Chapter 8
Synthesis

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8.1 Definition

Animals and plants that have small ranges are called endemics. *Small* is a relative term. Ultimately, every taxon can be called *endemic* in an area that includes its entire range. We use the term *endemic* for any taxonomic category entirely restricted to a given geographical or biogeographical unit such as a locality, island, region, mountain range, country, grid cell etc.

The vascular plant species *Stapelianthus madagascariensis* is endemic e.g. to the Indian Ocean Islands, to Madagascar, to the South of Madagascar, and also to the dry spiny bush in the South of Madagascar.

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8.2 Causes

A taxon can be endemic for both environmental and biological reasons. Environmental factors include, for example, dispersal barriers such as salt water or mountain ranges, unique geological and soil conditions such as those supporting serpentine habitat isolates, and unique combinations of ecological conditions such as those in high mountain regions. Examples of biological causes of endemism include reduced seed or fruit production, reduced pollination opportunities outside of the taxon's range, or limited dispersal opportunities. Other positive and negative species interactions, such as competition, maintain the border of the endemic's range.

8.3 Meaning/Perception

Endemism is a subject of growing interest and importance in biogeography, ecology and nature conservation management. The terms *endemism* and *endemic*, formerly limited to scientific circles, are now becoming wider currency amongst

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non-scientists in many countries and in many languages and are quoted in environmental protection laws and nature conservation measures all over the world.

The perception of *endemism* is geographically biased. Knowledge of endemism on marine islands that are popular tourist regions, for example, is often much better than in inaccessible terrestrial regions that lack any infrastructure. We hypothesise that this disparity in perception is related to the uneven distribution of scientific, economic and political effort, including tourism and scientific excursions.

Addressing this imbalance in perception as well as the general lack of knowledge on the endemism phenomena is vital for nature conservation management theory and practice. The education of young people is the foundation on which the future survival of species depends.

8.4 Quantification

Endemism can be quantified in different ways. The most popular measures are the absolute number (E) and the proportion (E/S) of endemic species. The number of endemics (E) in a region reflects the environmental and biological history including speciation processes and extinction events. The proportion (level, percentage) of endemics (E/S) is an indicator for geographic separation, genetic isolation and/or uniqueness of ecological conditions. Islands and archipelagos often have high rates of endemism. However, this does not necessarily mean that they have many endemics per unit area (density). For example, the density of endemics in the Eastern Arc Mountains and Southern Rift, Africa, is similar or a little higher than the density of endemics on the Hawaiian Islands. The rate of endemism, however, is c. 90 % in Hawaii but only 30 % in the Eastern Arc Mountains and Southern Rift. In this regard, regions with special habitat types, such as the area supporting the dry spiny bush in SW Madagascar, or unique ecological conditions, such as regions with serpentine soils, are very like oceanic islands; they are often ecologically isolated and covered by a vegetation with high levels of endemism.

Other, recently developed, parameters such as Range-Size Rarity (RSR) or Phylogenetic Analyses of Endemism (PE), when combined with the recent progress in molecular genetics, are likely to result in important innovations in landscape ecology and nature conservation practices.

8.5 Systematic Groups

Endemism develops over evolutionary timescales. Different phylogenetic groups exhibit different amounts of endemism within a given region. In general, systematic groups of vascular plants with high total species numbers also have high numbers of endemics. In many non-tropical regions, asteroids or Asteraceae is the taxonomic group with the highest number of both species and endemic taxa. Like the Orchidaceae, for example, this family is characterised by a high proportion of taxa that have wind-dispersed seeds. Thus, even though long-distance dispersal is a normal phenomenon, the two richest families in the world harbour very many species that are restricted to small regions. Factors other than mode of dispersal, such as pollination mode or competition with other taxa, can also limit the expansion of a taxon and explain its spatial restrictedness. Most taxa of Orchidaceae and Asteraceae are characterised by insect pollination. In Fabaceae and Myrtaceae, large plant families with many endemic species (e.g. in Australia), insect pollination is also common but wind dispersal of seeds is not.

Gymnosperms were the first seed-bearing plants on earth; they are much older than angiosperms. China has the richest flora of gymnosperms in the world – more than a quarter, and more than a tenth of the world's gymnosperms are endemic here. The proportion of Tertiary relict trees in central and southern China that are gymnosperms is higher than that of putative old angiosperm tree taxa, even though the overall diversity of gymnosperm trees is much lower than that of angiosperm trees. However, the family Asteraceae harbours more endemic taxa in China than any other plant family.

8.6 Genetics

Taxa that are restricted to small regions generally have a lower genetic diversity than more widespread congeners. Lower heterozygosity and genetic variation implies higher inbreeding levels and less ability to adapt to changing environmental conditions.

Reduced pollination, low fruit sets, and other problems of reproduction are often ecologically and not genetically controlled. However, most endemic vascular plant taxa do not show any problems with reproduction in their original habitat.

8.7 Increase of Endemism Over Time

Most, but not all, taxa start (and finish) their existence – branch of the phylogenetic tree – with quite a small range.

The high diversity of vascular plant taxa including endemics at regional scales seems to be related to long, uninterrupted evolutionary processes under relatively stable climate conditions and/or conditions that favour high evolutionary speed. Evolutionary speed depends on biological and environmental parameters: productivity, warmth, light and high precipitation rate might be relevant factors.

Most of the regions with high plant diversity are characterised by high environmental heterogeneity and habitat diversity. We assume that environmental heterogeneity (different aspect, gradient, substrate, water and nutrient conditions etc.) stimulates and promotes speciation. Furthermore, especially under changing conditions, environmental heterogeneity can ensure the local or regional survival of (endemic) species: under changing conditions, having a sufficient number of patches ensures that changes in one patch will not necessarily affect other patches and that there is therefore little or no net change over the landscape or ecoregion. For example, almost all the mid- or high altitudes of the Andes, Himalaya, Alps and other high mountain ranges were covered by Pleistocene glaciers, but the higher zones currently harbour many endemic vascular plants which had survived in the valleys or at lower altitudes during the height of the glaciations. Stability at this scale is nevertheless a stochastic phenomenon which involves local and regional processes, such as catastrophes, gap dynamics, successions and vertical displacement of the biota.

Geographical separation increases genetic isolation and thereby favours speciation processes. It also decreases dispersal opportunities. Many oceanic islands far from the mainland have a small species pool and gene pool; a small gene pool resulting from reduced dispersal and a small population size is a less favourable precondition for the evolution of new species. Thus, separation both promotes and limits speciation.

8.8 Decrease in Endemism Over Time – The Need for Conservation

Habitat loss, habitat degradation, habitat fragmentation, disturbance of habitat dynamics and biological resource use and pollution have all been identified as major drivers of species decline. Other factors such as climate change are of minor importance at the moment.

Nature conservation management needs to focus more on those threatened species which are restricted to small regions. Securing appropriate habitat conditions, including maintenance of traditional and sustainable resource use, is often the best protection from extinction.

Fortunately, while many groups of animals (e.g. small insects or large vertebrates such as whales) cannot be effectively safeguarded in zoos, almost all vascular plants could be protected in botanical gardens and indeed in horticulture in general. Only if plants have problems with reproduction or if they have very special ecological demands might conservation of these plant taxa become difficult. Having said that, gardening should be the exception and the last step adopted for the protection of threatened and endemic plant species.

8.9 Biogeography – Climate Zones

As expected, we can confirm that endemism (E, E/S, and other values) is high in the tropics, especially in the wet tropics, e.g. in tropical rainforests. However, other tropical landscapes and habitat types, such as those in extremely arid regions, are poor in endemic vascular plants. Endemism in most water bodies and wetlands in the tropics is also relatively low.

Endemism is also high in (not extremely) arid regions such as Namaqualand, parts of the Atacama or Socotra, for instance, and in regions with a Mediterranean climate, particularly in the more or less open shrub and dwarf-shrub formations. Other subtropical regions are also rich in endemics, for example in Southern Africa, Madagascar and the Brazilian Cerrado with their thickets, heaths, scrub and savanna.

In most temperate regions, endemism is low compared to subtropical and tropical climates but high in comparison to boreal-arctic zones. The highest endemism in temperate regions of the Holarctic is found in rocky habitats, screes, grasslands, heaths and other shrubby habitats. Endemism is low in water bodies and wetlands, as in water bodies and wetlands of most regions and climate zones of the world.

Endemism in boreal-arctic regions is very low, something which seems clearly related to glaciation cycles. However, to date this apparent fact has been explained by different and competing hypotheses. These take into account various historical and contemporary parameters and processes, environmental and biological constraints, and also include evolutionary, ecological and genetic aspects.

8.10 Biogeography – Altitudinal Zones

Endemism is normally higher in mountainous regions and lower in the lowlands. Central America, northern South America and South-West China, with their complex geology and high mountain ranges, are some of the most botanically diverse regions of the world. The *rate* of endemism (proportion of endemics) usually increases with altitude, whereas the belt with the highest *number* of endemics is found at mid- or low altitudes in mountain ranges.

However, exceptions to the rule also occur. Because of the Pleistocene glaciations, high latitude mountain ranges are also poor in endemics. Some flatland areas, notably the maritime chaparral of Baja California, the lowlands of Ecuador, the South-West of the Iberian Peninsula, various lowland regions of southern Africa, Madagascar and Australia are characterised by a high diversity of vascular plants and show rich endemism in combination with low or intermediate environmental heterogeneity.

8.11 Biogeography – Substrates

Vascular plant diversity and endemism in northern and Central Europe is higher on substrates with intermediate or high pH-values, although acidic substrates cover much larger areas in these regions. In other regions, the opposite is true e.g. in the Mediterranean climate regions of South-Western Australia and in the Cape Floristic Province. In these areas, most endemics occur on the very poor and acidic soils which represent the majority of substrates.

Serpentine soils, with high levels of heavy metals, low levels of nutrients, intermediate or high pH-values, and a low Ca/Mg ratio, often show high levels of endemism – serpentine endemics. Regions or countries with appreciable areas of serpentine outcrops, soils and serpentine endemism are e.g. eastern North America, Cuba, Brazil, Aegean Islands, Turkey, Zimbabwe, southern Africa, New Caledonia.

Thus, in some regions endemism is higher on dominant substrates, in other regions on non-dominant substrates.

8.12 Biogeography – Habitats

The richness of endemics associated with a certain habitat type can be discussed in the context of zonal, extrazonal and azonal vegetation types. *Zonal* vegetation types are controlled by climate. Such vegetation types sometimes have outlier occurrences in adjacent climatic zones but on special soils or landscape conditions; these are extrazonal. Azonal vegetation types are determined by local edaphic or hydrographic factors, such as aquatic vegetation, swamps, fens, bogs, salines, but also sparse vegetation of steep rock faces or mobile screes, etc. *Orobiomes* are the vegetation belts of mountain ranges, and *pedobiomes* are controlled by extensive edaphic factors.

The relationship between zonality and endemism is not clear. Some azonal vegetation types are very rich in endemics, e.g. on serpentine soils, which often give rise to sparse associations with many endemic plants. Rocky habitats of subalpine and alpine orobiomes which are strongly affected by both climate and substrate normally also harbour many endemic plants. In contrast, azonal vegetation types such as aquatic vegetation, or bogs, are normally poor in endemics. Different zonal vegetation types also differ remarkably with respect to endemism.

At the moment it is impossible to quantify habitat-related endemism in vascular plants at global scales, i.e. we do not know whether or not more endemic vascular plant taxa on earth occur in forest/woodland or in (semi-) open habitat types and landscapes, nor do we know whether or not most endemics are woody or herbaceous plants. And we do not know the proportion of annuals, perennials, epiphytes, shrub or tree species which have small distributional ranges.

However, for a few regions we can relate endemism to the array of ecological conditions and to habitat composition. The highest proportion of endemics associated with forest can be found e.g. in wet tropical regions of Middle America and northern South America (Ecuador), Madagascar, New Caledonia, and also on islands such as the Juan Fernandez and Madeira Islands.

In most Mediterranean climate regions the largest number of endemics occurs in heath, garigue, fynbos, kwongan, Chilean matorral, chaparral or thornbush including sparse units with a low vegetation cover on rocky ground.

We assume that rocks, screes, scrub, dwarf shrub habitats and grasslands of tropical, subtropical and temperate mountain ranges are in general relatively rich in endemics, whereas water bodies and wetlands, for example are normally poor.

8.13 Biogeography – Case Study Baja California/CFP

The California Floristic Province exhibits lower endemism than most other Mediterranean regions except for the Central Chile Hotspot. The formation of the arid deserts of Baja California and California over the last 10,000 years resulted in the emergence of several new ecotones where speciation is promoted via either 'synclimatic' or 'anticlimatic' migration. In Baja California the consistent presence of a stable fog zone has created a climate refugium through deep time that has both conserved ancient lineages and promoted the radiation of new lineages as water availability from precipitation has fluctuated. Whereas endemism normally increases with elevation, we see a narrow coastal band of very narrowly endemic plants at elevations below 500 m. Although fossil evidence for this region is very limited, it appears that chaparral was historically dominant, with the modern coastal scrub species previously existing as understorey elements. The coastal scrub we see today may be a very recent habitat type; this supports the notion that many of the micro-endemic plants found here are neo-endemics. The paleo-endemic taxa in the region are more often long-lived woody chaparral or tree species, although some genera appear to have radiated more recently as well. For example, *Arctostaphylos australis* is a putative palaeo-endemic taxon; however several seeder-*Arctostaphylos* species appear to have radiated recently as a result of changes in disturbance patterns, primarily shifting fire regimes with long-term weather patterns.

8.14 Biogeography – Case Study Ecuador, South America

Ecuador is one of the most endemic- and species-rich countries in the world, with two thirds of the country's area falling into two Biodiversity Hotspots: the Tropical Andes Hotspot and the Tumbes-Chocó-Magdalena Hotspot.

The main vegetation belts, in sequence from the coast to the highest mountains, are: mangroves, rain forest, wet to dry and deciduous forest, scrub paramo, other paramo types, rock and scree habitats.

A third of the endemics are in the Orchidaceae, less than 10 % belong to the Asteraceae. More than one third of the endemics are epiphytes, making these the largest group. The second largest group are shrubs or dwarf shrubs, followed by herbs, trees, lianas and vines, and finally others such as hydrophytes. In the regions of continental Ecuador most endemics (more than three quarters) are found in forest or woodland, with a minority occurring in paramo vegetation, including scrub paramo in the subalpine belt and other habitat types, such as scrub or thicket, in the dry parts of the Andes or in near-coastal South-West Ecuador.

The high number of endemics in such a small country occurs in a context of high spatial heterogeneity combined with more or less stable climate conditions over long time-periods. The relatively low endemism of the Amazonian part of Ecuador is most likely related to the lower topographical, geological and climatic heterogeneity there.

Many endemics are threatened by the same human activities in Ecuador as in many other parts of the wet tropics: deforestation and destruction of habitats by the expansion of arable land, settlements and roads, the extraction of oil, and so on. The potential threat from global warming cannot be quantified.

8.15 Biogeography – Case Study Europe

In Europe, rock and scree areas harbour the highest number of endemic vascular plant taxa. The second largest group of endemics is found in grassland, followed by scrub and heath, forest, arable land, ruderal and urban habitats, coastal/saline habitats, freshwater habitats, and finally mires and swamps.

In general, the diversity of endemic taxa increases from North to South and from flatlands with low environmental heterogeneity to mountain regions with high heterogeneity. Notwithstanding the general trend, the distribution patterns of wetland endemics in Europe do not show a clear North-South gradient. The highest wetland endemism occurs in temperate western Europe, including the Alps, with very low endemism in some southern, eastern and northern regions of Europe.

The East of Europe shares many taxa with the West of Asia. Many landscapes, habitat types and ecological conditions are quite similar to the West and East of the border between Europe and Asia. The southern part of the continental border, in particular, is artificially defined. Thus, the marginal regions bordering Asia necessarily have fewer endemics than comparable regions close to the Atlantic Ocean or Mediterranean Sea.

However, some of the most serious nature conservation problems concern grassland ecosystems. This is because most European grassland habitats are threatened by both abandonment – the cessation of livestock grazing or mowing – and intensification/ploughing. In Europe, the use of farmland is heavily influenced by payments made under European Union schemes. Changing these policies is essential, with payments being shifted from continuing to support productivity to supporting biodiversity and other environmental objectives. In the absence of such a change, the European Union will fail to achieve its environmental goals, specifically the halting of biodiversity loss.

8.16 Biogeography – Case Study Great Escarpment, Southern Africa

Southern Africa includes both tropical and sub-tropical regions of endemism, with the highest concentration in the exceptionally rich Cape, fynbos of the south-western Cape, which has a mediterranean climate and fringes the adjacent dry lands with sharp ecotones. High endemism is also associated with the Great Escarpment and its coastal forelands. While many factors affect endemism in this region, the strongest cause of endemism appears to be long-term climatic stability from reliable winter rainfall in the southern and western areas and a stable moisture regime from orographic rainfall and the ameliorating effects of altitude on the Escarpment itself. While substrate does play an important role in local endemism on e.g. ultramafic and ultrabasic geologies, it appears to be localised on specific substrates as a secondary causal factor or in response to high soil toxicity.

8.17 Biogeography – Case Study Madagascar

Madagascar is the fourth largest and most likely the oldest island in the world. Its environmental heterogeneity and habitat diversity is low or intermediate in most parts of the island. The outstanding plant and animal richness of Madagascar can be explained by the age of the geological surface, by the fact that Madagascar is of continental origin and by its long and uninterrupted evolutionary history. The level of endemism among the indigenous vascular flora is calculated as four-fifths or more. The flora is predominantly woody, and most endemics occur in forest ecosystems, woodlands and thickets.

Madagascar has a peripheral ring of lowland to montane forest surrounding an upland that is covered by fire-simplified grassland and savanna. The largely degraded and depauperated open landscapes are dominated by a few cosmopolitan fire-adapted grasses. The remaining primary vegetation, species richness and endemism are therefore concentrated in near-coastal rather than inland regions.

The human population is still growing, and man is destroying the natural habitats even in protected areas. The island's problems include burning, livestock grazing, deforestation and the selective cutting of particular tree species, e.g. of *Diospyros* (black timber), *Uapaca* spp. (red timber), and other tree species in the remaining humid forest areas. The impact of global warming or invasive plants currently seems to be low or insignificant.

8.18 Biogeography – Case Study China

In the rugged mountainous subtropical regions of central and southern China, a considerable number of Tertiary relict trees have survived. These regions were never covered by a single large ice-sheet; during the Pleistocene the climate was less severe than in other parts of the Northern Hemisphere, where it was cold and dry and glaciations were extensive. Since surviving the cold period, the relicts have had to contend with other, apparently often more competitive species. In the subtropical zone, most phylogenetically primitive taxa, which are classified as palaeoendemics, that were once widespread across the Northern Hemisphere (exemplified by the gymnosperms *Ginkgo biloba*, *Glyptostrobus pensilis*, *Metasequoia glyptostroboides*, *Cathaya argyrophylla*, *Cunninghamia lanceolata*, *Taiwania cryptomerioides*, and the angiosperms *Camptotheca acuminata*, *Davidia involucrata*, *Eucommia ulmoides*, and *Tapiscia sinensis*) now grow only in unstable habitats in central and southern China; on steep slopes, scree slopes, rocky or limestone areas, stream sides, and river deltas. Those relict trees are pioneer, shade-intolerant, and long-lived species. Natural disturbances may play a chief role in their persistence in unstable habitats where competition from other plants is limited. A broad zone of modern tree species on the more stable ground creates a soft boundary that does not allow long- or intermediate-distance dispersal of the older taxa. It might be that regional and local climate conditions such as combinations of annual dry/wet and hot/cold periods also prevent the successful dispersal of the endemics.

In SW China the most derived group of asteroids has the largest number of endemic species, accounting for nearly half of the total number of endemic species. This is consistent with the floristic composition of endemism in East Asia and North America at the genus level. Endemic plant species in SW China are largely concentrated in the major mountains of the west, whereas lower mountains and flat areas in the east have a low density of endemic species. The high endemism in the mountainous regions is probably due to the high speciation and low extinction rate, and in particular to the presence of refugia during the Pleistocene glacial episodes.