Chapter 5
Biogeography of Endemic Vascular Plants – Overview

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5.1 Latitudinal, Longitudinal, Radial and Altitudinal Gradients in Endemism

The overall taxonomic diversity of vascular plants is low towards high latitudes and high towards the tropics. This latitudinal gradient is, in general, also true for endemic vascular plant taxa. A large number of processes which might be responsible for latitudinal gradients of species diversity have been discussed and tested. These include processes such as productivity, competition or mutualism, as well as dispersal, genetical isolation, geographical separation, speciation, survival and extinction processes (Jansson 2003; Gaston 1996; Pianka 1966). Thus, it is clear that environmental heterogeneity and contemporary and historical climate parameters are important factors explaining regional to continental patterns of diversity, independent of the fact that the underlying processes are not yet fully understood.

In contrast to latitudinal or altitudinal gradients, longitudinal and radial gradients of species diversity (cf. Huston 1994) are often not recognised or non-existent. However, hardly any biodiversity hotspots and endemic-rich regions are located far from the sea. Exceptions to this rule are found in Asia (Caucasus, Himalaya and SW China; cf. Huang et al. 2011a, b; Mittermeier et al. 2005; Davis et al. 1994, 1995, 1997).

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The inverse richness gradients of endemism from the coasts to the central parts of the continents often reflect a climatic gradient of decreasing humidity and increasing amplitude between summer and winter temperature.

Latitudinal and altitudinal patterns and gradients have often been compared with regard to ecology and biodiversity. The richness of all vascular plant taxa declines with latitude and altitude as well, and biogeographers have long recognised that the altitudinal gradient of biodiversity and climate mirrors the latitudinal gradient (Körner 2000). Stevens (1992) has shown that total maximum species diversity along an altitudinal gradient is often found towards the lower end of the elevation. This finding is compatible with the view that tropical climates harbour the highest biodiversity.

However, the mirror does not work perfectly (see Körner 2000 also for differences of latitudinal and altitudinal richness patterns). The alpine zone in mountain areas of the tropics is climatically different from arctic regions in the North or South because, for example, the amplitudes of temperature, light, vegetation period and also precipitation can differ remarkably if one compares average winter and summer or night and day values in these regions. One of the biologically most important differences between the climate of tropical alpine zones and arctic regions is that the tropics have warm days, cold nights and long vegetation periods whereas the winter of arctic regions is cold and long and the vegetation period is short.

In many temperate, subtropical and tropical regions endemism peaks at mid-altitudes; this does not reflect the altitudinal distribution of vascular plants in total which, in general, shows highest diversity at the lower end of the altitudinal gradient.

The interval of maximum endemic species richness – in absolute numbers – in Nepal is between 3,800 and 4,200 m (Vetaas and Grytnes 2002), in SW China 1,000–2,000 m (Huang et al. 2011a, b), in Taiwan 0–1,500 m (Hsieh 2002), in Peru 2,500–3,000 m (Van der Werff and Consiglio 2004), and in Ecuador 1,300–2,500 m (assessment of the list given in Valencia et al. 2000). Endemics of Corsica, in the Mediterranean, are also concentrated at intermediate levels of elevation between 1,000 and 1,800 m (see figure 48 in Hobohm 2000a). In Europe, endemics of rocks and screes are concentrated between 500 and 1,800 m, grassland endemics peak between 550 and 2,100 m, endemics of scrub and heath formations between 200 and 1,550 m, forest endemics between 300 and 1,500 m, endemics of coastal and saline habitats, arable land, ruderal habitats and settlements at altitudes between 0 and 1,200 m, endemics connected to freshwater habitats, mires, swamps, fens and bogs between 100 and 1,750 m (Hobohm and Bruchmann 2009).

We assume that the higher altitude of maximum endemism in contrast to total taxonomic diversity is related to both the stricter separation/isolation of the high mountain zones and the higher total species diversity at lower altitudes which is the basis for evolution and dispersal (cf. Hobohm 2008b; Vetaas and Grytnes 2002). Interestingly, in continental SW China and in Taiwan (Huang et al. 2011a, b; Hsieh 2002) the number of endemics and the total number of vascular plant taxa seem to peak at the same altitudinal zone in the lowlands, whereas in most other regions endemism peaks at higher elevations than overall diversity.

The number of endemics found in an altitudinal zone is also a function of the area and climate of each zone and depends on maximum elevation. These factors might

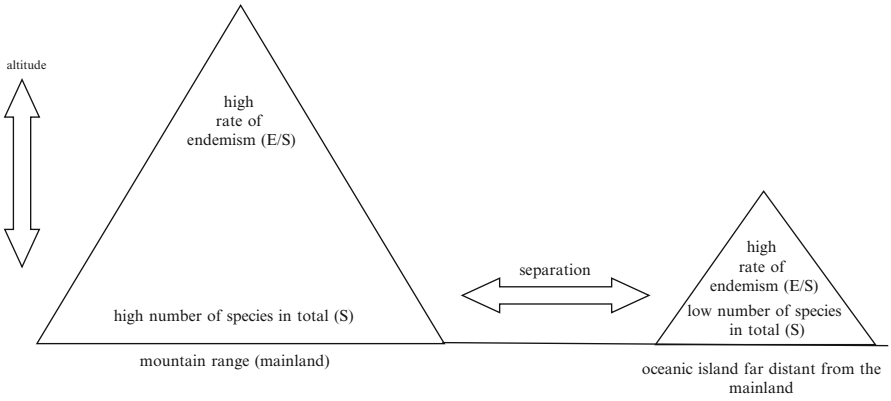

Fig. 5.1 High rates of endemism and total species richness. In the case of oceanic islands far distant from the mainland, a high ratio (E/S) is often combined with a relatively low number of species in total (S)

explain the differences in the maxima in the two neighbouring countries Ecuador and Peru. The coastal zone of Ecuador is relatively large relative to the whole size of the country. This zone is part of the Tumbes-Chocó-Magdalena Hotspot (Mittermeier et al. 2005) and very rich in endemics. The altitude of maximum endemism in Peru is more elevated because the coastal zone is small, extremely dry and relatively poor in endemics (Van der Werff and Consiglio 2004).

The rate of endemism (as a percentage of all taxa) in a mountain range normally increases continuously with altitude. This finding is not in conflict with the patterns discussed above showing that absolute numbers of endemics peak at intermediate or lower altitudes in most cases. The increasing rates in high mountain areas are comparable with values for oceanic islands which are highest far distant from the mainland (Fig. 5.1). However, the altitudinal gradient of the proportion of endemics (in %) is normally not mirrored by a latitudinal gradient (Hsieh 2002; Dhar 2002; Vetaas and Grytnes 2002; Hobohm 2000a; Talbot et al. 1999).

Stebbins and Major (1965: 16) analysed the endemic flora of California and concluded that

> *"...a high degree of endemism is found in those regions having a great variety of plant habitats."*

Hendrych (1982) examined the diversity of endemic plant species in Europe. He concluded that endemics are concentrated in high mountain areas such as the Alps, Sierra Nevada and Greater Caucasus, which are characterised by high habitat diversity.

At regional to continental scales, the diversities of higher plant species and endemic species increase with increasing habitat diversity. Areas with high habitat diversity generally also have high species diversity, although this is not always the case (cf. Cowling and Lombard 2002; Trinder-Smith et al. 1996; Huston 1994).

The main reasons are positive effects such as the number of speciation processes caused by a greater species pool and the avoidance of negative influences, including

anthropogenic impacts, which are more effective in habitat-poor than habitat-rich environments. It is more likely that suitable habitats will remain in habitat-rich as compared to habitat-poor regions.

Habitat diversity is not an obligatory precondition for the coexistence of (endemic) species under stable ecological conditions. This finding does not question the positive effects of spatial heterogeneity for endemism. Spatial heterogeneity might be primarily important for the survival of species under changing climate conditions.

On the other hand, it is very easy to find high-elevation and habitat-rich ecoregions with relatively poor endemism. For example, mountain areas in northern North America, South Chile and Argentina, Norway, Central Australia, and the Cape Verde Islands are such regions. All these areas have been influenced by strong climate change, the northern and southern territories by Pleistocene glaciation cycles, Central Australia and the Cape Verde Islands by several dramatic cycles of wet and dry periods during the Quaternary (Crisp et al. 2001; Brochmann et al. 1997; Hendrych 1982).

Size of area, which is a factor often strongly correlated with the diversity of (endemic) species (see e.g. discussion in Körner 2000; Rosenzweig 1995a, b), has similar effects. According to Rosenzweig's area hypothesis the size of geographic area is responsible for the latitudinal gradient of species diversity. This hypothesis is based on the fact that the tropics, as the largest zone and having a continuous cover stretching into the northern and the southern hemisphere, can host species with larger range sizes, resulting in higher speciation rates and lower extinction rates (cf. Rohde 1992; Rapoport 1982). But, as the discussion of Chown, Gaston and Storch (Chown and Gaston 2000; Storch 2000) has shown, too little is currently known about range sizes of species in a given latitudinal gradient or in a humidity gradient. And actually, such gradients may divide the tropics into a larger number of different wet to dry ecozones than higher latitude areas (e.g. Bailey 1998). We are not aware of any studies that have tried to examine range size differences of vascular plant taxa in relation to area size of different climate zones or ecoregions.

However, area as a driver of biological processes means very little (cf. Ricklefs and Lovette 1999; Buckley 1985; MacArthur and Wilson 1967; Abbott 1977). But, in the context of negative influences on biodiversity in combination with a variety of environmental conditions area becomes important for the probability of the survival of individuals and populations. Survival of the biota in large regions under changing conditions depends on having a sufficient number of patches so that changes in one patch will not affect other patches, and consequently there is only little or no net change over a large area. For example, almost all the mid- and high altitudes of the Alps were covered by Pleistocene glaciers. But, the Alps harbour many endemic vascular plants which survived in the valleys or in the foothills of the Alps close to the Mediterranean Basin. Stability at this scale is a stochastic phenomenon where local and regional processes such as catastrophes, gap dynamics and successions are involved, and is different from the deterministic mathematical equilibrium of the competitive exclusion principle.

5.2 Oceanic Islands, Continental Islands and Mainland Regions

Oceanic islands are defined by their origin and development within the marine environment. When an oceanic island rises above sea level, colonisation from other islands or mainland regions can begin. All plants which are endemic to an oceanic island must have been developed and evolved in three steps: (i) dispersal of ancestors, which in the case of a great distance is an improbable event, (ii) establishment of a founder-population which normally involves finding adequate ecological conditions and overcoming a genetic bottleneck, and (iii) speciation processes on the basis of a reduced genepool and genetic drift in an environment which is more or less different from the original habitat. Because of reduced dispersal across the sea, oceanic islands are often relatively poor in total species numbers. On the other hand, isolation favours speciation. Thus, the percentage of endemics can be high.

In contrast, continental islands were by definition part of the mainland before they became separated. When they first became islands they were normally already covered by vegetation. This is the reason why continental islands do not normally reach high rates of endemism. Because of the larger species pool the conditions for increasing endemism are favourable compared to oceanic islands, and continental islands, in general, are not poorer in endemic vascular plant taxa than oceanic islands.

Unlike islands, mainland regions do not have clear natural borders, such as a coastline, everywhere. Biogeographical information about countries such as Austria or Switzerland is often much better than information related to mountain ranges which belong to two or several countries, such as the Alps. This is the reason why terrestrial ecoregions are often analysed with a strong focus on countries.

5.3 Habitats

Endemic vascular plants are found in diverse habitat types in almost all tropical, subtropical, temperate, boreal and arctic climate zones of the world. Tables 5.1, 5.2, 5.3, 5.4, and 5.5 present examples of regions with the respective numbers of endemics and information about the main physiognomic habitat types to be found there. Many of the examples show a relatively high total number of endemic species. This might be a result of the major scientific effort, especially in species-rich areas, and overestimations due to taxonomic double, or even triple, identity or to the revised taxonomic status of species (Kier et al. 2005; Yena 2007). We assume that the scientific effort into biogeography in general is greater where biodiversity is high or unique.

Table 5.1 Examples of biodiversity hotspots, ecoregions and landscapes with numbers of endemic vascular plants and the main habitats in various parts of the Americas (partly nested or overlapping), from North to South or West to East, respectively

Region (country or archipelago, area in km^2)	Total numbers of endemic vascular plant taxa (note that the term species is often used in the meaning of species plus subspecies)	Description of biomes, main formations, or vegetation units	Reference
California Floristic Province (Oregon, California, Mexico; 293,804)	2,124–2,133 species	Many different forest types, shrubland, coastal dunes, coastal salt marshes, maritime chapparal, savanna, coastal prairie scrub, vernal pools, freshwater marshes; 189 endemics are strictly confined to serpentine areas.	Kruckeberg (1992), Raven and Axelrod (1978), Davis et al. (1997), Mittermeier et al. (2005)
Klamath-Siskiyou Region (Oregon, California; 55,000)	280 taxa	Mixed evergreen, montane and subalpine forests, also serpentine vegetation.	Davis et al. (1997)
Vernal Pools (California, Mexico; 20,000)	c. 140 species	Ephemeral pools and vernal lakes with concentric rings of standing water-connected vegetation types (many annuals).	Lazar (2004), Keeler-Wolf et al. (1998), Zedler (1990), Holland and Jain (1988)
Sonoran Desert (USA, Mexico; 310,000)	650 species	Semi-desert vegetation dominated by succulent plants, shrubs, hemicryptophytes and therophytes.	Major (1988), Davis et al. (1997), Breckle (2000)
Mojave Desert (USA; 140,000)	138 taxa	Semi-desert vegetation dominated by shrubs, perennials and therophytes. Creosote bush in which the most common dominants are *Larrea tridentata* and *Ambrosia dumosa*, covering 70 % of the desert.	Stebbins and Major (1965), Davis et al. (1997), McGinley (2008i)
Central Highlands of Florida (USA; 10,000)	8 species and subspecies, plus 35 species and subspecies endemic or subendemic to Florida and whose centre of distribution is the Central Highlands	Xerophytic scrub vegetation with evergreen oaks and sand pine.	Davis et al. (1997), McGinley (2007c)

California Floristic Province of Baja California (California, Mexico; 14,000)	172 taxa, 67 near-endemics	Succulent scrub and chaparral, at higher elevations also rocky habitats, only few endemics in riparian habitats or permanent oases (such as *Brahea armata*).	O'Brien in Sula Vanderplank (Chap. 7, this book)
Baja California (Mexico; 143,396)	740 species	Tropical deciduous dry forest, conifer forest, winter-rain Mediterranean chaparral, coastal sage scrub, microphyllous scrub, coastal vegetation, desert scrub communities.	Davis et al. (1997), Riemann and Ezcurra (2005, 2007)
Madrean Pine-Oak Woodland (Mexico, small parts of the USA; 461,265)	<3,975 species	*Pinus*, oak and *Abies* forest, mixed pine-oak forest, cloud forest.	Mittermeier et al. (2005)
Montane Forests of Sierra Madre del Sur (South Pacific region of Mexico; 9,000)	16 species (to Guerrero) and 161 species (to Mexico)	Oak forest (1,900–2,500 m); cloud forest (2,300 m); pine-oak forest (2,400–2,500 m).	McGinley (2007g)
Coahuila and adjacent areas (Mexico; c. 17,500)	350 (subendemic) species	Desert shrubland is the dominant vegetation type (highest endemism) pine and oak forest are also rich in endemic species.	Villarreal-Quintanilla and Encina-Dominguez (2005)
Mesoamerica (from central Mexico to Panama; 1,130,019)	>2,941 species	Tropical and subtropical rain forest, moist, seasonal, dry forest formations, montane forest, grassland, mangrove, semi-desert and thornscrub.	Mittermeier et al. (2005)
Uxpanapa-Chimalapa Region (Mexico; 7,700)	>47 species	Evergreen, semi-evergreen and semi-deciduous tropical rain forests, montane rain forest, pine and pine-oak forests, xeric vegetation.	Davis et al. (1997)
Tehuacan-Cuicatlan Region (Mexico; 9,000)	810 taxa	Several dryland scrub formations with many species succulent, spiny or thorny, or forming rosettes; deciduous forest.	Davis et al. (1997)

(continued)

Table 5.1 (continued)

Region (country or archipelago, area in km^2)	Total numbers of endemic vascular plant taxa (note that the term species is often used in the meaning of species plus subspecies)	Description of biomes, main formations, or vegetation units	Reference
Cuatro Cienegas Region (Mexico; 2,000)	23 species	Grassland with aquatic, semi-aquatic and gypsum-dune habitats in valley, desert scrub and chaparral, oak-pine woodlands, and montane forests of pine, fir and Douglas fir.	Davis et al. (1997)
La Amistad Biosphere Reserve (Costa Rica, Panama; >10,000)	3,000 species	Ten life zones in altitudinal gradient from tropical humid forest to subalpine rain paramo.	Davis et al. (1997)
Cerro Azul-Cerro Jefe Region (Panama; 53)	45 species	Tropical premontane wet forest, tropical wet forest, tropical premontane rain forest.	Davis et al. (1997)
Sierra Nevada de Santa Marta (Colombia; 12,232)	125 species	Three endemics are located in equatorial forest, 32 species in sub-andean-forest; 29 endemic species in Andean forest, 61 endemic species in paramo.	Davis et al. (1997), Carbonao and Lozano-Contreras (1997)
Coastal Cordillera (Venezuela; 45,000)	c. 500 taxa	Mangroves, coastal thorn scrub, hill savanna, deciduous forest, semi-deciduous lower montane forest, evergreen lower montane forest, evergreen montane cloud forest (highest endemism), upper montane elfin forest, upper montane scrub.	Davis et al. (1997)
Tropical Andes (from western Venezuela to northern Chile and Argentina; 1,542,644)	c. 15,000 species	Tropical wet, cloud, moist and dry forests, woodlands, scrub ecosystems, high altitude grasslands, many other habitats.	Mittermeier et al. (2005)
Tepuis ecoregion (Venezuela, Guyana, Suriname, Brazil; 3,260–7,000)	766 species	Forest, savanna, montane shrubland, grassland, rivers, waterfalls, cliffs, rock communities.	Steyermark (1986), Huber (1995), Davis et al. (1997), McGinley (2008g)

Tumbes-Choco-Magdalena (Peru, Ecuador, Colombia, Panama; 274,597)	2,750 species	Dry, moist and wet forest, rain forest, scrub, mangrove areas, beaches, rocky shoreline, desert vegetation.	Mittermeier et al. (2005) (see also Davis et al. (1997))
Continental Ecuador (275,680)	3,834 species	Mangroves, different coastal forest and scrub types, lowland rainforest, other wet to dry forest types, wet to dry and scrub paramo. Most endemics are associated in forest.	Valencia et al. (2000), Davis et al. (1997)
Caatinga of north-eastern Brazil (Brazil; 70,000–1,000,000)	c. 360 species	Low shrubby caatinga (up to 1 m tall) to tall caatinga forest (up to 30 m tall).	Davis et al. (1997), McGinley (2007b)
Cerrado (Brazil; 2,031,990)	4,400 species	Dry forest, woodland savanna, other savanna types, scrub grassland, open grassland; the herbaceous species are almost totally endemic.	Mittermeier et al. (2005), Pennington et al. (2006)
Atlantic Forest (Mata Atlantica: Brazil, Paraguay, Argentina, Uruguay; 1,233,875)	8,000 species	Lowland forest, woodland of the coastal plain, slope forest, high- altitude woodland, grassland or 'campo rupestre' (rocky grassland).	Mittermeier et al. (2005)
Chilean Winter Rainfall Valdivian Forests (Chile, Western Argentina; 397,142)	1,957 species	Dry desert communities (30 % of the area), sclerohyllous matorral and forest (30 %), decidous forest (15 %), Andean-Patagonean forest (4 %), broad-leaved rainforest (1 %), high elevation alpine vegetation (20 %).	Mittermeier et al. (2005)
Anconquija Region (Argentina; 6,000)	80–400 species	Different forest types from winter-dry rain forest to temperate cloud forest, Andean paramo-grassland, high Andean vegetation, spiny shrubland with tree cacti, semi-arid shrubland.	Davis et al. (1997)
Peninsula Valdes (Argentina; 3,600)	38 species	Predominant vegetation is Patagonian desert steppe, including e.g. tussock grasslands, xerophytic cushion grasses.	Clough (2008)

Table 5.2 Examples of biodiversity hotspots, ecoregions and landscapes with numbers of endemic vascular plants and the main habitats in various parts of the Atlantic Ocean and Caribbean (partly nested or overlapping), from North to South or West to East, respectively

Region (country or archipelago, area in km^2)	Total numbers of endemic vascular plant taxa (note that the term species is often used in the meaning of species plus subspecies)	Description of biomes, main formations, or vegetation units	Reference
Caribbean Islands (228,000–240,000)	6,550–7,920 species	Dry evergreen bushland and thicket, savanna, woodland, seasonal, montane, moist tropical forest, lowland rain forest, brackish and freshwater swamp, mangrove forest, many other habitats.	Davis et al. (1997), Mittermeier et al. (2005), Gillespie and Clague (2009), Anádon-Irizarry et al. (2012)
Cuba (108,722–110,860)	3,226–3,421 species	Different wet to dry forest types, woodland, swamps and gallery forests, thorny thickets, savanna, wetlands, coastal habitats, cultivated land. 23 % of the area is covered by forest, 24 % by shrublands and savanna, 44 % by cropland and crop/natural vegetation mosaic, 0.4 % by urban and built-up habitats, and 9 % by wetlands and water bodies including sea, brackish and freshwater habitats.	Davis et al. (1997), WRI (2003), Republica de Cuba (2009), Foster et al. (2012)
Cajalbana Tableland and Preluda Mountain region (Cuba; 100)	40 species	Pine forests, thorny xerophytic thickets, some gallery forests.	Davis et al. (1997)
Coast from Juragoa to Casilda Peninsula; Trinidad Mountains; Serra del Escambray (Cuba; 2,700)	40 species	Succulent and evergreen scrub thickets, including cacti, evergreen and semi-deciduous forests, seasonal and montane forests at higher elevations.	Davis et al. (1997)
Jamaica (10,990–11,425)	800–923 species	Different wet to dry forest types, sandy savanna (small areas), swamps dominated by palms, tall grasses and sedges, cultivated ground, coastal habitats with mangroves, dunes and rocks.	Davis et al. (1997)

		Fifty-eight percent of the area is covered by forest, 23 % by shrubland, savanna and grassland, 11.4 % by cropland and urban habitats, and 7 % by wetlands and water bodies including sea, brackish and freshwater habitats.	WRI (2003), Pryce et al. (2008)
Blue and John Crow Mountains (Jamaica; 782)	87 species	High altitude shrubby "elfin" woodland with bryophytes and lichens (2,000 m and higher), lower and upper montane rain forest, montane scrub, tall-grass montane savanna, cliff and landslide vegetation, cultivated ground.	Davis et al. (1997)
Cockpit Country (Jamaica; 430)	101 species	Evergreen seasonal forest, mesic limestone forest and degraded limestone forest, limestone cliff and landslide vegetation, pastures and agricultural crops in valleys.	Davis et al. (1997)
Hispaniola (76,190–76,261)	c. 1,445–2,016 species	Different wet to dry forest types (33 % of the area), thickets with cacti, humid savanna and primary dry grassland (together 25 % of the island), rocky and sandy coastal habitats. 27 % of the area is cropland and crop/natural vegetation mosaic, and urban habitats, and 13 % is wetlands and water bodies.	Bolay (1997), Davis et al. (1997), WRI (2003)
Bermuda (UK; 53)	15 species	Mangrove (without endemics) and woodland. Most endemics are connected to woodland, 1 to caves.	Sterrer (1998), McGinley (2007a), WRI (2003)
Greenland (2,180,000)	15 taxa	Different tundra vegetation types dominated by cryptogams, hemicryptophytes or chamaephytes, coastal vegetation including salt marsh and patches of mires, small stands of birch trees up to 7 m in the South of the island.	Groombridge and Jenkins (2002), Daniels et al. (2005), Lepping and Daniels (2006)

(continued)

Table 5.2 (continued)

Region (country or archipelago, area in km^2)	Total numbers of endemic vascular plant taxa (note that the term species is often used in the meaning of species plus subspecies)	Description of biomes, main formations, or vegetation units	Reference
Atlantic Ocean Islands (Ascension, Azores, Canary Islands, Cape Verde, Iceland, Madeira Islands, St. Helena, Tristan da Cunha; 117,804)	881 species	Laurisilva forest, dry conifer forest, other forest types, succulent scrub, other scrub communities, heath, swamps, rocky habitats, cliffs, coastal habitats.	Davis et al. (1994), Pott et al. (2003), Schäfer (2005a, b)
Azores (Portugal; 2,250)	80 taxa (72 species, subspecies and varieties, 8 hybrids)	Laurisilva (very reduced), montane cloud forest, shrubland, grassland, several communities on volcanics, wetlands, littoral communities. Fifty-seven or more endemics inhabit rocky habitats, cliffs, lava flows, ravines, steep slopes or volcanic craters, 34 are connected to juniper, laurel or *Pittosporum* forest and scrub, 18 endemics occur in littoral habitats, 3 in grasslands, 6 in freshwater habitats, 2 in bogs, and 4 in anthropogenic habitats (many of them in more than one habitat group).	Davis et al. (1994), Schäfer (2005a, b), Gillespie and Clague (2009)
Madeira Archipelago incl. Salvage Islands (Portugal; 815)	141 taxa (125 species, 26 subspecies)	Fourteen or more taxa in freshwater habitats and swamps, 36 in coastal habitats, 12 in cropland, ruderal and urban habitats, 4 in grasslands, 88 in rocky habitats and cliff communities, 23 in scrub and heath, 43 in forests (many of them in more than one habitat group).	Davis et al. (1994), Borges et al. (2008), Hobohm, data base in progress

Canary Islands (Spain; 7,542)	545–650 species and subspecies	Coastal vegetation, dry lowland with succulent scrub, thermophilous lowland, laurel and montane pine forest, montane scrub, rocky habitats. One endemic species occurs in freshwater habitats, 44 taxa in coastal areas, 22 in cropland, ruderal and urban habitats, 388 in rocky habitats and cliff communities, 239 in scrub, heath and succulent dominated communties, and 96 in forests (many of them occur in more than one habitat type, other endemics are not confined to habitat types, yet).	Davis et al. (1994), Pott et al. (2003), Hobohm, data base in progress, counts based on Izquierdo et al. (2004)
Tenerife (Canary Islands, Spain; 2,043)	134 species and subspecies	Rocks and screes (largest proportion of endemics), scrub, heath, succulents (second large proportion), forest (laurel forest, *Pinus canariensis* forest and other types), coastal and saline habitats.	Hobohm and Moreira-Muñoz (this book) based on counts in Izquierdo et al. (2004)
Cape Verde Islands (4,033)	82 (sub) species	Dominant vegetation types are open grassland and semi-desert, coastal habitats, shrubland and other vegetation types subdominant or in small patchesOf the endemic taxa, 31 are hygrophytic, 34 mesophytic and 17 xerophytic.	Davis et al. (1994), Brochmann et al. (1997), Duarte et al. (2008)
Sao Tomé and Principe (1,001)	148 taxa	Mangroves, low altitude forest (<800 m asl.), secondary forest, dry forest, shade forest for cocoa and coffee, shrublands and grasslands, mountain forest (800–1,400 m asl.), mist forest (1,400–2,024 m asl.).	Juste and Fa (1994), Davis et al. (1994), Nau (2003), Ministry for Natural Resources and the Environment (2007)
St. Helena (British Dependent Territory; 122)	50 species	Tree fern thickets, forestry plantations, rocks, semi-desert, various introduced shrub communities, cattle pasture and abandoned New Zealand flax (*Phormium tenax*) plantations.	Davis et al. (1994), Gillespie and Clague (2009)

(continued)

Table 5.2 (continued)

Region (country or archipelago, area in km^2)	Total numbers of endemic vascular plant taxa (note that the term species is often used in the meaning of species plus subspecies)	Description of biomes, main formations, or vegetation units	Reference
Tristan da Cunha Islands (UK; 159)	40 species	Tussock grassland in coastal areas, fern bush vegetation interspersed with single trees (300–500 m), wet heath with ferns, sedges, grasses, angiosperms, and mosses (up to 800 m), peat bogs with *Sphagnum* in depressions (above 600 m), feldmark and montane rock communities (above 600 m).	Davis et al. (1994), Ashworth et al. (2000)
Gough Island Wildlife Reserve (South Atlantic Ocean, including Inaccessible Island, UK; 75)	4 species	Tussock grassland (100–300 m), vegetation of fernbush with shrub (up to 500 m), wet heath (800 m), peat bogs (above 600 m).	Cooper and Ryan (1994), McGinley (2008c)
Falkland Islands (UK; 12,173)	15 species	Coastal margins with rocks, dunes and tussac grassland, acid grassland, dwarf shrub heath with ferns, scrub, feldmark and inland rocks, bogs and fens, standing and running waters, non-native habitats (arable and horticultural land, coniferous woodland).	Ashworth et al. (2004)

Table 5.3 Examples of biodiversity hotspots, ecoregions and landscapes with numbers of endemic vascular plants and habitats in various parts of Europe and Africa (partly nested or overlapping), from North to South or West to East, respectively

Region (country or archipelago, area in km^2)	Total numbers of endemic vascular plant taxa (note that the term species is often used in the meaning of species plus subspecies)	Description of biomes, formations, or vegetation units	Reference
Europe (from Canary Islands to Ural Mountains, from Iceland and Svalbard to Cyprus, Caucasus and Asian Turkey excluded; c. 10,500,000)	6,250–6,500 taxa (c. 165 groups of microspecies, 5,250–5,500 species, 850 subspecies)	At least 2,772 endemics occur (also) in rocky habitats, 1,320 in grassland, 1,125 in scrub/heath, 773 in forest, 450 in coastal habitats, 413 in urban and agricultural lands, 266 in freshwater habitats (including connected habitats such as embankments), 104 in bogs/mires/fens (wide overlap, not all endemics assigned to habitat types yet). Large areas in Europe are covered by agricultural land, urban habitats and forests (together $\gg$50 % of the area) whereas grasslands, coastal and saline habitats, freshwater habitats, bogs, mires and fens, or rocks and screes only represent sizes of <10 %.	Hobohm (2004, 2008a, b), Hobohm and Bruchmann (2009)
		Many more taxa – 4–7 times – are basiphilous than acidophilous, but many are indifferent.	
		Mean number (median value) of regions per endemic is 1 (of 42) for rocky habitats, scrub/heath and coastal habitats, 2 for forests, agricultural lands and urban habitats, and freshwater habitats, and 3 for grasslands and bogs/mires/fens.	Hobohm, EvaplantE in progress
Nordic regions in Europe (from Denmark to Svalbard and Iceland to NW Russia; c. 1,750,000)	180 species, subspecies, varieties and hybrids	More or less open ground in the alpine belts (Scandes: 47 endemics) and on the alvars (Gotland and Öland: 20 endemics), heathland or rocky habitats (Iceland: 10 endemics), coastal habitats (Arctic coasts: 8 endemics, Baltic shores: 30 endemics), dunes and sea-facing hillsides (Jylland: 4 endemics). Another 61 endemics occur in Norden.	Jonsell and Karlsson (2004)

(continued)

Table 5.3 (continued)

Region (country or archipelago, area in km^2)	Total numbers of endemic vascular plant taxa (note that the term species is often used in the meaning of species plus subspecies)	Description of biomes, formations, or vegetation units	Reference
Pyrenees (France, Spain and Andorra; 30,000)	120–200 species	Mediterranean evergreen forests, semi-deciduous submediterranean forests, deciduous Atlantic forests, montane and subalpine coniferous forests, Mediterranean montane scrub, meadows and pastures, rock and scree habitats, freshwater habitats, bogs and fens.	Davis et al. (1994), Burga et al. (2004)
Alps (from France to Slowenia; 200,000)	350–400 species, 50 subendemic species in whole area	Broadleaved and conifer forests, dwarf shrub communities and moorland, alpine grasslands, moraine, rock and scree communities, arable land, meadows and pastures, running and standing waters. 35–60 % of endemic and subendemic species live in rocky places, stony slopes and grassland of mid to high altitudes, few in freshwater and amphibic habitats or woods (59 % of the Austrian taxa are basiphytes, 28 % are acidophytes.).	Pawlowski (1969), Davis et al. (1994), Dullinger et al. (2000), Casazza et al. (2005, 2008), Rabitsch and Essl (2009)
Carpathians (Slovakia, Hungary, Poland, Ukraine, Romania; 190,000)	100–120 endemic species, 30 subendemics	Forest, grassland, rock communities. Most of the (sub)endemics are inhabited in grassland, 10–15 % of endemic and subendemic species live in rocky places/stoney slopes, very few species belong to forest.	Pawlowski (1969), Davis et al. (1994)
South Crimean Mountains and Novorossia (Ukraine, Russia; 80,500)	Some 220 species	Maquis and shiblyak, oak, pine, pine-beech and juniper woodland, dry grassland.	Davis et al. (1994)

Mediterranean Basin (including the Azores, Madeira, Canary, Cape Verde Islands and parts of North-Africa and West Asia; 2,085,292)	11,700–13,000 species	Evergreen sclerophyllous, lauriphyllous, coniferous and deciduous forest types, hard-leafed or sclerophyllous shrublands, softleaved and drought phrygana, different types of coastal vegetation (saltmarsh, saline shrubland, dunes, rocky shores), many fire adapted vegetation types Endemic vascular plant taxa in the French Mediterranean region occur in habitats on steeper slopes, with higher rock cover and in lower and more open vegetation than their widespread congeners, but they are not more stress-tolerant.	Mittermeier et al. (2005), Gillespie and Clague (2009)
Southeast France (France, including Corse; 38,750)	215 (sub) species	Most of the (sub)endemics belong to calcareous rocky grasslands, cliffs and rocks at mid and high altitudes.	Médail and Verlaque (1997)
Corse (France; 8,750)	126–130 species c. 162 subendemic species	Most of the (sub)endemics belong to siliceous rocky grassland and ridges, to maritime rock crevices and to riparian grassland, moist banks, to torrents at low and mid altitudes, many endemic taxa occur in mid and high altitudes above 700 m.	Davis et al. (1994), Gamisans and Marzocchi (1996), Medail and Verlaque (1997), Hobohm (2000b)
Crete (Greece; 8,700)	248 taxa (species groups, species, subspecies)	Evergreen scrub, fragments of evergreen oak, pine and cypress forest, montane rock and cliff vegetation; island extensively cleared or modified by agricultural management. 9 endemics occur in freshwater habitats, bogs, mires or fens, 21 in coastal, brackish and saline habitats, 36 in cropland, ruderal and urban habitats, 171 in rocky habitats and screes, 74 in scrub and heath, 28 in forests (many of them in more than one habitat type).	Davis et al. (1994), Hobohm, data base in progress

(continued)

Table 5.3 (continued)

Region (country or archipelago, area in km^2)	Total numbers of endemic vascular plant taxa (note that the term species is often used in the meaning of species plus subspecies)	Description of biomes, formations, or vegetation units	Reference
Cypres (9,250)	108 species and subspecies	1 % of the area is covered by forest (26 endemic taxa), 13 % by shrublands including grassy habitats (46 endemics), 82 % by cropland and urban area (28 endemics), and 3 % by wetlands and water bodies (12 freshwater and 6 coastal endemics). Few taxa occur in more than one group of habitats.	Hobohm, data base in progress, WRI (2003)
Troodos Mountains (Cypres; 1,800)	36 species	Evergreen scrub, evergreen oak, pine, Cyprus cedar forest, rock and cliff communities; extensively cleared or modified by agriculture in lowlands.	Davis et al. (1994)
Mediterranean conifer and mixed forests of the Middle Atlas Range (Morocco, Algeria, Tunesia)	>450 species: 237 species in Middle Atlas Range, 190 s in the Rif Massif, 91 species in the Tellien Atlas	Mediterranean conifer and mixed forest in relatively humid, medium to high elevations.	McGinley (2007e)
High Atlas (Morocco; 7,000)	160 species	Forest (28 % of the area), meadows (pozzines) and various scrub communities (30 %), eroded rock, alpine pseudo-steppe, dwarf spiny scrub and scree (over 30 %).	Davis et al. (1994)
Nile Delta (Egypt; c. 22,750)	8 species	Dominated by swamp (of *Cyperus papyrus* or of *Phragmites australis* with *Typha capensis*, *Juncus maritimus*, with some small sedges), freshwater wetlands and salt-tolerant marsh vegetation.	McGinley (2008f)
Sinai (Egypt including Saint Catherine mountains; 60,000)	28–30 species	Irano-Turanian steppe vegetation, 16 endemics to gorge habitats of the rugged mountainous districts which contains Saint Catherine mountains.	Davis et al. (1994), Moustafa and Zaghloul (1996)

Southern Sinai (Saint Catherine Protectorate; 4,350)	19 species	Arid, mountain ecosystem that forms an island of central Asian steppe vegetation along with Irano-Turanian biota.	Grainger (2003)
Saharan Desert (North Africa; 9,000,000)	162–375 species	Desert and semi-desert vegetation with therophytes, hemicryptophytes and shrubs including rock and scree habitats, scrub, dunes and saline habitats. Only few tree species as relicts of wet palaeoclimate.	Major (1988), Breckle (2000)
Sudanian Regional Centre of Endemism (from Senegal to the foothills of the Ethiopian Highlands; 3,731,000)	c. 960 species	Woodland, wooded grassland, other grasslands, rocky inselberg vegetation, riparian forest, upland dry or semi-evergreen forest, extensive wetlands, different secondary vegetation types (scrub), farmland.	Davis et al. (1994)
Eastern Afromontane (from Saudi Arabia and Yemen to Zimbabwe; 1,017,806)	2,356 species	Montane forest, other forest types, woodland and savanna, alpine moorland and bog, zones with heather, bamboo vegetation, *Papyrus* and *Carex* wetland, hot springs, sclerophytic vegetation on old lava flows.	Mittermeier et al. (2005)
Horn of Africa (from NE Kenya to SE Oman and SW Saudi Arabia; 1,650,000)	2,750 species	Bushland, succulent shrubland, dry evergreen forest and woodland, semi-desert grassland, low-growing dune and rock vegetation, mangrove and riverian vegetation.	Mittermeier et al. (2005)
Ethiopian Highlands (Ethiopia, Erithrea, Sudan, Egypt; 519,278)	555 species	Moist and dry forests, woodland vegetation at foothills and lower elevations, montane bamboo, 'dega' and 'weyna dega' (vegetation dominated by conifers), heathland scrub, Afroalpine ecosystems at high altitudes. The majority of endemics is associated with open grassland, dry woodland, and heathland.	Mittermeier et al. (2005)

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Table 5.3 (continued)

Region (country or archipelago, area in km^2)	Total numbers of endemic vascular plant taxa (note that the term species is often used in the meaning of species plus subspecies)	Description of biomes, formations, or vegetation units	Reference
Guinean Forests of West Africa (from Guinea to Cameroon, including Sao Tomé and Príncipe; 620,314)	1,800 species	Moist forest, freshwater swamp forest, semi-deciduous forest.	Mittermeier et al. (2005)
Upper Guinea (from Guinea to Togo; 340,000)	650 species	Tropical rain forest.	Holmgren and Poorter (2007)
Tai National Park (Cote d'Ivoire; 3,500)	150 species	Evergreen rain forest of the Guinea zone.	Davis et al. (1994)
Mont Nimba (Guinea, Cote d'Ivoire, Liberia; 480)	c. 13 species	Lowland and transitional rain forest, grasslands.	Davis et al. (1994)
Cross River National Park (Nigeria; 4,227)	130 species	Lowland rain forest, freshwater swamp forest, montane forest, grassland.	Davis et al. (1994)
Mount Cameroon (Cameroon; 1,100)	49 species (with another 50 subendemics)	Submontane and montane forest, subalpine grassland.	Davis et al. (1994), Cable and Cheek (1998), Blom (2001)
Cristal Mountains (Gabon; 9,000)	>100 species	Wet evergreen coastal Guineo-Congolian rain forest.	Davis et al. (1994)
Salonga National Park (Zaire; 36,560)	150–200 species	Tropical evergreen Guineo-Congolian rain forest, swamp and riverine forest, secondary vegetation, grassland.	Davis et al. (1994)
Haut Shaba (Zaire; 496,871)	>300 species	Steppic savannas dominated by grasses, with many shrubs and bulbous plants, woodland, localized swamps, ravine and riparian gallery forests.	Davis et al. (1994)

Garamba National Park (Zaire; 56,727)	c. 50 species	Dominant vegetation types: shrub savanna, savanna woodland, and long grass savanna.	Davis et al. (1994) McGinley (2008b)
Coastal Forests of Eastern Africa (from Mozambique to Somalia, including islands lying immediately offshore; 291,250)	1,360–1,750 species	Moist forest, drier forest, with coastal thicket, fire-climax savanna woodland, seasonal and permanent swamp, littoral habitats that include mangrove vegetation; 70 % of all endemics have been recorded from forest habitats; 550–554 in coastal forest.	Burgess et al. (1998), Burgess et al. (2003), Mittermeier et al. (2005)
Rondo Plateau (Tanzania; 250)	>200 strict or near-species	Dry semi-deciduous lowland forest, woodland, thicket, secondary communities, large parts converted to farmland and plantations.	Davis et al. (1994)
Maputaland-Pondoland-Albany (from South Africa to southern Mozambique; 274,316)	1,900 species	Warm temperate forest, different types of thickets, bushveld, grassland, many stem succulents.	Davis et al. (1994), Mittermeier et al. (2005)
Albertine Rift (including parts of Uganda, Rwanda, Democratic Republic of Congo, Burundi, Tanzania; 313,051)	>551 species (taxa) with 92 species restricted to Virunga Vocanoes	Glaciers and rocks at the top of the Rwenzori Mountains (5,100 m), alpine moorland (3,400–4,500 m), giant *Senecio* and *Lobelia* vegetation (3,100–3,600 m), giant heather (3,000–3,500 m), raised bogs (3,000–4,000 m), bamboo forest (2,500–3,000 m), montane forest (1,500–2,500 m), lowland forest (600–1,500 m), savanna woodland (600–2,500 m) and savanna grassland (600–2,500 m). *Papyrus* and *Carex* wetland, together with lakes and streams, have their own unique habitat types varying from the rocky and sandy edges to the benthic zones of the lakes.	Owiunji et al. (2005), Mittermeier et al. (2005), Plumptre et al. (2007)
Eastern Arc Mountains and Southern Rift (from southern Kenya to North Mozambique; 16,123)	1,200 species	Lowland, submontane, montane and upper montane forest, grassland, heathland, bog.	Davis et al. (1994), Mittermeier et al. (2005)

(continued)

Table 5.3 (continued)

Region (country or archipelago, area in km^2)	Total numbers of endemic vascular plant taxa (note that the term species is often used in the meaning of species plus subspecies)	Description of biomes, formations, or vegetation units	Reference
Namib Desert (Namibia; 134,400)	492 species	Desert and xeric shrublands.	Cowling and Hilton-Taylor (1999)
Nama-Karoo (Namibia; 198,500)	377 species	Desert and xeric shrublands.	Cowling and Hilton-Taylor (1999)
Succulent Karoo (Western Cape Domain; South Africa, Namibia; 102,691)	1,750–2,539 species	Low to dwarf succulent shrubland dominated almost entirely by leaf succulents, stem succulents and fine-leaved evergreen shrubs, clustered in broken, rocky habitats rather than sandy or loamy flats.	Davis et al. (1994), Cowling and Hilton-Taylor (1999), Mittermeier et al. (2005)
Kaokoveld (Damaraland-Kaokoland Domain; Namibia, Angola; 70,000)	116 endemic or near-endemic taxa	Desert vegetation, xeric shrubland, montane savanna, escarpment vegetation.	Davis et al. (1994), Cowling and Hilton-Taylor (1999)
Cape Floristic Region (South Africa; 78,555)	6,210 species	Fynbos (shrubland which covers c. 60 % of the whole area characterized by evergreen rush or reed-like plants, restioids, small leafed shrubs, ericoids, relatively tall shrubs, proteoids, and bulbs or geophytes) and several non-fynbos vegetation types, endemism largely confined to fynbos. Most endemics grow on nutrient-poor substrates with low pH.	Cowling (1992), Davis et al. (1994), Mittermeier et al. (2005)

Cape Peninsula (South Africa; 471)	88 species (+ 2 subspecies)	Forest and thicket harbour 11 endemics, dune asteraceous fynbos 29, wet restioid fynbos 32, ericaceous fynbos and upland restioid fynbos 38, sandplain proteoid fynbos 40, coastal scree asteraceous fynbos and mesic oligotrophic proteoid fynbos 63, mesic mesotrophic proteoid fynbos 49, undifferentiated cliff community 17, wetland 22, wet and oligotrophic proteoid fynbos 23, wet mesotrophic proteoid fynbos 24, Renosterveld/grassland 8 endemic taxa (many endemics occur in more than one vegetation type).	Trinder-Smith et al. (1996), Mittermeier et al. (2005)
Sneeuberg (South Africa; 20,000)	33 endemics, 13 subendemic species (5 of them previously reported as Drakensberg Alpine Regions)	Karoo Escarpment Grassland above 1,600 m, arid Fynbos above ca. 2,100 m on rocky peaks and stony plateaux, southern Mistbelt Forest on southern slopes, elements of temperate forest, moist and other thickets, dominant on foothills at altitudes of ca. 1,000–1,400 m, elements of the Nama-Karoo biome.	Clark et al. (2008)
Drakensberg Alpine Region (Lesotho, South Africa; 40,000)	334–394 species	Chiefly subalpine and alpine grassland, shrubland (heathland), with scrub and savanna at lower altitudes, extensive wetlands in the alpine belt.	Davis et al. (1994), Van Wyk and Smith (2001), Mucina and Rutherford (2006), Carbutt and Edwards (2006)

Table 5.4 Examples of biodiversity hotspots, ecoregions and landscapes with numbers of endemic vascular plants and the main habitats in various parts of the Arctic, Asia and Indian Ocean Islands (partly nested or overlapping), from North to South or West to East, respectively

Region (country or archipelago, area in km^2)	Total numbers of endemic vascular plant taxa (note that the term species is often used in the meaning of species plus subspecies)	Description of biomes, formations, or vegetation units	Reference
Arctic (circumpolar; c. 4,500,000)	96 species	Different tundra vegetation types (e.g. dominated by rocks, screes, arctic-alpine dwarf shrubs, herbs, grasses, bryophytes and/or lichens).	Talbot et al. (1999)
Central and Northern Asia (from Ural Mountains eastwards to the Pacific Ocean, and southwards to the Caucasus and the Middle Asian Mountains; 16,794,400)	c. 2,500 species	Different forest types (33 % of the region), tundra, *Sphagnum* bogs, forest steppe and steppe, semi-desert and desert vegetation, montane and alpine vegetation.	Davis et al. (1995)
Caucasus (Armenia, Azerbaijan, Georgia, Russia; 532,658)	1,200- > 1,600 species	Lowland broadleaved forests, montane broadleaved and coniferous forests, swamp forest, montane steppe and woodlands, subalpine meadows, semi-desert to desert vegetation, subalpine and alpine meadows.	Davis et al. (1995), Burga et al. (2004), Mittermeier et al. (2005)
Mountains of Central Asia (including Pamir and Tien Shan; 863,362)	1,500 species	Desert, semi-desert, and steppe vegetation types, subalpine and alpine meadows, tundra-like vegetation at high altitudes, riverine woodland, shrub communities, spruce and other forest types.	Davis et al. (1995), Mittermeier et al. (2005), Nowak and Nobis (2010)
Altai Mountains (Russia, Mongolia, Kazakhstan, China; 261,700)	200–390 (sub) species	Mixed coniferous forests, steppe and forest steppe, subalpine and alpine vegetation, tundra.	Davis et al. (1995), Burga et al. (2004), Pyak et al. (2008)
Irano-Anatolian area (from Central Turkey to Turkmenistan; 899,773)	2,500–3,000 species	Mountainous forest steppe, primary steppe, salt steppe, halophytic marsh, subalpine vegetation including thorn-cushion (tragacantic) formations, alpine vegetation, riparian forest.	Mittermeier et al. (2005), Şekercioğlu et al. (2011)

Mountains of South-East Turkey, North-West Iran and Northern Iraq (Turkey, Iran, Iraq; 147,332)	c. 500 species	Oak forest at lower altitudes, mountain steppe between 2,200 and 2,700 m, thorn-cushion zone of spiny plants between 2,700 and 3,300 m, alpine zone including grassland, scree and rock vegetation above 3,300 m.	Davis et al. (1994)
Isaurian, Lycaonian and Cilician Taurus (Turkey; 45,120)	235 species	Littoral dune communities, halophytes and remnants of alluvial forest, wetland vegetation, maquis and phrygana at low altitudes, oak and pine forest, some stands of *Cedrus libani* at mid altitudes, mountain steppe and scree communities at higher altitudes.	Davis et al. (1994), Vogiatsakis (2012)
Gypsum areas in Sivas (Turkey, Central Anatolia, Eastern part of Cappadocia; 4,000)	122 species (to Turkey)	Gypsum habitats only with vegetation of low density: many hemicrytophytes, annuals, chamaephytes and shrubs.	Akpulat and Celik (2005)
Badkhiz-Karabil Semi-desert (Turkmenistan; 133,600)	75 species	Xeric savanna-like vegetation with therophytes, perennial grasses, sedges and forbs, shrubs and arid pistachio scrub.	Atamuradov et al. (1999), McGinley (2008a)
The Levantine Uplands (Turkey, Syria, Lebanon, Israel, Jordan; 96,675)	c. 635 species	Oak forest and scrub, other forest types, *Juniperus* scrub, subalpine tragacanthic communities and alpine vegetation, degraded vegetation with maquis, garigue and batha.	Davis et al. (1994)
Alpine Regions of Iran (Iran; c. 10,000)	357 (sub) species	Communities dominated by large herbs and thorn-cushion plants, alpine meadow communities, high alpine xerophytic communities covered by graminoids, rocky and scree habitats.	Noroozi et al. (2008), Chap.7 by Noroozi, this book
Negev Desert (Israel; 11,000)	80 species	Desert and semi-desert vegetation.	Breckle (2000)
Highlands of South-Western Arabia (Saudi Arabia, Yemen; 70,000)	c. 170 species	Deciduous bushland and thicket from 200 m to c. 2,000 m altitude, evergreen bushland and thicket and *Juniperus* scrub, above c. 2,000 m.	Davis et al. (1994)

(continued)

Table 5.4 (continued)

Region (country or archipelago, area in km^2)	Total numbers of endemic vascular plant taxa (note that the term species is often used in the meaning of species plus subspecies)	Description of biomes, formations, or vegetation units	Reference
Central Desert of Oman (Oman; 150,000)	12 species	Vegetation can be broadly classified as part of the Acacia-*Zygophyllum-Heliotropium* savanna (in the central plains) and *Prosopis-Calligonum* semi-desert (in the dune desert).	Ghazanfar (2004)
Dhofar Fog Oasis (Oman, Yemen; 30,000)	c. 60 species	Dry deciduous shrubland on the seaward-facing escarpment, semi-deciduous thicket and grassland at higher altitude.	Davis et al. (1994)
Himalaya (from North Pakistan to North Myanma; 741,706)	3,160 species	Open woodland savanna, mixed evergreen forest at low altitudes, temperate humid forest, subtropical evergreen broadleaf and pine forest, alluvial and alpine grassland, shrubby rhododendron stands, alpine scrub communities, rocky vegetation.	Mittermeier et al. (2005)
Indian Subcontinent (India, Pakistan, Nepal, Bhutan, Bagladesh, Myanma, Sri Lanka, northeastern Indian Ocean Islands; 4,850,000)	>11,330 species	Tropical evergreen rain forest to high-altitude alpine vegetation, mixed broadleaved and coniferous forests, woodland, savanna, thorn scrub, dwarf shrub, alpine grassland, scree communities.	Davis et al. (1995)
Thar-Desert (India; 200,000–300,000)	36 taxa (24 species, 12 subspecies)	Semi-desert and desert vegetation.	Bhandari (1979), Khan (1997)
Western Ghats (India and Sri Lanka; 182,500)	1,700 species	Scrub forests, deciduous, moist and tropical rain forest, montane forest and rolling grassland in higher altitudes. Tropical rainforest covers 11 % of the area, dry, moist deciduous, and scrub forests cover another 11 %.	Mittermeier et al. (2005)
Agastyamalai Hills (India; 3,500)	100 species	Tropical thorn forest, tropical dry decidous forest, tropical moist deciduous forest, tropical evergreen rain forest and subtropical montane forest, lowland and montane grasslands.	Davis et al. (1995)

Nilgiri Hills (India; 5,520)	100 species	Tropical evergreen rain forest, tropical semi-evergreen forest, tropical moist deciduous, tropical dry thorn forest, tropical montane evergreen shoal forest and grassland.	Davis et al. (1995)
Mountains of Southwest China (China and small parts of Myanma; 262,466)	3,500 species	Broadleaved and coniferous forest, bamboo grove, scrub communities, savanna, meadow, prairie, freshwater wetland, and alpine scrub and scree communities.	Mittermeier et al. (2005)
Mount Emei (Sichuan Province, China; 154)	>100 (subendemic?) species	Subtropical evergreen broad-leaved forest (below 1,500 m), evergreen and deciduous broad-leaved mixed forest, coniferous and broad-leaved mixed forest, subalpine coniferous forest, subalpine shrubs (above 2,800 m).	McGinley (2008e)
Xishuangbanna Region (Yunnan Province, China; 19,220–19,690)	120–153 species	Tropical lowland seasonal rain forest, tropical evergreen dipterocarp forest, seasonal rain forest over limestone, monsoon forest, montane seasonal rain forest, montane evergreen broadleaved forest.	Davis et al. (1995), Shou-qing (1988)
Phong Nha-Ke Bang National Park (Central Vietnam; 2,746)	13 species (to Vietnam) 1 species (to the National Park)	Mostly tropical dense moist evergreen forest (>800 m) and low tropical montane evergreen forest (<800 m).	Clough (2008)
Indo-Burma (from South China and eastern Bangladesh to North Peninsular Malaysia; 1,938,745–2,373,285)	7,000 species	Wet to dry broadleaf evergreen forest, deciduous and montane forest, coniferous forest, savanna forest, coastal heath forest, shrubland and woodland, xerophytic formations at high altitudes, lowland floodplain swamp, mangrove, seasonally inundated grassland.	Mittermeier et al. (2005), Pawar et al. (2007), Tordorff et al. (2012)
North Myanmar (Myanmar; 115,712)	c. 1,250 species	Lowland tropical forest, various types of monsoon forest, mixed and conferous temperate forest, Rhododendron forest and alpine meadows.	Davis et al. (1995)
Bago (Pegu) Yomas (Myanmar; 40,000)	c. 100 species	Wet evergreen dipterocarp forest, pyinkado forest, moist teak forest, dry teak forest, dry dipteropcarp forest, pyinma forest, bamboo where canopy has been opened.	Davis et al. (1995)

(continued)

Table 5.4 (continued)

Region (country or archipelago, area in km^2)	Total numbers of endemic vascular plant taxa (note that the term species is often used in the meaning of species plus subspecies)	Description of biomes, formations, or vegetation units	Reference
Taninthayi (Tenasserim) (Myanmar; 73,845)	c. 500 species	Wet evergreen dipteropcarp forest, montane rain forest, mangrove forests, fresh and brackish swamp vegetation and pinle-kanazo tidal forest, bamboo where forest has been cleared and on poor soils.	Davis et al. (1995)
Dong Phayayan Khao-Yai Forest Complex (Thailand; 6,155)	16 species	Evergreen forest (73.8 % of the area), mixed dipterocarp/deciduous forest (3 %), deforested scrub, grassland and secondary growth (18 %).	McGinley (2009)
Korean Peninsula (South Korea, North Korea; 220,759)	242–340 species (s. str.)	Evergreen broadleaved forest, deciduous and mixed forests, alpine forest (taiga), many other habitat types.	Davis et al. (1995), Kim et al. (2009)
Madagascar and the Indian Ocean Islands (600,461)	9,000–>10,800 species	Tropical rain forest, humid to dry deciduous forest, other dry and moist forest formations, several high elevated mountain ecosystems which are characterized by forests with mosses and lichens (21 % of the area is covered by forest), shrubland, savanna, grassland and spiny desert (63 % of the area), littoral vegetation including mangroves. 2 % is wetlands and water bodies.	Davis et al. (1994), Mittermeier et al. (2005), WRI (2003)
Socotra (Yemen; 3,625)	c. 230–296 species	Semi-desert and dry-deciduous shrubland on coastal plains and lower slopes of mountains, semi-deciduous thicket and grassland at higher altitudes.	Davis et al. (1994), Miller and Morris (2004)
Andaman and Nicobar Islands (India; 8,249)	c. 227 species	Tropical evergreen rain forest, semi-evergreen rain forest, moist deciduous forest, beach forest, swamp forest, bamboo scrub.	Davis et al. (1995)

Seychelles (450)	72–120 species	Mangrove and coastal forest, lowland rain forest, palms, pandan and hardwood characterize the natural forest of the granitic islands (below 610 m), cloud forest with tree ferns and mosses (above 610 m); Most endemics are found at intermediate and high altitudes whereas only two species are confined to the coastal zone and no endemics occur in mangrove vegetation.	Robertson (1989), Fleischmann (1997), Fleischmann et al. (2003), McGinley (2008d), Gillespie and Clague (2009)
Madagascar (585,000–587,000)	c. (6,400-)7,570–10,000 (-11,400) taxa, 8,884 species s. str.	Several evergreen and deciduous forest types (23 % of the area) including primary rain forest, xerophyllous forest, gallery forest, mangroves, secondary forest and other forest types, scrub (42 % of the area) including spiny and succulent thicket, degraded scrub (more than 25 % of the scrub area) and rupicolous shrubland, wetlands (2 % of the area) including swamps, rice cropland, other natural or semi-natural freshwater and wet brackish habitats, rock outcrops, grasslands including secondary savanna or pseudosteppe, coastal and urban habitats. Endemism is high in primary forest (89 %), rocky habitats (82 %), swamps (56 %), and lower in coastal habitats (21 %), grassland (little) and urban habitats (0 %).	Davis et al. (1994), Goodman and Benstead (2003), Burga and Zanola (2007), Moat and Smith (2007), Gillespie and Clague (2009), Cribb and Hermans (2009), Callmander et al. (2011)
Mascarene Islands (Mauritius with Rodrigues, Reunion, France; 4,481)	700–749 species	Tropical to subtropical vegetation, ranging from mangroves, lowland coastal and dry forests to moist montane and upland mist forests, and high-altitude heath.	Davis et al. (1994), Gillespie and Clague (2009)

Table 5.5 Examples of biodiversity hotspots, ecoregions and landscapes with numbers of endemic vascular plants and the main habitats in various parts of Australasia and Pacific Ocean Islands (partly nested or overlapping), from North to South or West to East, respectively

Region (country or archipelago, area in km^2)	Total numbers of vascular plant taxa (note that the term species is often used in the meaning of species plus subspecies)	Description of biomes, formations, or vegetation units	Reference
Japan (373,490)	(>222-)1,950–2,000 species	Boreal mixed or conifer forest to subtropical broadleaf evergreen forest with many different forest types (57 % of the area), 17 % of the area is covered by shrubland and grassland, 21.3 % cropland and urban habitats, 5 % wetland and water bodies.	Davis et al. (1995), Mittermeier et al. (2005), Conservation International and Duffy (2008), Gillespie and Clague (2009), Natori et al. (2012)
Yakushima (Japan; 503)	45 species and 27 subspecies/varieties – 94 species plus subspecies	Different forest types, with zones of evergreen forest, mixed *Cryptomeria* forest, *Rhododendron-Juniperus* scrub and subalpine vegetation.	Davis et al. (1995), Tokumara (2003), United Nations Environment Programme-Wo and Clough (2008)
Bonin-(Ogasawara) Islands (Japan; 73)	150–215 species	Subtropical evergreen broadleaved forests, scrub.	Davis et al. (1995), Mueller-Dombois and Fosberg (1998), Ito (1998)
Taiwan (including further 72 small islands; 36,210)	1,041–1,075 species	Tropical rain forest, evergreen broadleaved forest, mixed forest, coniferous forest, alpine grassland.	Davis et al. (1995), Mittermeier et al. (2005), Hsieh (2002), Huang (1993–2003)
Hainan Island (China; 34,000)	397 (−505) species	Tropical lowland seasonal rain forest, monsoon forest, savanna, montane seasonal rain forest, mangrove forest.	Fuwu et al. (1995), Francisco-Ortega et al. (2010)
Philippines (297,179)	3,470–5,832 ->6,091 species	Rain forest, montane forest, pine dominated cloud forest, seasonal forest (9 % of the area covered by forest), cropland and urban habitats represent 86 % of the area, wetlands and water bodies 5 %.	Davis et al. (1995), Myers et al. (2000), Mittermeier et al. (2005), WRI (2003), Gillespie and Clague (2009)

Palawan (Philippines; 14,896)	200–400 species	Lowland evergreen dipterocarp rain forest, lowland semi-deciduous forest, montane forest, forest over limestone, forest over ultramafic rocks, mangroves, beach forest.	Davis et al. (1995)
Sibuyan Island (Philippines; 445)	54 species	Lowland primary rain forest, montane forests, summit grassland, heath forest, mangroves, beach vegetation.	Davis et al. (1995)
Sundaland (from South Thailand to Java, Sumatra and Borneo; 1,500,000)	15,000 species	Lowland rain forest, beach forest, mangrove, peat swamp forest, alluvial bench forest and freshwater swamp, montane forest, scrubby, subalpine forest, bare exposed peaks of high mountain areas.	Mittermeier et al. (2005)
Sumatra (Indonesia; 472,610)	>1,200	Lowland evergreen rain forest, peat swamp forest, mangroves, montane rain forest, limestone vegetation, heath forest, montane graslands, subalpine vegetation.	Davis et al. (1995), Kalla (2003)
Borneo (Brunei Darussalam, Malaysia, Indonesia; 10,000,000)	6,000–7,500 species	Lowland tropical evergreen rain forest, montane forest, heath forest (kerangas), limestone forest, ultramafic vegetation, alluvial and peat swamp forests, mangroves, beach forest, subalpine and alpine vegetation including scrub and rocky habitats.	Davis et al. (1995), Barthlott et al. (2005), Gillespie and Clague (2009)
Java (Indonesia; 138,204)	c. 230–250 species	Submontane and montane forests, lowland forests.	Davis et al. (1995), Caujape-Castells et al. (2010)
Wallacea (Indonesia between Java, New Guinea and Australia; 338,494)	1,500 species	Tropical rain forest, savanna woodland, *Eucalyptus* forest, lowland forest on ultrabasic soils dominated by the myrtle family.	Mittermeier et al. (2005)
New Guinea (Irian Jaya, Papua New Guinea; 790,000)	9,900 (−16,000) species	Mangrove, freshwater, swamp and peatswamp forest, lowland alluvial and hill tropical rain forest, mountain rain forest, sedgeland, heath communities, subalpine forest and scrub, alpine grasslands and rocky habitats. Broadleaf forest covers about two-thirds of the island.	Myers (1988), Davis et al. (1995), Nau (2003), Barthlott et al. (2005), Gillespie and Clague (2009)

(continued)

Table 5.5 (continued)

Region (country or archipelago, area in km^2)	Total numbers of vascular plant taxa (note that the term species is often used in the meaning of species plus subspecies)	Description of biomes, formations, or vegetation units	Reference
East Melanesian Islands (from Bismarck Islands to Vanuatu; 99,384)	3,000–3,500 (−4,000) species	Coastal vegetation, mangrove forest, freshwater swamp forest, lowland rain forests, seasonally dry forests and grasslands, montane rain forest.	Mueller-Dombois and Fosberg (1998), Mittermeier et al. (2005), WWF Australia (2009)
Polynesia-Micronesia (47,000)	3,074 species	Strand vegetation, mesic forest, tropical rain forest, cloud forest, savanna, open woodland of grassland and scrub, wetland including mangrove forest.	Davis et al. (1995), Mueller-Dombois and Fosberg (1998), Allison and Eldridge (2004), Mittermeier et al. (2005)
Hawaiian Islands (USA; 16,641–16,760)	927–1,198 taxa (937 species, 124 subspecies, 137 varieties)	Tropical dry and moist forest, tropical low and high shrubland, herbland, grassland, coastal vegetation, wetland and bog.	Davis et al. (1995), Mueller-Dombois and Fosberg (1998), Wagner et al. (2005), Barthlott et al. (2005), Caujape-Castells et al. (2010)
Fiji Islands (18,275)	812–814 species	Rain forest, montane forest, dry forest and open woodland, shrub and grassland, mangroves.	Davis et al. (1995), Mueller-Dombois and Fosberg (1998)
Islands of Samoa (14 volcanic islands; Samoa, USA; 3,039)	150–165 species	Tropical rain forest most extensive is lowland forest, followed by montane forest, and cloud forest (>650 m). Some other minor habitat types including montane scrub, *Pandanus* scrub, littoral scrub, montane swamp forests, and summit scrub.	Davis et al. (1995), Mueller-Dombois and Fosberg (1998), Nau (2003), Honeycutt and McGinley (2008), Whistler (2011)
Kingdom of Tonga (scattered distribution of 170 islands; 750)	11–13 species	Dominated by tropical moist forest, <500 m: lowland broadleaf rain forest, >500 m: subtropical rain forest.	Mueller-Dombois and Fosberg (1998), World Wildlife Fund (2011)

Marquesas Islands (France; 1,275)	163–166 taxa (150 species, 2 subspecies, 14 varieties)	Coastal vegetation, para-littoral and lowland forest, dry forest at low or mid elevation (100–1,000 m), grassland (>600 m), moist and wet forest (up to 800 m), high elevation cloud forest(>1,000 m), wet shrubland or heathland (>1,200 m).	Davis et al. (1995), Florence and Lorence (1997), Mueller-Dombois and Fosberg (1998), Wagner and Lorence (1997), Lorence and Wagner (2011)
Australia (7,682,428)	14,260–19,870 species	Closed forest (0.4 %), open forest (4.6 %), woodlands (13.9 %), open woodlands (25.8 %), tall shrublands (31.1 %), low shrublands (6.2 %), hummock grassland (= spinifex grass steppe; 0.6 %), tufted grasses/graminoids (9.2 %), other herbaceous plants (6.4 %), littoral complex (0.3 %), other (1.5 %).	Green (1985), Davis et al. (1995), WRI (2003), Australian National Herbarium 2012: www.anbg.gov.au/aust-veg/australian-flora-statistics.html (assessed 20/9/2012)
Northern Territory (Australia; 1,420,970)	567 species	Rain forest (with 41 endemic sp.), non-rain forest habitats (with 526 endemic sp.).	Woinarski et al. (2006)
Kakadu-Alligator Rivers Region (Northern Territory, Australia; 30,000)	40 species	Tropical sclerophyll forest, woodland, rain forest, swamp forest, mangroves, saltmarsh, sedgeland, grassland.	Davis et al. (1995)
Central Australian Mountain Ranges (Australia; 168,000)	120 species	Grasslands, shrub steppe in saline areas, shrublands, woodlands, riparian vegetation in gorges and gullies, rock and cliff vegetation.	Davis et al. (1995)
Queensland Wet Tropics (Eastern Australia; 18,487)	576–654 species	Rain forest, sclerophyll shrubland, sclerophyll woodland, tall sclerophyll forest, woodlands, swamp forest, eucalypt forest, sclerophyll shrubland, dune vegetation, sedge swamp communities.	Davis et al. (1995), Mittermeier et al. (2005), UNEP (2011)
Northern Province of Western Australia (Australia; c. 320,000)	241 species	Savanna with Poaceae and scattered *Eucalyptus* trees.	Beard et al. (2000)
North Kimberley Region (Northern Province of Western Australia; 99,100)	102 species	High grass savanna, other savannas with short grasses, eucalypt woodland, mangroves, rain forest patches.	Davis et al. (1995), Government WA (2001)

(continued)

Table 5.5 (continued)

Region (country or archipelago, area in km^2)	Total numbers of vascular plant taxa (note that the term species is often used in the meaning of species plus subspecies)	Description of biomes, formations, or vegetation units	Reference
Eremaean Province (Western Australia; c. 1,600,000)	432 species	Vegetation cover varies from dry *Spinifex* grassland in the north to low *Acacia*-woodlands in the South.	Beard et al. (2000)
Southwest Australia (Australia, including Southwest Province; 356,717–489,944)	2,472–3,620 species	Woodland, *Eucalyptus* forest, Mediterranean shrubland (Kwongan); all vegetation types are dominated by almost entirely woody species (there is no grassland).	Davis et al. (1995), Beard et al. (2000), Hopper and Gioia (2004), Mittermeier et al. (2005), WWF Australia (2006)
Sydney Sandstone Region (New South Wales, Australia; 24,000)	c. 50 species	Evergreen sclerophyll forests, woodlands, shrublands, grasslands, coastal dunes and swamps, mangroves, small areas of rain forest.	Davis et al. (1995)
Kangaroo Island (Australia; 4,405)	36 species	*Eucalyptus* woodland, sclerophyll woodland, open and grassy woodland, and grassland.	Cleveland (2007)
New Caledonia (France; 18,972)	2,432–2,582 species	>1,750 endemics of the archepelago occur in wet evergreen forest (which recently covers c. 18–22 % of the area), 987 or more endemic species in natural and semi-natural maquis vegetation (which covers c. 30 % of the area), 223 endemic species in sclerophyllous forest (pristine stands cover less than 0.5 % of the area), 6 endemic species in savanna, 1 endemic species in mangrove (1 % of the area), 23 endemic species in littoral vegetation. Secondary vegetation including cropland (20 % of the area), savanna and secondary forest covers c. 50 % of the area. Endemism is much higher on ultrabasic substrates than elsewhere. Many endemics occur in more than one habitat.	Schneckenburger (1991), Morat (1993), Davis et al. (1995), Lowry (1998), Mueller-Dombois and Fosberg (1998), Mittermeier et al. (2005), WRI (2003), Gillespie and Clague (2009)

Norfolk and Lord Howe Islands (Australia; 54)	154 species and subspecies	Pine forest, mixed hardwood forest, palm/hardwood forest, palm/tree fern forest, evergreen rain forest, scrub vegetation, grassland, mangroves.	Davis et al. (1995), Mueller-Dombois and Fosberg (1998)
New Zealand (270,197)	1,865–1,944 species	Cover (area in %): high-productive exotic grassland 33–34, low-productive grassland 6, native forest 24, exotic forest 7, wetlands and water bodies 6, cropland and urban habitats 8–9. Forest and woody scrub harbour 506 endemics. Alpine habitats house 530 endemics (alpine and other grasslands some 180), mud banks and wetland margins 87, bogs 135, swamp, lagoons and lake margins 32, aquatic habitats 10.	Davis et al. (1995), McGlone et al. (2001), Connor (2002), Mittermeier et al. (2005), WRI (2003), De Lange et al. (2006, 2009)
Northland (New Zealand; 14,000)	60 taxa	Evergreen warm-temperate to subtropical forest, scrub, wetland communities, including mangrove forest, coastal communities.	Davis et al. (1995)
New Zealand areas with ultramafic soils (New Zealand)	34 species	North Cape: 15 endemics in low-growing shrubland (widespread) and forest; Nelson-Marlborough: 18 endemics in low forest, small leaved shrub, low scrub and heathland, tussock grassland; Otago-Southland: 1 endemic in stunted and patchy forest, low woodland and shrubs, subalpine and alpine tussock grassland.	Lee (1992), Mueller-Dombois and Fosberg (1998)
Chatham Islands (New Zealand; 963)	40 taxa	Evergreen cool temperate forest, mixed broadleaved forest, scrub, rush/scrubland, grasslands, peatlands, wetland and coastal communities.	Davis et al. (1995)
Subantarctic Islands (Auckland Islands, Campbell Islands, Antipodes Islands, Macquarie Island, Australia and New Zealand; 949)	35 taxa	Grasslands, fellfields, herbaceous communities, wetlands, forests, coastal vegetation.	Davis et al. (1995)

(continued)

Table 5.5 (continued)

Region (country or archipelago, area in km^2)	Total numbers of vascular plant taxa (note that the term species is often used in the meaning of species plus subspecies)	Description of biomes, formations, or vegetation units	Reference
Macquarie Island (Australia; 150)	3 species	Tundra vegetation dominated by herbaceous angiosperms and bryophytes (endemic species are not serpentinite species although serpentinite outcrops are common).	Adamson et al. (1993), Parks and Wildlife Service (2006)
Rapa Nui (Easter Island; 166)	3 species	Almost completely covered by herbaceous grassland, except for a few isolated stands of ornamental trees and shrubs.	Mueller-Dombois and Fosberg (1998), Honeycutt and McGinley (2007)
Galapagos Islands (Ecuador; 7,880)	180 species or 229 taxa (224 species, 5 subspecific taxa)	Mangroves and other coastal communities in the littoral zone, drought-tolerant scrub with cacti in the arid zone (up to 80–400 m), humid zones above 300 m with scrub and open forest, and fern-sedge vegetation and bogs with *Sphagnum* spp. above 900 m.	Lawesson et al. (1990), Davis et al. (1995), Mueller-Dombois and Fosberg (1998), McGinley (2007d), Gillespie and Clague (2009)
Islas Desventuradas (Chile; 3.9)	21 species	Dwarf forest (<4 m), scrub and patches of annual forbs and grasses.	Mueller-Dombois and Fosberg (1998)
San Ambrosio (Islas Desventuradas, Chile; 2.2)	11 species	Dwarf forest (up to 4 m) in the moister parts of the island, matorral, low scrubland, patches of annuals and herbaceous plants.	Mueller-Dombois and Fosberg (1998), McGinley (2007f)
San Felix (Islas Desventuradas, Chile; 1.4)	2 species	Dwarf shrub (matorral), patches of annuals.	Mueller-Dombois and Fosberg (1998), McGinley (2007f)
Juan Fernandez Islands (Chile; 100)	121–130 species	Subtropical montane rain forest, tall dry forests, tree fern forests, brushwood and scrub, subalpine heath-fern vegetation, primary and secondary grasslands, ridge, cliff and alpine communities, seashore vegetation.	Davis et al. (1995), Mueller-Dombois and Fosberg (1998), Gillespie and Clague (2009), Moreira-Muñoz (this book)

Most regions and landscapes with endemic vascular plants represent more than a single group of physiognomic habitats. Furthermore, many endemics occur in more than a single vegetation unit. Thus, it is very often difficult to determine how many endemics are related to a particular habitat type. Even those scientists who have expert knowledge of a certain region, such as a biodiversity hotspot or an ecoregion, might find it difficult to estimate where endemics are concentrated or which habitat type harbours most endemics.

We were only able to obtain information for a few regions on both the relationship between endemism and habitat type and the importance (size) of different habitat types within the region. These regions are e.g. Europe, Cape Floristic Region, Madagascar, New Caledonia, and New Zealand (cf. Tables 5.1, 5.2, 5.3, 5.4, and 5.5).

In Europe, most endemics are found in habitats with rocks and screes or in grasslands and scrub which together cover much smaller areas than cropland, forest or urban habitats. Most endemics in Europe are basiphytes or indifferent to soil-pH, but acidic substrates are dominant throughout the continent; acidic substrates harbour fewer endemics (Ewald 2003; Hobohm 2008a).

The predominant habitat in the Cape Floristic Region is fynbos. This habitat type harbours the largest number of endemics, almost all of which grow on nutrient-poor and acidic soils.

In New Caledonia, the majority of endemics inhabit wet evergreen forest which nowadays has been reduced to a fifth of its former range. A further large proportion of the endemics is found in the maquis vegetation which covers a third of the archipelago's area. Endemism on this archipelago is much higher on ultrabasic substrates than elsewhere.

On Madagascar, most endemics are woody plants that inhabit forest and woodland. The majority inhabit tropical and subtropical humid forest. Many others inhabit more or less dry woodlands and thickets. Today, secondary grassland and wooded grassland cover most of the island. These open vegetation types are extremely poor in endemics.

In New Zealand, the majority of the endemics are found in alpine habitats although low and mid-altitude habitats are dominant in the landscape. Forest, woody scrub, wet and aquatic habitats also house many endemics in New Zealand.

In the following we group habitats according to Davies et al. (2004) or Song and Xu (2003), respectively.

5.3.1 Coastal and Saline Habitats

Many coastal and saline habitats that extend in narrow strips along coasts or shorelines represent very old arrays of environmental conditions. The abiotic factors of certain regions in this transition zone might be as old as the ocean. However, marine currents, winds and migrating birds support dispersal processes which lead to a low likelihood of genetic isolation.

At a regional scale, the database for endemism in these habitats is largely fragmentary.

Analyses of the European endemic flora show that at least 450 endemic species and subspecies are restricted to coastal habitats (Hobohm 2008a; Hobohm and Bruchmann 2009, Hobohm, database EvaplantE in progress).

Van der Maarel and Van der Maarel-Versluys (1996) found that many of the coastal endemics are not necessarily restricted to coastal habitats but that the latter represent their optimal habitat. They found that about 30 % of the endemic species are dune and beach species and another 30 % are species of maritime rocks. It should be noted that this distribution pattern varies greatly, depending on the different coastal regions of Europe, as the coastlines extend from Arctic and Subarctic to Mediterranean regions (further analyses in Van der Maarel and Van der Maarel-Versluys 1996).

The Eastern mangroves of the Indian, Indo-Pacific and Pacific Ocean on the coasts of Indonesia, Madagascar, Southeast Asia and North Australia are more species-rich than western mangroves on the Atlantic Ocean coasts of Africa and America. This might also be the case for endemic species (Schroeder 1998; Wikramanayake et al. 2002). However, at present we can only speculate on this, and further research and data are indispensable.

5.3.2 Inland Waters, Mires, Bogs and Fens

5.3.2.1 Overview

Only few comprehensive analyses on endemic vascular plant taxa deal with lakes, rivers, bogs, mires, swamps, or other aquatic habitats. These are, for example, associated with the vernal pools of California, wetlands, mires, bogs, fens and swamps of Europe, aquatic and semiaquatic vegetation on Madagascar and New Zealand, and swamps and other freshwater habitats of the Nile Delta in Egypt (Bruchmann 2011; Hobohm and Bruchmann 2009; McGinley 2008h; Hobohm 2008b; Lazar 2004; Gautier and Goodman 2003; Ranarijaona in Goodman and Benstead 2003; McGlone et al. 2001; Ferry et al. 1999; Davis et al. 1994, 1995, 1997). Information about single endemic plants and their (aquatic or wet) habitats can be found on a number of websites (e.g. IUCN Red List data, www.iucnredlist.org) and many regional floras.

Only a few regions show moderate or high endemism associated with water bodies or wetlands. The vernal pools of California harbour c. 140 endemics in ephemeral freshwater communities and related vegetation types (Lazar 2004; Keeler-Wolf et al. 1998; Zedler 1990; Holland and Jain 1988).

In Baja California only few taxa are associated with water habitats or wetlands, e.g. the palm *Brachea armata* which is found in permanent oases (Vanderplank in lit.).

In the swamp habitats and other freshwater wetlands of the Nile Delta in Egypt McGinley (2008f) identified 8 endemic species (of a total of 553 plant species).

According to Ranarijaona (in Goodman and Benstead 2003: 251) c. 128 aquatic and semiaquatic vascular plant taxa are endemic to Madagascar. This number is relatively low compared to the total number of endemics on the island (8,000–10,000; see Gautier and Goodman 2003). Ferry et al. (1999) suggest that the low number of endemic aquatic plants on Madagascar may be a result of Quaternary climate fluctuations; during dry periods, freshwater and semi-aquatic habitats were essentially dry, eliminating local floras which depended on wet conditions. The small total area of water bodies and wetlands and the fact that lakes and running waters are normally relatively young and discrete units are not the best conditions for promoting endemism. Compared to other regions in the world the percentage of wetland inhabitants that are endemic to Madagascar is high. Of the 338 Malagasy vascular plants that belong to the flora of aquatic and semiaquatic vegetation, 128 (or 38 %) are endemics. The relatively high ratio can be explained by the fact that Madagascar is most likely the oldest island in the world and separated from the mainland of Africa about 165 million years ago (Goodman and Benstead 2003).

For New Zealand a figure of 264 endemic species is given for wetlands (McGlone et al. 2001). The relatively high number for the much smaller areas of New Zealand (269,000 km^2) compared to Europe (275 endemic taxa, 10,500,000 km^2) or Madagascar (128 endemic taxa, 587,000 km^2) might be explained by less marked effects of climate fluctuations, higher precipitation rates, and the higher proportion of wetland areas in New Zealand in general (De Lange et al. 2006, 2009; Connor 2002; Davis et al. 1994, 1995).

We assume that the global proportion of endemics in wetlands and water bodies is indeed very low (Photos 5.1, 5.2, and 5.3).

In the following we give an overview of the endemics which are associated with the wetlands of Europe.

5.3.2.2 Wet Habitats of Europe

We here present an analysis based on an earlier publication (Hobohm and Bruchmann 2011). The improvement of the list of endemics and discussions with colleagues resulted in a few changes. However, the main result of the earlier publication remain valid.

Analysis of Endemism Associated with Wet Habitats in Europe

The area covered here is Europe as defined in Fontaine et al. (2007). We divided Europe into 42 geographical units representing islands or groups of islands, nations, groups of small nations or, in the case of the former Soviet Union, parts of a nation (cf. Bruchmann 2011; Hobohm and Bruchmann 2009; Tutin et al. 1968–1993, see Fig. 5.2). The details are given in Bruchmann (2011).

Photo 5.1 *Colchicum figlalii*, extremely rare and restricted to temporarily inundated depressions in serpentinite areas of Turkey (Photographed by Gerhard Pils)

The data base EvaplantE (cf. Bruchmann 2011; Bruchmann and Hobohm 2010; Hobohm and Bruchmann 2009; Hobohm 2008a) contains information about most endemic vascular plant species or subspecies of Europe. The version EvaplantE 11/2012 shows 6,244 vascular plant taxa as endemics of Europe.

The taxonomic status and our species concept is primarily based on Flora Europaea (Tutin et al. 1968–1993) plus floras and lists of the Canary Islands, the Madeira archipelago and Cyprus (Borges et al. 2008; Izquierdo et al. 2004; Press and Short 1994; Meikle 1977, 1985). Many other regional and national floras were also used to gather information about habitats, ecological conditions, altitudes, and so on (cf. Bruchmann 2011; Hobohm 2008a, b; Kliment 1999).

In general, biogeographical analyses based on field data of plant compositions show some degree of bias. An imbalance in the biogeographical data arises as a result of geographically different perceptions and activities in the field and from the use of different taxonomies (different floras). We tried to minimise this problem by using a broad species concept and international floras and checklists, such as Flora Europaea (Tutin et al. 1968–1993, reprints 1996) and Euro + Med plantbase (cf. e.g. Greuter and Raab-Straube 2012) as primary sources.

We filtered and analysed the recent version of the data base (EvaplantE; version 11/2012) with a focus on European endemic vascular plants occurring under wet conditions or in the succession stages following inundation. We excluded taxa which primarily inhabit coastal habitats such as saltmarshes or rocky habitats

Photo 5.2 Nutrient-poor mire with carnivorous *Nepenthes madagascariensis* (S Madagascar near Fort Dauphin; photographed by Carsten Hobohm)

Photo 5.3 Freshwater lagoon with *Pandanus peyrierasii*, *Pandanus rollotii*, *Pandanus longistylus*, *Typhonodorum lindleyanum* (large leaves), *Barringtonia racemosa* (to the *left*). All but one Malagasy *Pandanus* spp. are endemic to the island (Mandena, S Madagascar; photographed by Carsten Hobohm)

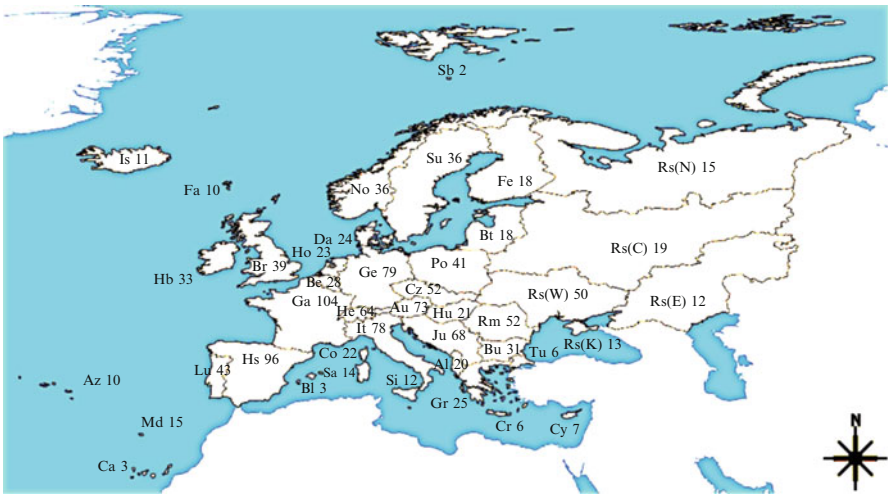

Fig. 5.2 Distribution of 275 endemic vascular plant taxa associated with wet or regularly inundated habitats in Europe

near the sea, taxa that only exceptionally occur in wet or inundated habitats, and apomictic microspecies (*Alchemilla*, *Taraxacum*, *Ranunculus auricomus*). Recently, we excluded *Marsilea azorica* which is conspecific with *M. hirsuta* from Australia. Thus, this species was reclassified from *endemic* to *neophytic* (Schaefer et al. 2011).

Additionally, we verified or corrected the nomenclature and geographical distribution for most taxa on our list using the Euro+Med plantbase on the internet (Euro+Med 2006–2011). In a few cases, this procedure had the effect that taxa changed their designation from *endemic* to *subendemic* because they have since been found in North African countries, such as Morocco, Algeria, Tunesia, or in parts of western Asia. These taxa were also eliminated from the list.

The analysis is founded on absolute numbers of taxa per region and descriptive statistics. As a first step, we summed up numbers of species or subspecies for the whole of Europe, and numbers of species and subspecies per region. The regions are of different sizes. At the moment it is impossible to reliably determine numbers of European endemic vascular plant taxa in relation to habitat for an artificially defined grid cell. This is the reason why certain statistical methods cannot be applied (see also the discussions of species-area and endemics-area relationships, e.g. in He and Hubbell 2011; Dengler 2009; Werner and Buszko 2005; Green and Ostling 2003). Preliminary investigations, for example, showed a negative correlation between area and endemism of vascular plants in Europe (log-log-space, all endemics) because many small regions in the South of Europe show high endemism, whereas very large regions in Scandinavia and Russia are poor in endemics. Further problems and restrictions related to the statistics are discussed in Bruchmann (2011).

If we compare numbers of regions of the same area then we can use these values as direct measurements for the density of endemics (Bruchmann 2011). Also in other cases we can compare density values directly (see Chap. 2). In our division of Europe this allows a direct comparison of density values of many pairs of regions.

Endemic Vascular Plants in Wetlands of Europe

The data base EvaplantE comprises at least 275 endemic plant taxa – species and subspecies – which occur more or less regularly in wetland communities (Table 5.6). All of these are restricted to the boundaries of Europe as defined in Fontaine et al. (2007). This number is a minimum value because c. 20 % of the listed taxa in EvaplantE have not yet, or have only inadequately, been characterized in relation to ecological conditions or habitat.

However, compared with endemics of other habitat types the number of 275 is low (Bruchmann 2011).

Only few of the taxa listed are hydrophytes living in standing or running waters. Many more taxa are not strongly associated with wet habitats and occur in both wet and other habitats (Hobohm and Bruchmann 2011, Table 5.6).

Figure 5.2 shows distribution patterns of endemic vascular plants related to wet habitats. The numbers in the South-west of Europe are higher than in the North-east. The numbers for a triangle-shaped region between Spain, former Yugoslavia and Germany are much higher than for the rest of Europe. The highest absolute numbers of taxa were found in France and Spain. Austria, Italy and Germany also have high numbers.

We assume that this fact reflects a combination of processes and conditions which favour endemism in general and endemism of wet habitats in particular (e.g. oceanic climate, high precipitation rate, humidity). Southern France is located within and between two high-mountain ranges with high environmental heterogeneity, the Pyrenees and the Alps. The country is also located between two marine environments which influence and stabilise the climate. Therefore, three major climate regimes occur in France: Mediterranean, temperate Atlantic and high-mountain climate. Mainland France is connected with other species-rich regions – e.g. the Iberian Peninsula, the Alps, Italy. Some of the Pleistocene refugia are located in the country or not far away. Thus, migration distances after glacial cycles might have been relatively short (Medail and Diadema 2009; Krebs et al. 2004).

The East of Europe shares many taxa with the West of Asia. Many landscapes, habitat types and ecological conditions are quite similar West and East of the border between Europe and Asia. The southern and south-eastern part of the continental border, in particular, is artificially defined (along the narrow Bosporus and along the Ural River). Thus, the marginal regions bordering Asia necessarily have fewer endemics than they would have if these regions were located in another part of Europe. This applies particularly to the European part of Turkey, which is rather small.

Table 5.6 Comparison of the density (E/A) of wetland endemics in different parts of Europe (Left column: increasing area; abbreviations refer to the geographic areas mapped in Fig. 5.2)

Higher density of endemics	Lower density of endemics (area increasing to the right side)
Madeira archipelago (Md)	Fa, Az, Bl, Ca, Cr, Cy, Tu, Sa, Si, Rs (K), Sb, Is, Rs (E), Rs (N)
Faroe Islands (Fa)	Az, Bl, Ca, Cr, Cy, Tu, Sb
Azores (Az)	Bl, Ca, Cr, Cy, Tu, Sb
Balearic Islands (Bl)	Ca, Sb
Canary Islands (Ca)	Sb
Crete (Cr)	Tu, Sb
Corsica (Co)	Cy, Tu, Sa, Si, Rs (K), Al, Sb, Hu, Is, Bt, Fe, Rs (E), Rs (N), Rs (C)
Cyprus (Cy)	Tu, Sb
Turkey (Tu)	Sb
Sardinia and Malta (Sa)	Si, Rs (K), Sb, Is, Rs (E)
Sicily (Si)	Sb, Is, Rs (E)
Crimean Peninsula Rs (K)	Sb, Is, Rs (E)
Albania (Al)	Sb, Is, Bt, Fe, Rs (E), Rs (N), Rs(C)
Belgium and Luxembourg (Be)	Ho, Da, Sb, Hu, Is, Gr, Bt, Fe, Rs (E), Rs (N), Rs (C)
Netherlands (Ho)	Sb, Hu, Is, Bt, Fe, Rs (E), Rs (N), Rs (C)
Switzerland (He)	Da, Sb, Hb, Lu, Hu, Is, Bu, Gr, Cz, Bt, Br, Rm, Po, No, Fe, Su, Rs (W), Rs (E), Rs (N), Rs (C)
Denmark (Da)	Sb, Hu, Is, Bt, Fe, Rs (E), Rs (N), Rs (C)
Ireland (Hb)	Hu, Is, Bu, Gr, Bt, Fe, Rs (E), Rs (N), Rs (C)
Austria (Au)	Lu, Hu, Is, Bu, Gr, Cz, Bt, Br, Rm, Ju, Po, No, Fe, Su, Rs (W), Rs (E), Rs (N), Rs (C)
Portugal mainland (Lu)	Hu, Is, Bu, Gr, Bt, Br, Po, No, Fe, Su, Rs (E), Rs (N), Rs (C)
Hungary (Hu)	Is, Bt, Fe, Rs (E), Rs (N), Rs (C)
Bulgaria (Bu)	Gr, Bt, Fe, Rs (E), Rs (N), Rs (C)
Greece without Crete (Gr)	Bt, Fe, Rs (E), Rs (N), Rs (C)
Czech Republik and Slovakia (Cz)	Bt, Br, Rm, Po, No, Fe, Su, Rs (W), Rs (E), Rs (N), Rs (C)
Estonia, Latvia, Lithuania and Oblast Kalingrad (Bt)	Fe, Rs (E), Rs (C), Rs (N)
Great Britain (Br)	No, Fe, Su, Rs (W), Rs (E), Rs (N), Rs (C)
Romania (Rm)	Po, No, Fe, Su, Rs (W), Rs (E), Rs (N), Rs (C)
Italy (It)	Ju, Po, No, Fe, Su, Rs (W), Rs (E), Rs (N), Rs (C)
former Yugoslavia (Ju)	Po, No, Fe, Su, Rs (W), Rs (E), Rs (N), Rs (C)
Poland (Po)	No, Fe, Su, Rs (E), Rs (N), Rs (C)
Norway (No)	Fe, Su, Rs (E), Rs (N), Rs (C)
Finland (Fe)	Rs (E), Rs (N)
Germany (Ge)	Su, Rs (W), Rs (E), Rs (N), Rs (C)
Sweden (Su)	Rs (E), Rs (N), Rs (C)
Spain (Hs)	Rs (W), Rs (E), Rs (N), Rs (C)
France (Ga)	Rs (W), Rs (E), Rs (N), Rs (C)
Former Soviet Union, southwestern division (Rs (W))	Rs (E), Rs (N), Rs (C)

These factors together might explain the relatively high numbers of European endemic vascular plant taxa related to wet habitats in France and neighbouring countries (cf. Rull 2004; Rosenzweig 1995a, b) and relatively low numbers to the East. However, this cannot easily been verified at present.

Table 5.6 shows the result of all (250) pairwise comparisons of the density of endemism (E/A) that can be calculated directly. Some regions, such as the Madeira archipelago, Corsica, Switzerland, Austria, Italy, Germany, mainland Spain and France are only to be found in the left column. These countries show relatively high density values. Others occur only in the right column: Regions such as Svalbard and the eastern, northern and central divisions of the former Soviet Union have relatively low density values. All other regions occur in both columns.

The comparison shows that the density of endemics increases roughly from the continental regions in eastern Europe to the more oceanic regions towards the west. However, Switzerland has a higher density value than Ireland. Austria, the Czech Republic and Slovakia have higher values than Great Britain.

The highest density values on a N-S gradient are in general not represented by the Mediterranean regions, e.g. Austria has a higher density than Portugal, Greece or former Yugoslavia, and even the Faroe Islands towards the North-west have a higher density than the Canary Islands, Crete, or Cyprus, to the South. In general, temperate regions do not have lower values than Mediterranean regions. However, the boreal-arctic regions towards the north, such as Svalbard, Iceland, Finland and northern Russia, have extremely low values.

We obtained altitudinal range data for 156 taxa on the list. Wetland endemics occur at all altitudes between sea level and alpine zones. The average of the minima (median) is 300 m above sea level, the average of the maxima 1,800 m. This means that most endemics occur in the montane and subalpine zones. *Gentiana bavarica* occurs in damp places, e.g. moors with spring water, wet alpine meadows, and snow patches. This species represents the absolute maximum of 3,600 m above sea level in our list.

Forty-one endemics are basiphytes, 31 acidophytes. Many species are indifferent to pH or have not yet been characterized (Table 5.7).

5.3.3 Forest and Woodland

Many publications cited in Tables 5.1, 5.2, 5.3, 5.4, and 5.5 name forest or woodland as the only or as one of the main habitat types – often in the warm-temperate and tropical zones of the world. Data for the boreal-arctic and cold temperate zones is scarce and seldom provides quantified information on patterns of endemism.

In the coastal forest of the Eastern Africa Biodiversity Hotspot many endemics have been recorded from forest habitats. However, it is difficult to give quantified data because numbers for the areas studied diverge considerably between sources. While Burgess et al. (1998, 2003, 2004) state that of the 1,750 strictly endemic species 554 species are confined to the coastal forest habitat and 812 species inhabit

Table 5.7 List of European endemics that are connected with wet habitats (Excerpt from EvaplantE, version 11/2012)

European endemic vascular plants which occur in wet habitats or after inundation (according to EvaplantE, last updated version 11/2012)	Habitats, ecology (plant communities)
Achillea asplenifolia	Wet lowland meadows (Molinion) and swampy grasslands
Achillea ptarmica	Damp grassy places, wet meadows, marshy fields, banks of running waters, tall forb communities and swamps (Molinietalia)
Achillea oxyloba	Mountain rocks, pastures, stoney river banks and screes, calcicole
Aconitum corsicum	Tall herb communities, edges of moors and swamps
Aconitum variegatum ssp. variegatum	Scrub, river banks, riparian forests, subalpine tall herb communties, moist or wet, nutrient- and base-rich substrates
Agropyron tanaiticum	Sandy river-banks, upper stream terraces, pioneer grass that profits from sodding activities
Allium schmitzii	River banks and moist rock-crevices
Allium suaveolens	Damp meadows and moors
Alyssum wulfenianum	Calcareous rocks and screes, river banks and gravel, secondary localities metalliferous substrates
Angelica heterocarpa	Muddy banks of tidal rivers
Angelica razulii	Banks of streams (tall herb communities), also in forest clearings and wet pastures
Arabis kennedyae	Shaded rocks near streams
Arabis soyeri	Alpine and subalpine spring vegetation and banks with permanent cold water
Arenaria gothica	Dry limestone pavement and lake shores
Armeria maritima ssp. purpurea	Marshy meadows and inundated lake-shores (Deschampsietum rhenanae, Cratoneurion, Primulo-Schoenetum)
Armoracia macrocarpa	Reeds, wet meadows, wet pastures and salt steppe (Scirpo-Phragmitetum, Phalaridetum arundinaceae, Agrostio-Alopecuretum pratensis), preferably on alkaline and nutrient-rich soils
Asparagus pseudoscaber	Temporarily inundated meadows
Baldellia alpestris	Ponds, glacial lakes, streamlets and peat bogs, acidic substrates or waters
Brassica glabrescens	Calcareous river banks, on gravel (pioneer communities)
Calamagrostis scotica	Bogs, marshes and fens
Callitriche brutia	Still, often shallow water
Callitriche hamulata	Base-poor, cool, flowing water and lakes (Batrachion fluviatilis, Nanocyperion flavescentis)
Callitriche platycarpa	Fresh water (rarely brackish water), flowing or still, often base-rich water
Callitriche truncata	Always submerged, including brackish waters

(continued)

Table 5.7 (continued)

European endemic vascular plants which occur in wet habitats or after inundation (according to EvaplantE, last updated version 11/2012)	Habitats, ecology (plant communities)
Calycocorsus stipitatus	Montane and subalpine zones, moorland, spring vegetation and river banks (Caricion fuscae, Cardamino-Montion)
Campanula pulla	Rocks and screes, stony slopes and mountain pastures, spring vegetation, secondary localities on river banks and river gravels, somewhat calcicole
Cardamine amara ssp. austrica	Streamsides, marshes and flushes
Cardamine amara ssp. balcanica	Streamsides, marshes and flushes
Cardamine amara ssp. opicii	Streamsides, marshes and flushes
Cardamine amara ssp. pyrenaea	Spring vegetation, streamsides, wet pastures
Cardamine asarifolia	Streamsides and other damp places, calcifuge
Cardamine crassifolia	Peatbogs and other wetlands
Cardamine raphanifolia	River banks and spring vegetation, also wet grassland, herb communties and humid forests
Carduus crispus ssp. multiflorus	Roadsides, waste places and streamsides
Carduus personata	Streamsides, meadows, scrubland and woods, tall herb communties (Arunco-Petasition, Rumicion alpini, Adenostylion, Alnetum incanae)
Carex bergrothii	Fens and wet woods
Carex camposii	Flushes and streamsides
Carex cretica	Damp places, banks, riparian *Platanus orientalis* woodland, steep wet banks (Adiantion capilli-veneris), spring vegetation and seepage meadows (Brachypodio-Holoschoenion)
Carex durieui	Damp grassland, pastures and moors
Carex frigida	Streamsides, trickling waters and wet mountain grassland
Carex fuliginosa ssp. fuliginosa	Alpine zone, rock-ledges, stream-sides and wet, stony places (Festucion variae)
Carex jemtlandica	Fens
Carex lowei	Among rocks and along ditches and small rivers in damp wooded valleys
Carex nevadensis	Wet places, river banks, wet slopes and mires
Carex pulicaris	Damp and marshy meadows and moors (Caricion nigrae, Caricion davallianae, Molinietalia)
Carex randalpina	Banks and wet slopes, preferably associated with *Carex acutiformis* or *Phalaris arundinacea* (Caricetum oenensis, Magnocaricion)
Carex trinervis	Damp maritime sands, wet dune slacks, wet heaths and fens (Caricetum trinervi-nigrae and Empetro-Ericetum)
Caropsis verticillatoinundata	Ponds and temporary ponds/lakes, peat bogs and other locations in sandy places and temporarily soaked near the seaside

(continued)

Table 5.7 (continued)

European endemic vascular plants which occur in wet habitats or after inundation (according to EvaplantE, last updated version 11/2012)	Habitats, ecology (plant communities)
Centaurea appendiculata	River sands
Centaurea arenaria ssp. sophiae	Sandy river-banks
Centaurea donetzica	River sands; pine forests
Centaurea konkae	River sands
Centaurea macroptilon	Molinietalia caeruleae
Centaurea paczoskii	Sandy steppes, open river sands
Centaurea protogerberi	River sands
Centaurea savranica	River sands and sandy steppe slopes
Centaurium microcalyx	Wet grasslands,temporarily inundated places, moors and other wet places
Cephalaria litvinovii	Ravines, among scrub, along river valleys, gullies
Cephalorhynchus cyprius (Cicerbita cypria)	In moist, shaded positions, by streams and moist hillsides among pine and riverine forest on igneous formations
Cerastium azoricum	Humid rocks in rivines and cliffs and near waterfalls
Cerastium brachypetalum ssp. doerfleri	Wet roadsides, screes, stony mountain slopes, river banks in the mountains
Ceterach lolegnamense	On roadside walls in hills, and on stream banks
Chaerophyllum elegans	Wet meadows, river banks, spring vegetation, tall herb communities, nutrient-rich, wet substrates
Chondrilla chondrilloides	River gravels, calcicole
Chrysosplenium alpinum	Mountain spring vegetation and flushes
Chrysosplenium oppositifolium	Spring vegetation in woods, wet ground near small rivers (Cardaminion amarae, Alnenion glutinoso-incanae)
Cirsium bourgaeanum	Marshes
Cirsium brachycephalum	Fens and wet meadows, saltmarshes (Cirsion brychycephali-Bolboschoenion, Loto-Trifolenion, Magnocaricion elatae)
Cirsium creticum ssp. triumfetti	Wet meadows and marshes
Cirsium dissectum	Wet places, usually on peaty soils; fens, bogs, wet fields on peaty soil (Juncion acutiflori)
Cirsium glabrum	Damp screes and streamsides
Cirsium rivulare	Damp places, calcifuge; wet meadows, swamps, forest glades, banks of streams and rivers, forest gullies
Cirsium tymphaeum	Spring vegetation and other damp places
Cochlearia pyrenaica	Near spring vegetation and permanently flowing, cold rivers, also in moors and wet forest
Cochlearia tatrae	Rocks, screes, spring vegetation, along streems, on gravel banks, restricted to granite (Oxyrio digynae-Saxifragetum carpaticae)
Coronilla globosa	Cliffs and river gravels
Coronopus navasii	Banks of ponds and ephemeral waters which occur during winter times

(continued)

Table 5.7 (continued)

European endemic vascular plants which occur in wet habitats or after inundation (according to EvaplantE, last updated version 11/2012)	Habitats, ecology (plant communities)
Cymbalaria hepaticifolia	Shady places and on rocks by streams
Cyperus cyprius	By streams and ditches with flowing water on igneous formations
Dactylorhiza alpestris	Damp meadows and fens
Dactylorhiza cordigera	Mountain grassland, also marshes
Dactylorhiza incarnata ssp. coccinea	Marshes, fens and bogs, dune-slacks and other damp alkaline sandy areas near sea, damp inland lake-shores
Dactylorhiza incarnata ssp. pulchella	Bogs and other neutral to acidic wet peaty places
Dactylorhiza islandica	Moorland, grassland and damp woods, mainly on acid soils
Dactylorhiza lapponica	Fens and marshes, wet meadows and banks, sometimes in open woods
Dactylorhiza maculata ssp. schurii	Moorland, grassland and damp woods, mainly on acid soils
Dactylorhiza majalis ssp. occidentalis	Damp meadows and fens
Dactylorhiza praetermissa	Damp meadows and fens
Dactylorhiza pseudocordigera	Fens and calcareous grasslands
Dactylorhiza purpurella	Damp meadows and fens
Dactylorhiza sphagnicola	Peat bogs, wet meadows, dune slacks and nutrient-poor reeds
Deschampsia littoralis	Periodically inundated lake shores, also on river banks
Deschampsia wibeliana	Estuaric marshes; sandy banks influenced by North sea tides and freshwater
Diphasiastrum madeirense	Moorlands, juniper forests and damp heathland
Doronicum cataractarum	Stream-sides and other shady places, preferably damp and wet tall herb communities in contact with cold freshwater of small rivers
Dryopteris aitoniana	Moist woods and along shady levadas in laurisilva regions
Dryopteris maderensis	Damp forest, beside levadas and streams
Eleocharis carniolica	River-banks and seasonally flooded grassy places
Elymus alaskanus ssp. subalpinus	River-banks, rocks and stony slopes
Elymus scandicus	River-banks, rocks and stony slopes
Epilobium alsinifolium	Humid and marshy places, near brooks, lakes and snow patches, and spring vegetation ((hygrophilous herb communities, Cardamino-Montion, Adenostylion, Cardaminion amarae)
Epilobium fleischeri	Pioneer-communities on subalpine river banks and moraines
Epilobium nutans	Subalpine wet spring vegetation and moors (Cardamino-Montion, Adenostylion, Cardaminion amarae, Drepanocladion exannulati)

(continued)

Table 5.7 (continued)

European endemic vascular plants which occur in wet habitats or after inundation (according to EvaplantE, last updated version 11/2012)	Habitats, ecology (plant communities)
Erica tetralix	Bogs, wet heaths and pinewoods; in the more humid and oceanic regions also in dryer habitats such as damp, shady walls
Erucastrum palustre	Marshes and rice fields
Eryngium viviparum	Places liable to winter flooding
Erysimum creticum	Gravelly riverbeds, roadsides and garigues
Euphorbia uliginosa	Temporary ponds, wet heath and other temporarily flooded or wet locations
Euphrasia calida	Apparently associated with warm spring vegetation
Euphrasia scottica	Wet moorland, fens and flushes
Festuca nitida	Calcicole; Petasition paradoxi
Festuca rubra ssp. thessalica	Mountain springs
Fraxinus pallisiae	River-banks and flood-plains
Galanthus nivalis	Open places wettet in spring, deciduous woodland and shady streamsides, forest edges, scrublands
Galeopsis pyrenaica	Sandy or gravelly ground by mountain streams, calcifuge
Genista berberidea	Damp meadows and bogs, wet banks with shrub communities
Gentiana bavarica	Damp places, spring vegetation and moors, snow patches and wet or damp alpine grassland
Gentiana clusii	Alpine grassland, screes, rocky habitats, moors
Geranium palmatum	Rocky cliffs and along levadas, usually in moist, shady places
Geranium yeoi	Woodland, on banks, and along levadas
Geum rhodopeum	Wet and marshy places, wet meadows
Goniolimon graminifolium	Sandy ground by rivers
Hemerocallis lilioasphodelus	Rocky mountain woods and riversides; naturalised by rivers and in wet meadows
Herniaria ciliolata	Coastal dunes and rocks, secondary localities at the edge of ephemeral ponds
Hierochloe hirta ssp. hirta	Nutrient-poor wet meadows, fens and lake-shores, also river banks, on sand or gravel
Hierochloe odorata ssp. baltica	Wet meadows, fens, riversides and lake-margins
Holcus gayanus	Ephemeral sources of rocky habitats in high mountain regions (Holco-Bryetum, Isoeto-Nanojuncetea)
Huperzia dentata	Damp, shady, rocky places in wooded slopes, gullies and banks above levadas, steep, often sandy slopes
Hypericum elodes	Damp or shallow water, standing waters in peat bogs
Inula helvetica	Woods and streamsides
Isoetes azorica	Pools and small lakes
Isoetes boryana	Shallow lakes
Isoetes heldreichii	Schistose soil of lake margin

(continued)

Table 5.7 (continued)

European endemic vascular plants which occur in wet habitats or after inundation (according to EvaplantE, last updated version 11/2012)	Habitats, ecology (plant communities)
Isoetes longissima	Rapidly flowing water
Isoetes malinverniana	Rapidly flowing water of irrigation channels
Isoetes setacea	Ponds and small lakes
Isoetes velata ssp. asturicense	Shallow lake-margins and seasonal pools
Isoetes velata ssp. tenuissima	Shallow lake-margins and seasonal pools
Jasonia tuberosa	Rock-crevices and river gravels
Juncus jacquinii	Alpine streamsides and damp grasslands, acidic substrates
Juncus requienii	Fens and streamsides
Juncus thomasii	Mountain forests, alpine meadows, also in bogs
Knautia godetii	Damp meadows and bogs
Lathyrus neurolobus	Woodland streams, steep wet banks (Adiantion capilli-veneris), spring vegetation and seepage meadows (Brachypodio-Holoschoenion)
Lathyrus palustris ssp. nudicaulis	River margins, ponds, streams, marshes, other damp or inundated places on all kinds of soils
Leontodon berinii	River gravels and banks (Epilobion fleischeri)
Leucojum vernum	In meadows, foothills, and upper limit of beech forests, in forest edges, river banks, and riparian meadows and herb communties
Limosella tenella	Muddy lake-shores
Lonicera nigra	Mountain spruce and beech forests, on forest edges, in scrublands, along riverbanks
Luzula sylvatica ssp. henriquesii	Damp woods, moorland and damp rocky places
Malcolmia graeca	Gravelly or rocky places, river banks, open phrygana, open *Abies cephalonica* forest, subalpine meadows, rock crevices
Malus praecox	Decidous woodland along rivers
Mentha longifolia ssp. cypria	Streams and spring vegetation
Myosotis lamottiana	Wet mountain meadows
Myosotis rehsteineri	Summer-inundated lake-margins, dry during spring and autumn (Deschampsion littoralis)
Najas mircrocarpa	Shallow water (associated with *Chara fragilis*)
Narcissus cyclamineus	Damp mountain pastures and banks of permanent watercourses, preferably with tree crown cover of alders and others
Narcissus jonquilla	Riparian zones, in wet meadows on the banks of rivers and in stony areas on streambed and river margins
Narcissus longispathus	In or near mountain streams
Narthecium ossifragum	Bogs and wet acidic heaths (Ericion tetralicis)
Narthecium reverchonii	Damp places by mountain streams
Noccaea cypria	Moist rocky slopes and igneous rocks near streams
Odontites kaliformis	Dry places, coastal pioneer communties and salt marshes, secondary localities inland at the edge of ephemeral waters

(continued)

Table 5.7 (continued)

European endemic vascular plants which occur in wet habitats or after inundation (according to EvaplantE, last updated version 11/2012)	Habitats, ecology (plant communities)
Oenanthe conioides	Estuaric pioneer communities; muddy banks influenced by North sea tides and freshwater
Oenanthe divaricata	By streams and levadas and among wet rocks
Oenanthe fluviatilis	In still or slowly flowing water
Oenanthe lisae	Marshes
Oenanthe tenuifolia	Marshes
Oenothera ammophila	Open, sandy and sometimes ruderal habitats, especially on seashores, dunes, sandy river banks
Oxytropis triflora	Alpine grassland and rocky habitats, secondary localities on river banks (pioneer communities)
Papaver laestadianum	Screes, barren rock outcrops, open gravel in the middle alpine belt, secondary localities along river banks in the lowland
Papaver sendtneri	Moving screes and river gravels, sometimes in rock crevices
Paradisea lusitanica	Woods, damp meadows and marshes
Pastinaca kochii ssp. latifolia	Riverbanks and rocky places
Pedicularis foliosa	Meadows, stream-sides and scrub (Caricion ferrugineae; Caricion davallianae, Erico-Pinion), calcicole
Pedicularis limnogena	Streamsides, spring vegetation and wet grassland
Pedicularis pyrenaica	Alpine humid pastures and screes; preferably on acidic substrates
Pedicularis recutita	Mountain meadows, river banks (Alnion viridis, willow scrub) and damp or shady places
Pedicularis sylvatica ssp. hibernica	Wet heaths and bogs, often also in dryer habitats
Petagnia gussonei	Alongside woodland streams
Petasites kablikianus	Wet gravel, stream-banks and wooded gorges (Petasition officinalis)
Petasites paradoxus	Stream-banks and wet stony ground, calcicole
Peucedanum gallicum	Nutrient-poor grassland, herb and scrub communities, river banks and fringe communties, preferably on acidic substrates
Peucedanum lancifolium	Wet meadows, marshes and bogs
Pilularia globulifera	Shallow water, marshy ground, pools and lake margins
Pilularia minuta	Seasonally wet hollows and at margins of ditches
Pinguicula grandiflora	Bogs and damp moorland, also wet rocky habitats, planted and persistent in scattered places of SW England
Pinguicula leptoceras	Wet places in the mountains, spring vegetation and moors
Pinguicula nevadensis	Bogs and wet places in the mountains
Plagius flosculosus	Damp meadows, pastures, swamps and river banks (Molinio-Juncetea, Juncetea maritimi)
Polygala amara	Subalpine and alpine rocks and stony slopes, moor-meadows, bogs and spring vegetation

(continued)

Table 5.7 (continued)

European endemic vascular plants which occur in wet habitats or after inundation (according to EvaplantE, last updated version 11/2012)	Habitats, ecology (plant communities)
Polygala amarella	Dry grassland, wet meadows, moorland, near spring vegetation
Primula clusiana	Rocks and stony slopes, nutrient-poor mountain grassland, moors, snow-patches, calcicole
Primula deorum	Wet places, peat bogs, banks of lakes, wet grassland (hygrophilous herb vegetation and pastures in the subalpine and alpine belts)
Primula frondosa	Marshes and damp meadows, wet, grassy places along brooks and peat bogs, shady cliffs, rock crevices, snow patches
Pseudorchis albida ssp. albida	Damp and marshy meadows, marshy tundra, peat bogs, pastures and grassy heaths, on mountain slopes
Ranunculus aconitifolius	Spring vegetation, streamlets and wet grasslands in montaneous regions, herb communities and open forests (Calthion, Adenostylion, Salicion herbaceae)
Ranunculus barceloi (*R. chaerophyllus var. balearicus*)	Banks and brooksides
Ranunculus cordiger	Moist moorland, grassland, and river banks
Ranunculus flammula ssp. minimus	All kinds of wet places
Ranunculus flammula ssp. scoticus	All kinds of wet places
Ranunculus fluitans	Running waters, non-freezing ditches, winter-green hydrophyte communities
Ranunculus hederaceus	Water plant communities, slow flowing gullies and small rivers
Ranunculus kykkoensis	Moist slopes with open pine, or golden oak stands and road banks
Ranunculus longipes	Shallow ponds and seasonal inundated places
Ranunculus montanus	Subalpine and alpine pastures, moor-meadows, open pine or deciduous forests on mountain slopes, eutrophic and often calcareous subtrates
Ranunculus ololeucos	Oligotrophic ditches, ponds and glacier lakes
Ranunculus platanifolius	Damp wooded ravines, tall herb communities (Alnetum viridis, Sorbo-Calamagrostietum, Betulo-Adenostyletea, Aceri-Fagetum, Tilio-Acerion, Berberidion)
Ranunculus revelieri	Small temporary waters (Isoetion)
Ranunculus wilanderi	Damp moss tundra below a bird cliff
Rheum rhaponticum	Wet mountain rocks; wet, rocky and stony places, along brooks and river beds, on silcate places
Rhododendron ponticum ssp. baeticum	In woods or by streams in the mountains; calcifuge
Romulea revelierei	Damp or seasonally inundated ground near the sea
Rumex balcanicus	Beside mountain streams
Sagina pilifera	Wet and damp pastures and moors, also other wet places (Saginetea piliferae)

(continued)

Table 5.7 (continued)

European endemic vascular plants which occur in wet habitats or after inundation (according to EvaplantE, last updated version 11/2012)	Habitats, ecology (plant communities)
Salix appennina	Damp woods and marshes
Salix bicolor	Subalpine spring vegetation and banks of small rivers
Salix cantabrica	Along mountain rivers
Salix daphnoides	Near rivers, ponds, lakes, and other wet places
Salix glabra	Subalpine and alpine forb and scrub communities, often close to small rivers or spring vegetation
Salix mielichhoferi	Along small rivers in the mountains (Alnion viridis), secondary localities in rocks and screes of high mountan regions, also in swamps
Salix repens ssp. repens	Coastal dunes, moorland and heaths, also beside sandy routes; ssp. *repens* in wet places such as dune slacks, ssp. *arenaria* also in wet places such as coastal reeds dominated by *Phragmites communis*.
Salix salviifolia	River margins with occasionally high water levels
Salix silesiaca	Riversides and damp clearings
Sanguisorba dodecandra	Subalpine meadows and streams
Sanguisorba lateriflora	Wet pastures, scrub, river banks, also near rocks and in screes
Saponaria cypria	Rocky mountainsides with forest openings, road banks, by streams and streamlets
Saponaria ocymoides	Subalpine, dry calcareous srees and pine forest, river gravel
Saussurea alpina ssp. macrophylla	Meadows, forest glades and edges, rocks and stony slopes, banks of rivers and streams
Saussurea esthonica	Meadows, forest glades and edges, rocks and stony slopes, banks of rivers and streams
Saussurea porcii	Subalpine meadows, swamps in alpine zone
Saxifraga aquatica	Margins of fast-flowing streams
Saxifraga clusii	Damp, shady rocks, springs and by mountain streams
Saxifraga hostii	Rock crevices and wet calcareous sinter, calcicole
Saxifraga hypnoides	Moist grassland, screes, streamsides and mountain-ledges, damp rock ledges, boulders and dunes and by mountain streams
Saxifraga mutata	Moist and wet rocks and screes, on river gravels
Saxifraga oppositifolia ssp. amphibia	During summer inundated lake-margins, on gravel (Deschampsietum rhenanae; most likely extinct)
Saxifraga spathularis	Damp rocks in the mountains, humid forests, small river banks, somewhat calcifuge
Saxifraga umbrosa	Shady banks, streamsides and mountain grassland, also in wet and shady forests
Schedonorus uechtritzianus	Damp grassland, river-banks and sea-shores
Scorzonera fistulosa	Wet meadows and other seasonally wet places

(continued)

Table 5.7 (continued)

European endemic vascular plants which occur in wet habitats or after inundation (according to EvaplantE, last updated version 11/2012)	Habitats, ecology (plant communities)
Scrophularia alpestris	Damp woods and by streams
Scrophularia hirta	Cliffs, banks, rocks, walls, along levadas and roadsides, usually in damp or wet places
Scrophularia racemosa	Wet rocks, steep slopes, along levadas and in other damp or wet places
Scrophularia trifoliata	Streamsides and other damp, shady places
Scutellaria minor	Damp places (Molinietalia caeruleae)
Securinega tinctoria	Sandy riverbanks and streambeds (shrub communities)
Sedum aetnense	Ephemeral ponds
Senecio doria ssp. legionensis (*S. fontanicola*)	Meadows and marshes, spring vegetation and fens
Senecio subalpinus	Damp places, wet meadows, river banks and forest glades in middle and upper mountain zones (Alnion viridis, Calthion, Caricion fuscae, Alnion incanae)
Sibthorpia peregrina	Woodland, along levadas, and on banks, in damp, shady places
Silene asterias	Marshy places
Silene laconica	Rocky limestone slopes, streambeds, roadside gravel, olive groves
Silene pusilla	Moist mountain rocks, screes and stream sides, subalpine and alpine spring vegetation, also on shady rocks in lower altitudes (preferably associated with bryophytes)
Silene saxifraga	Mountains, rocky habitats and sunny slopes, river gravels, prefering alkaline substrates
Sisymbrella aspera ssp. praeterita	Alluvial gravels and damp soils
Sisymbrium supinum	Muddy and gravelly lake shores (Agropyro-Rumicion, Chenopodion rubri)
Solanum patens	Near river beds and ravines, wet slopes of laurisilva forest
Soldanella pindicola	Close to mountain spring vegetation
Symphytum officinale ssp. uliginosum	River-banks and damp grasslands, tall herb communities on wet ground
Syringa josikaea	Along rivers, on wet, shady slopes, in ravines
Thalictrum morisonii	Marshes and wet grassland
Thalictrum speciosisimum	Humid and damp river banks, wet hay meadows
Tofieldia calyculata	Fen meadows and fens on alkaline ground (Caricion davallianae)
Tolpis azorica	Shady rocks; juniper forests and ravines, on grassy slopes and moorland
Tragopogon brevirostris ssp. bjelorussicus	River sands and pine woods

(continued)

Table 5.7 (continued)

European endemic vascular plants which occur in wet habitats or after inundation (according to EvaplantE, last updated version 11/2012)	Habitats, ecology (plant communities)
Tragopogon brevirostris ssp. longifolius	Damp and wet meadows
Tragopogon floccosus	River sands, maritime sands
Trichomanes speciosum	Near waterfalls and caves, and other damp or dark places such as levadas; this fern also is epiphytic
Trifolium saxatile	Screes, dry gravel in river beds and moraines
Trisetum fuscum	Moist mountain meadows and stream-sides
Vaccinium padifolium	On open slopes and moorland, also growing in light shade of humid wooded ravines
Veronica dabneyi	Steep slopes and rocks in the most humid regions, often close to waterfalls or crater lakes
Veronica repens	Damp places in mountains, nutrient-poor wet ground, moors and river banks
Viola cretica	Forests, stony pastures, river beds, spring vegetation

the surrounding non-forested habitats, Mittermeier et al. (2005) claim that some 1,225 (about 70 % of all endemic species in the hotspot region) have been recorded from forest.

Approximately one half of the 1,605–1,957 endemic species within the Chilean-Winter-Rainfall-Valdivian-Forest Hotspot belong to shrub and forest ecosystems, which constitute 50 % of the whole area (Mittermeier et al. 2005).

In some biodiversity hotspotswith high endemism, such as Wallacea or the Guinean forests of West Africa (Tables 5.3 or 5.5, respectively), tropical rain forest is also predominant (Mittermeier et al. 2005). In the wet tropics of Mesoamerica many endemic species inhabit rain forest, cloud forest and montane forest (e.g. Mittermeier et al. 2005) but it was not possible to find specific numbers at smaller scales for this region. However, according to Gentry (1986) in montane regions of Central America and especially the Andes, local endemism seems to result mostly from a veritable explosion of speciation in relatively few taxa, mostly of shrubs, herbs and epiphytes. These groups constitute almost half of the neotropical flora. Many of them are not associated with forest but can also be found there. And they account for most of the excess floristic diversity of the Neotropics compared with the Paleotropics. In lowland Amazonia endemism is prevalent to habitat islands. Most of the taxa involved are canopy trees and lianas, with derivative species in specialised habitats such as white sands or seasonally inundated swamp forests. In some cases, it is clear that local endemic habitat specialists are derived from wide-ranging ancestors of the terra firme forest. Habitat specialisation has obviously been the prevalent evolutionary pathway of giving rise to local endemics in Amazonia (Gentry 1986).

Photo 5.4 *Arbutus canariensis* (Los Tilos, La Palma) is endemic to the western Canary Islands (Photographed by Carsten Hobohm)

Photo 5.5 *Sonchus canariensis* (in a *Pinus canariensis* forest near Villaflor, Tenerife; photographed by Carsten Hobohm) is endemic to Tenerife and Gran Canaria, Canary Islands

Photo 5.6 The genus *Micronychia* (*Micronychia macrophylla* Ranomafana, Madagascar; photographed by Carsten Hobohm), including three species, is endemic to Madagascar (Schatz 2001)

Photo 5.7 *Ravenala madagascariensis* is a pioneer tree in humid forest regions of Madagascar. The endemic monotypic genus (Schatz 2001) is planted in many regions of the humid tropics today (Photographed by Carsten Hobohm; near Brickaville, Madagascar)

On New Caledonia (Table 5.5) endemism peaks at an extraordinarily high level, with the highest percentage numbers reached in humid evergreen and sclerophyllous forest (Lowry 1998; Morat 1993; Schneckenburger 1991).

Some authors claim that the wet tropics or the tropical rain forest harbour most (endemic) vascular plant species (e.g. Mittermeier et al. 2005; Parmentier et al. 2007). Very often, tropical rainforest is named as the centre of endemism, with extraordinarily high endemism; however, this assumption should be checked carefully, as results from several ecoregions show a contrary trend. For the Northern Territory of Australia, for example, Woinarski et al. (2006) showed that rain forest-associated species have less propensity for endemism (602 species with 41 endemics) than species associated with other habitats (3,611 species with 526 endemics). Knowledge of the occurrence, distribution patterns, and diversity of endemic vascular plants in forest ecosystems (all layers) is quite limited and sometimes fragmentary. The analyses of Kreft et al. (2004) indicate that knowledge of the structure and diversity of neotropical forests was for a long time based on incomplete floristic inventories which misjudged large groups of vascular plants.

5.3.4 Scrub, Heath and Succulent Shrubland

Shrub-dominated communities may either be a mature vegetation type (e.g. in subalpine zones or some types of drylands) or may occur as temporary communities (successional stages) that develop following intense disturbances or degradations of woodland or forest. If disturbances such as fire, clearing, or heavy grazing regimes are regular phenomena then the adapted shrub vegetation may remain stable over a long period of time, even if forest could grow there.

Several sources state that Mediterranean climate and semi-desert ecosystems in Southern Africa, Southwest Australia, California, the Mediterranean Basin, and Mexico harbour a high number of endemic vascular plants. Many endemic-rich areas of the world have been found to be areas of shrubland vegetation.

In the Cape Floristic Region the highest numbers of endemic taxa are mostly found in the dominant fynbos vegetation (Mittermeier et al. 2005; Davis et al. 1994; Cowling 1992).

On New Caledonia the second largest group of endemics is associated with maquis vegetation (Lowry 1998; Morat 1993; Schneckenburger 1991).

We assume that the ecological conditions in many shrub-dominated landscapes promote endemism, especially under soil conditions and precipitation rates that are relatively stable over long evolutionary time periods (Desmet 2007; Ojeda et al. 2001; Wisheu et al. 2000; Cowling and Hilton-Taylor 1999; Cowling et al. 1992, 1994, 1996). Strong influences of the major ocean surface currents in the neighbourhood might favour high climatic constancy in these regions; thus relatively low precipitation totals (including mist) in some shrub- and dwarf-shrub dominated semi-desert and Mediterranean-climate areas are highly predictable (Hobbs et al. 1995) (Photos 5.8 and 5.9).

Photo 5.8 Dry thicket (*above*) with *Adansonia rubrostipa* (with treads for gathering fruits), *Didierea madagascariensis* (*background*, comose) and *Euphorbia laro* (*right*) near Ifaty, Madagascar (Photographed by Carsten Hobohm)

Photo 5.9 *Euphorbia canariensis* (cactaceous habit), forming succulent scrub communities in semi-desert zones, is endemic to the Canary Islands (Barranco Seco, Tenerife, photographed by Carsten Hobohm)

5.3.5 *Grassland and Habitats Dominated by Forbs, Mosses or Lichens*

As Mucina and Rutherford stated, "*the term grassland is one of the most used, misused and abused terms of vegetation ecology*" . . . (Mucina and Rutherford 2006: 350, see also Gibson 2009). In fact, the term grassland is often used as a generic term irrespective of the huge variety of environmental parameters, the different patterns of floristic or plant functional compositions, habitat extension and interface structures. Here we define grassland as a group of physiognomic habitats dominated by herbs and grasses which are not used as cropland. Sometimes shrubs or single trees occur but these cover less than 10 % of the area. This definition includes steppes, grassy savannas and paramo, and is consistent with other physiognomic classification systems (cf. EUNIS classification; Davies et al. 2004; White 1983).

Suttie et al. (2005) describe grassland ecosystems as one of the originally largest ecosystems in the world; estimates of the extent of this biome range from 31 to 40.5 % of the world's terrestrial area, depending on the definition of the term 'grassland'. Nowadays, large areas of grassland habitats are declining in quality and quantity, and some ecosystems are even dramatically threatened by extinction (Cremene et al. 2005; Mackay 2002; Dömpke and Succow 1998; Breymeyer 1990). Therefore, it is necessary that the great variety, and thus diversity, of grassland ecosystems should receive more attention than in the past (Photos 5.10, 5.11, 5.12, and 5.13).

The characteristic aspects of grassland-dominated ecosystems are widely influenced by their different developmental history. In the past, grassland was stabilised naturally either by specific climatic conditions such as low summer precipitation and winter drought, by periodical fire events, or by strong grazing regimes. Such habitats might be very old and thus characterised by long ecological continuity. On the other hand, there is the young semi-natural grassland that could potentially become forest if anthropogenic influences (cutting, burning, grazing, mowing) were less intensive (e.g. many grasslands at low- and mid altitudes in Europe).

The recent studies on occurrence of habitat specialists in grassland ecosystems show that, along with habitat persistence at the Holocene scale (Hájek et al. 2011), nutrient availability is also an important factor underlying specialist occurrence, while habitat-specialized grassland species tend to occur in nutrient-poor habitats (Fajmonová et al. 2012).

Mucina and Rutherford (2006) showed that some of the endemic-rich habitats of South Africa are linked to high altitude regions such as Drakensberg or Wolkensberg. The Drakensberg Alpine region, which is dominated by grassland, harbours about 334 endemic taxa (Mucina and Rutherford 2006) and for this reason it has been named a Centre of Plant Endemism (Van Wyk and Smith 2001). For many high altitude regions of the world, endemic-rich grassland such as alpine meadow, is mentioned in the literature, most often in connection with stony or rocky habitats (e.g. European Alps, Carpathians, Mountains of Central Asia and others). In the European flora, the group of grassland endemics is the second largest and

Photo 5.10 The composite *Cirsium dissectum* is endemic to W Europe and threatened by the decline in traditional management practices (Photographed by Carsten Hobohm; wet meadow in NW Germany)

Photo 5.11 *Orchis champagneuxii* is endemic to the Iberian Peninsula, S France and the Balearic Islands (Plus Morocco?; photographed by Carsten Hobohm in Serra da Estrela, Portugal)

Photo 5.12 *Phelypaea boissieri* is a parasite, endemic to Macedonia, Greece and Turkey and rare throughout almost all of its range (Photographed by Carsten Hobohm; subalpine grassland near Lake Prespa, Greece)

Photo 5.13 *Espeletia timotensis* is a character species of the paramos of the northern Andes (Photographed by Marinus Werger; Venezuela, Mucuchie, Piedras Negras, 4,100 m)

comprises many more taxa than e.g. forest ecosystems; this is not an area-effect because the area size of forest is much larger than that of grassland (Hobohm 2008a; Hobohm and Bruchmann 2009).

Beard et al. (2000) listed 241 endemic species for the savanna landscape of the Northern Province of Western Australia.

In summary, grasslands around the world are inhabited by a huge amount of endemics. Because this type of habitat is globally decreasing in area and quality many of the endemics are threatened with extinction (cf. Smolenice Grassland Declaration; EDGG 2010, and Hohhot Declaration 2008; on the internet).

5.3.6 Rock and Scree Habitats

5.3.6.1 Overview

Rock and scree habitats are found all over the world. Rocky habitats are dominant in many high mountain zones, in landscapes with steep slopes, and in coastal and desert regions. In these habitats differences in ecological conditions (light, water, wind speed, etc.) are much higher within small distances – a few meters – than in other habitat categories, e.g. grassland or forest. This also means that the impact of climate change might be small compared to habitats which are less heterogeneous (cf. Leuzinger et al. 2011).

The environmental conditions of rock and scree vegetation seem to have been relatively constant through time. Erosion and sedimentation patches are narrowly meshed. To find adequate ecological conditions under the pressure of climate change (glaciation periods and global warming) adapted vegetation types and endemic species would simply have to move a few hundred metres up or down the mountains (vertical displacement, Rull 2004). Rock and scree habitats as stepping stones that support the survival probability of the (endemic) species can be found at almost all altitudes of mountain ranges.

In the datasets analysed (Tables 5.1, 5.2, 5.3, 5.4, and 5.5) these habitats were not named very often as host areas for endemic species. On the other hand, in Europe, and possibly in many boreal-arctic and temperate regions worldwide, these are the habitats with very high or even the highest endemism. Studies on the endemic flora of Europe show that rocky habitats and screes represent the majority (>2,772 of c. 6,250–6,500 taxa) that are known to be endemic to Europe (Hobohm and Bruchmann 2009, data base EvaplantE in progress). In the Alps, 35–60 % of the 350–400 endemics species are found in habitats with rocks and screes, while in the Carpathians, which are not as high, only 10–15 % of 100–120 endemic species inhabit rocky habitats (Hobohm 2008a; Casazza et al. 2005, 2008; Dullinger et al. 2000; Pawlowski 1969). However, in Europe the highest endemism is confined to a habitat type which only represents a small percentage of the whole area (no exact data available yet). There is also data available on the endemic flora of the alpine regions of Iran (Noroozi et al. 2008) that reports a relationship between endemics

Photo 5.14 *Papaver sendtneri* is endemic to the Alps and shows preference for scree habitats (Photographed by Carsten Hobohm; Cogne Valley, Italian Alps)

and scree habitats. Talbot et al. (1999) list some endemic species of arctic regions that live in rock- and scree-dominated tundra vegetation.

Similarly high concentrations may exist in mountain areas of the tropics (e.g. the tropical Andes with about 15,000 endemic species) but no quantified data on endemics was found which could prove this assumption (Photo 5.14).

5.3.6.2 Comparison of High Endemism in Rocky Habitats with Low Endemism in Wetlands

In general, the number of endemics in wetlands is low compared to the numbers for rocky habitats and screes, grasslands, or scrub and heath landscapes (e.g. Bruchmann 2011; Bruchmann and Hobohm 2010 for Europe).

This fact should also be discussed in the context of zonal, extrazonal and azonal vegetation types. Walter (1954) defined zonobiomes as zonal vegetation types that are controlled by climate, orobiomes as different belts of mountain ranges, and pedobiomes as soil-dependent vegetation types that are azonal. For example, boreal spruce forest belongs to zonal vegetation, and aquatic vegetation, swamps, fens, bogs and riparian forest belong to azonal vegetation (cf. e.g. Bohn et al. 2000, 2003; Bailey 1998). However, the relationship between zonality and endemism is not clear. Some azonal vegetation types are very rich in endemics. Serpentine soils, for example, often give rise to sparse associations with many endemic plants (Chiarucci

and Baker 2007; Alexander et al. 2007; Stevanović et al. 2003; Roberts and Proctor 1992). Rocky habitats which are strongly affected by both climate and substrate also harbour many endemic plants (Bruchmann 2011). In contrast, azonal vegetation types such as aquatic vegetation, reeds or bogs are normally poor in endemics (e.g. Parolly 2004; Meusel and Jäger 1992).

Wetlands cover a small part (a few percent) of the world's surface (Hobohm and Bruchmann 2009, 2011; Revenga et al. 2000). This is also true for rocks and screes which are inhabited by far more endemic taxa than is the case for wetlands. Thus, the differences in endemism cannot be explained by the size of area because both habitat types represent vegetation types which cover only a very small proportion of the earth.

In contrast to rocky habitats, most freshwater habitats, mires and swamps are very young, often much younger than 10,000 years. These habitats are characterised by low ecological continuity during the late Pleistocene and Holocene. Many lakes, for example, originated as dead ice holes during the late Pleistocene and silted up or developed into fens, bogs or peaty substrates covered by forest during the Holocene (Pott 2010; Hobohm and Bruchmann 2009). Furthermore, sudden changes in the physico-chemical conditions can impact whole water bodies. Perhaps as an adaptation to this, many aquatic and wetland plants, such as *Alisma plantago-aquatica*, *Eleocharis acicularis*, *Lemna minor*, *Phalaris arundinacea* or *Phragmites communis*, have long-distance dispersal abilities (wind, migratory birds) and very large ranges of distribution (Meusel and Jäger 1992; Meusel et al. 1978, 1965; Hultén 1971). In Europe, even the endemics of wetlands have, on average, larger ranges than endemics of rocks and screes (Hobohm and Bruchmann 2009). The relationship between the distribution patterns of specialists and refugial history of mires in the West Carpathians and Bulgaria, for example, has been shown by Hájek et al. (2011) and Horsák et al. (2007).

Rocky habitats, in general, are composed of different micro-habitats with very different environmental conditions with respect to light, water, organic material, soil, dynamics, etc. Under changing conditions, inhabitants of rocky habitats can normally find suitable survival conditions very close to the place where they are located. The higher rates of endemism here might be due to the relatively fixed structural complexity of their environment, compared with the dynamics of the lotic and lentic aquatic environment (see Scherrer and Körner 2011). Therefore, we assume that rocky habitats and screes are less affected by changing physico-chemical conditions than standing and running waters, banks, mires and swamps.

5.3.7 Arable, Horticultural and Artificial Habitats

In Europe a few regional endemics (e.g. *Anthemis lithuanica*, *Bromus secalinus ssp. multiflorus*, *Bromus interruptus*, *Carduus litigiosus*, *Centaurea polymorpha*, *Erucastrum gallicum*, and *Urtica atrovirens*; see Tutin et al. 1996a, b, c, d, e) might be largely restricted to anthropogenic habitats, such as arable land or ruderal

Photo 5.15 *Delonix regia*, endemic to W Madagascar, is widely cultivated in tropical regions (Private garden in S Madagascar near Fort Dauphin; photographed by Carsten Hobohm)

habitats, and so are not expected to occur in natural or seminatural habitats. Discussing the fact that certain plant species only occur in anthropogenic habitats, Gams (1938) and Pignatti (1978, 1979) explored the possibility that plant evolution is influenced by, or dependent on, human activities. Another explanation for the existence of endemic taxa in anthropogenic habitats could be that the original habitats of these taxa were destroyed, while associated endemics survived under similar environmental conditions. A combination of both explanations might also be correct.

413 European endemics occur in this group of relatively young but widespread habitats (Hobohm and Bruchmann 2009). However, we did not find much information about endemics in anthropogenic habitats outside of Europe.

Because of the duration of human influence we expect that this group of endemics might also exist in Africa and perhaps in Asia, but most probably neither in Australia nor in the Americas.

According to the IUCN Red List c. 63 vascular plant species on earth are extinct in the wild and still survive in horticulture. Rauer et al. (2000) have discussed the role of botanic gardens in protecting threatened vascular plant taxa (Photos 5.15 and 5.16).

Photo 5.16 *Melanoselinum decipiens*, species and genus endemic to Madeira, is widely cultivated for fodder on this island. Original habitats are shady rocks and banks in ravines of northern Madeira (Photographed by Carsten Hobohm near Fontes, Madeira)

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