# Biodiversity and distribution of Cacti

*Wilhelm Barthlott[1,2], Kirsten Burstedde[1], Nadja Korotkova[1], Jens Mutke[1]*
*[1]Nees Institute for Biodiversity of Plants, [2]Botanical Garden, University of Bonn, Germany*
*www.nees.uni-bonn.de*

## 2010 – The International Year of Biodiversity

The United Nations have declared the year 2010 as the International Year of Biodiversity. This aims at enhancing public and scientific awareness of the importance of biodiversity and the putative impacts from its loss.

## How many species are there?

The diversity of life on our planet is still not sufficiently studied. There are an estimated 10 or maybe even 20 million species on Earth but only 1.7 million have been formally described. Hence we have to assume that 90% of all life on Earth is unknown!

There are only a few groups of organisms that are well known to science. These are the large and conspicuous animals, including vertebrates and birds, and attractive smaller creatures such as butterflies. Approximately 80% of the higher plants have also been described. Of these, however, there are only about 300,000 species, which is a small number compared to those estimated for animals. Insects and their relatives may already make up 15 million species. But while animals represent 80% of the biodiversity, plants represent 80% of the biomass. Plants are therefore the most important structural components of terrestrial ecosystems and also play an important role as the primary producers. In view of the importance of plants in terrestrial ecosystems, a sound knowledge of the spatial patterns of plant diversity is fundamental basis for an understanding of the ecosystems but also for planning conservation activities. This applies especially to those plant groups that constitute important elements of their individual ecosystems.

## The global spatial patterns of biodiversity

Fig. 1 shows a world map of patterns of plant diversity. Generating such a map was possible for vascular plants because they are so well known and there is a large amount of data for their distribution. A diversity map for animals would be only possible for few groups. However, we assume that the centres of plants diversity will overlap with the centres for animal diversity.

The diversity of vascular plants is very unevenly distributed across the planet. This is partly explained by the unequal distribution of environmental factors such as climate, geology, soil and water availability. The sum of all these factors is termed geodiversity (Barthlott et al. 1996, 2007). Global centres of vascular plant diversity coincide with highly geodiverse areas in the tropics and subtropics, where high tropical mountains exhibit the highest diversity.

There are more plant species native to the Andes than to the entire European continent. Thus, regions with high geodiversity and consequently a large number of different habitats are the basis for high biodiversity.

## Mapping the diversity of cacti

First approaches to describe or map patterns of distribution of cacti were made by Karl Schumann (1899) and Curt Backeberg (1942). Backeberg was maybe the first cactologist to recognize the importance of biogeographic patterns within cacti. His contribution has hitherto remained the best hypothesis concerning the biogeography and evolutionary history of cacti and his *Kakteenlexikon*

(Backeberg 1966) contained a series of generalized distribution maps for the numerous suprageneric groups he recognized or proposed.

Perhaps the first true biodiversity map for cacti (i.e. a map demonstrating the location of *centres* of diversity, rather than the ranges of individual taxa) was published by Barthlott (1983) showing the diversity patterns of the epiphytic Rhipsalideae. The work was continued in the 1990s by Barthlott and co-workers at the University of Bonn and a preliminary biodiversity map for cactus species and genera was published a few years ago (Mutke & Barthlott 2005). Subsequently new methods for generating diversity maps were developed and a new approach to cactus biodiversity mapping using GIS-based methods was started in 2008 at the Nees-Institute in Bonn.

A high-resolution GIS dataset and corresponding database consisting of >45,000 records with distribution data for cacti was compiled. The main data sources were literature such as floras, checklists, taxonomical works, monographs and lexica with distribution information or range maps. Electronically available herbarium records and field data were also used. From the database, range maps for all Cactaceae species recognized in the *New Cactus Lexicon* (Hunt 2006) ('NCL') were generated, as well as diversity maps for all genera, tribes, subfamilies and the complete family. The initial species maps were then further reviewed and revised by experts for the respective Cactaceae groups. Preparation of the maps and accompanying commentary as the major contribution to a third volume of NCL is now under way, and will be completed, it is hoped, in time for publication before the end of 2010.

**Centres of cactus diversity**

The main centres of cactus diversity are north-eastern Mexico, the eastern Andes of Bolivia and Argentina and south-eastern Brazil. However, the diversity patterns differ in terms of species diversity compared to generic diversity. The main centre of generic richness is also Mexico, but Bolivia/northern Argentina/Paraguay, south-eastern Brazil, the Caribbean region and Peru show high generic richness as well. The differences of species and generic diversity are most striking in the Opuntioideae. Their centres of species richness are is the arid south west of the USA, northern Mexico, and the Mexican altiplano. The centre of generic diversity is located in the dry forest zone of southern Bolivia and northern Argentina with about 12 genera occurring there. That centres of species-richness and genus-richness do not necessarily coincide, as observed in the Opuntioideae, is just an example of the insights that can be gained from diversity maps.

**Outlook – Further insights into cactus ecology and evolution**

The data used for the generation of the distribution and diversity maps are digitally available in a geographic information system. GIS-based methods will allow further analyses focussing on various aspects of cactus ecology and distribution. First, data from phylogenetic studies are already available for a number of Cactaceae tribes and genera, data from those studies can be linked with distribution patterns. This will allow us to infer likely ancestral areas of the groups and detecting possible links of distribution patterns with phylogenetic patterns. There is already evidence that such connections exist in Cactaceae, as it has been demonstrated in *Pereskia* (Edwards et al. 2005) that the two monophyletic groups indicated by phylogenetic studies coincide with two discrete distribution and diversity centres in the genus as a whole. The second aim of further research would be the correlation of distribution data and environmental parameters such as mean annual precipitation, mean annual temperature, seasonality, elevation and habitat heterogeneity. These data could be further linked to characters such as growth forms, pollination mechanisms or seed dispersal strategies. A first analysis of this kind is currently under way for the epiphytic cacti. Since these environmental factors certainly influence cactus distribution, it would be very interesting to study the degree to which environmental factors explain degrees of diversity.

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**Cited references and selected publications for further reading**
BACKEBERG, C. (1942): Zur Geschichte der Kakteen im Verlauf der Entwicklung des amerikanischen Kontinentes. Verlag J. Neumann, Neudamm

——— (1966). Das Kakteenlexikon. Gustav Fischer Verlag, Jena.

BARTHLOTT, W. (1983). Biogeography and evolution in neo- and palaeotropical Rhipsalinae (Cactaceae). *In* K. Kubitzki [ed.], Proc. Int. Symp. Dispersal and Distribution, Sonderbd. naturwiss. Ver. 7: 241–248. Hamburg.

———, LAUER, W. & PLACKE, A. (1996): Global distribution of species diversity in vascular plants: towards a world map of phytodiversity. Erdkunde 50: 317–328.

———, HOSTERT, A., KIER, G., KÜPER, W., KREFT, H., MUTKE, J., RAFIQPOOR, M.D., & SOMMER, J.H. (2007): Geographic patterns of vascular plant diversity at continental to global scales. Erdkunde 61(4): 305–315.

EDWARDS, E.J., NYFFELER, R., & DONOGHUE, M.J. (2005) Basal cactus phylogeny: Implications of *Pereskia* (Cactaceae) paraphyly for the transition to the cactus life form. American Journal of Botany, 92(7): 1177–1188.

HUNT, D. (2006). The New Cactus Lexicon. dh books, Milborne Port.

MUTKE, J., & BARTHLOTT, W. (2005) Patterns of vascular plant diversity at continental to global scales. Biologiske Skrifter 55: 521–531.

SCHUMANN, K. (1899): Die Verbreitung der Cactaceae im Verhältnis zu ihrer systematischen Gliederung. Königliche Akademie der Wissenschaften, Berlin.