al. 2007, 2008

Using natural experiments. Studies of environmental changes and associated changes in species' life histories can reveal how particular traits influence whether they succeed in adapting to environmental change. More research is needed on the factors that influence life-history traits and their mechanistic underpinnings at the local and global scale. For example, areas rich in species— biodiversity hotspots — tend to have species with greater longevity, delayed ages of first breeding and smaller clutch sizes, but the reasons for this are still unknown.

Better knowledge for better conservation. Biodiversity research should be applied to the needs of conservation. Analysis of a global 'knowledge map' of birds can highlight the areas where gaps in our information about species are most apparent. This emphasizes the point that the regions with the highest biodiversity are the most poorly understood in terms of basic biodiversity information.

BOUNDLESS BENEFITS

Getting to grips with the fundamental patterns and processes involved in the evolution and maintenance of biodiversity will allow us not only to anticipate how ecosystems and species respond to environmental change, but also to maximize the human benefits of a biodiverse planet[9]. Biodiversity science offers immediate benefits to humans, from enhancing world-wide crop output to reducing the cost of the continual fight against invasive pests. We are only on the verge of understanding the importance of biodiversity for human health issues. Due to their high mobility and frequent interactions with humans, birds present pivotal biomarkers allowing the establishment of a global early-warning system for environmental hazards.

Movement data are available from Movebank.org / Computer graphic: Courtesy of the Walter Jetz laboratory, Yale University (Connecticut, USA). / Photo: Reinhard Vohwinkel.

For references see pages 38 and 39