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Carsten Hobohm *Editor*

Endemism in Vascular Plants

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Preface

What is the aim of a book about endemism in vascular plants – biogeography and evolution of vascular plants that have small ranges, vegetation ecology, a little bit social sciences, politics, and nature conservation? Does it mainly review and comment on some new scientific results including spotlights of the revolution in genetics, systematics and phylogeography?

It will be impossible not to review important publications, and scientific experts may excuse the review character of many parts in this book. And, yes, the relevance of endemism also concerns nature conservation. Endemism is not only a scientific game of characters and numbers. Endemism matters. On the other hand we present many scientific results which have not been published before.

What is the relationship between endemism and global warming? We want to show that the amount of recent climate change means very little in terms of extinction risks for vascular plants. If a single rock in Central Europe represents a climate of northern Italy on its southern face and of southern Norway on the opposite side, if the variability in a single forest represents many different micro- and mesoclimates, then a changing temperature of 1 °C plus or minus perhaps means almost nothing for a population of plants living close to the rock or in the forest. If both, the rock and the forest, are becoming destroyed by man, then the populations of the rocky habitat or forest will probably not survive. In this book, we estimate the impact of climate and climate change on the composition of endemic taxa in different regions. However, it is clear that we are talking about other dimensions than a single degree centigrade in average.

What is the impact of invading species? Are they competing with the endemics? Competition or introgression are keywords in this context. Both processes can result in extinction of genes and taxa and we don't want to play down the extinction risk for endemic plant taxa. However, we also want to show that the extinction risk for endemic vascular plant taxa is relatively low in most mainland areas because competition and introgression between invading and endemic plants do not play an important role compared to the effects of habitat disturbance or resource use. We are aware that the situation becomes more complicated on islands or habitat isolates particularly due to invading animals which are able to destroy habitat structures and change environmental conditions or regional food web structures. However, neither competition nor introgression seem to be the main problems in this case.

What is new? We want to focus on the relationships between endemism in vascular plants and habitat. This topic is relatively new to science. And it is relevant because one of the most important factors for the loss of biodiversity in the past was habitat destruction by man including domestic livestock. We assume that this factor in the future will persist to be important.

To secure ecosystem services and goods is a modern feature of recent strategies and payments in biodiversity policies (CBD). Therefore, the question arises what the relationship between the occurrence of endemic taxa and a modern strategy securing ecosystem goods and services could be. An example: *Cephalaria radiata* is a beautiful flowering plant scattered in semi-natural grasslands and endemic to Transylvania in Romania, Europe. What are the goods and services of this plant? And if there are no such, why should we lower the extinction risk of this species? In this moment grasslands and semi-natural pastures and meadows all over the world are declining in quantity and quality.

Last but not least we will point out gaps in our knowledge. For many regions in the world, especially mainland regions, we don't have adequate information about the amount and ecology of endemism. For example, the number of publications focussing on range sizes of plant species in tropical forests is still very limited. Modern molecular analyses on systematics will change our knowledge and earlier ideas in systematics. This process has just begun. We still do not know if most vascular plant species or most endemics on earth live in forests or in open landscapes. We do not know all the threats in every part of the world. Even the very important Red List database of the IUCN covers only a small percentage of the vascular plants living on earth. Many ecological conditions and events in the past which have been influencing the species composition and endemism in a region presently cannot be reconstructed. Thus, we know that we are far away from understanding the interferences of all the basic processes. We will ask these questions in our book. Nevertheless, many of them cannot be answered at the moment.

The structure of the book is artificial because it is impossible to describe the time axis independent of space or to understand spatial patterns without discussing underlying processes. Thus, we did not try to absolutely avoid overlaps but to pronounce patterns on the one hand and processes on the other. Both levels are important for an understanding of the relating complex phenomena and for the understanding of nature conservation purposes.

As a result of the process in which we organized the development of this book the collection of regions is a little bit patchwork-like. We tried to describe and analyse both patterns and processes in endemic-rich regions and also in regions with fewer endemic taxa. We wanted to represent mainland regions, continental and oceanic islands in different parts of the world, because of the different evolutionary and climatic histories. And we tried to present new results. However, in a scientific world which is evaluated and financed on the basis of scientific indicators created by a private company, it becomes more and more difficult to find experts writing a chapter in a book. Hopefully this trend is not the end of the road.

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We invited many experts in the field of biogeography and endemism to write or to correct a chapter of this book. It is wonderful that many of them consented to take part. Therefore, I thank the coauthors Ines Bruchmann, Monika Janišová, Cindy Q. Tang, Caroline M. Tucker, Sula E. Vanderplank, Nigel P. Barker, V. Ralph Clark, Uwe Deppe, Sergio Elórtegui Francioli, Jihong Huang, Jan Jansen, Keping Ma, Andres Moreira-Muñoz, Masahiko Ohsawa, Jalil Noroozi, Gerhard Pils, Miguel de Sequeira, Marinus J.A. Werger, Wenjing Yang and Yongchuan Yang.

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Introduction

If you want to cross a river without a boat or without having to swim then you have to look for a ford. Thousand years ago Hamburg developed as a crossroad-settlement near a ford across the River Elbe. The river is naturally shallow in this area because of the decreasing influence of the North Sea tides.

This section of the Elbe is subject to a combination of two major influences: tides from the west, on the one hand and freshwater from the east, on the other, making it a freshwater tidal area. And only here is the vascular plant species *Oenanthe conioides* to be found. This plant occurs in the Elbe area as a pioneer on the muddy soil of tidal flats with no salt water influence.

A shallow river with freshwater influenced by tides were optimal conditions for *Oenanthe conioides* to evolve and grow and for the first people to settle in this area. *Oenanthe conioides* is an endemic plant almost entirely restricted to the area of Hamburg with only few individuals occurring outside the city boundaries.

When we started our study of this plant very little was known about it. Is this taxon really a genetically isolated species or are there also hybrids with other species of the genus? Where exactly does the plant grow? What are its ecological and community characteristics? What do we know about its biological traits such as dispersal type or the possibility of building soil seed banks? What human influences pose a risk of extinction?

The combination of the very limited distribution of this species and a very limited knowledge of its biology including environmental conditions was surprising. Even in rich European countries, we realised, there is no guarantee that ignorance and extinction can be ruled out.

Today, in good years a few hundred individuals of *Oenanthe conioides* flower worldwide – that is, in Hamburg.

After analysing the ecology and biology of *Oenanthe conioides* we began to investigate other vascular plants with limited distributions. We established that plants which occur only in a specific nation are often relatively well-known because countries are normally proud to present such endemics. For many countries, such checklists can be found on the internet.

However, if the distribution area of plant species with a small range of occurrence covers two or more countries, people less often are aware of their special status. If, for example, half the populations of a particular plant species occur in Austria and the other half in Switzerland, the species is neither endemic nor subendemic to one of these countries; nevertheless, it is endemic to the Alps. For this reason we decided to begin compiling a checklist (EvaplantE) of all vascular plants which are restricted to Europe. Our aim was to pay attention to rare and endemic species, independent of whether these are country-endemics or not.

Such a list will never be complete. It is like a phone book. A great deal of effort is required to update the information or, in our case, to rework the taxonomy, as well as ecological and distribution data.

Our knowledge is growing rapidly, not only our knowledge of the ecology and genetics of vascular plant taxa, but also of methodologies of analyses in the field, from satellites, or statistics, respectively.

Endemism is a phenomenon with so many features that a single book could never give answers to all the questions concerning the biology of endemic plants including genetics and population dynamics, biogeography and geobotany, ecology, etc.

This book is an attempt to integrate information which helps to explain the occurrence of plants that are restricted to a single country, mountain range, mountain top, island or estuary, for example.

We describe and analyse important patterns and processes. We focus on the biogeography of endemic, rare and threatened vascular plants. We discuss where and why endemics are concentrated or missing in a region. We focus on the relationship between endemism and habitat, which we consider to be important for species conservation policies.

Almost all countries in the world signed the Convention on Biological Diversity and agreed to its main goal, which was to lower the extinction risk for species. We assume that endemism as an obligatory stage before extinction is one of the best indicators and predictors world-wide of the necessity for conservation activities.

> One important criterion for determining the optimal design for conservation units is the degree of biotic endemism.
> Gentry (1986: 153)

We hope to support the attempt to protect and conserve rare, threatened and endemic species and their habitats by publishing this book.

Flensburg, Germany Carsten Hobohm

Part I
The Meaning of Endemism

Chapter 1
The Increasing Importance of *Endemism*: Responsibility, the Media and Education

Carsten Hobohm and Caroline M. Tucker

1.1 What Is Endemism?

While the term *endemic* (from Greek *en demos* = in people) has connotations today for both medicine (disease) and biogeography, the term *endemism* is used in biogeography to refer to taxa that have small ranges. De Candolle (1820: 54) first defined the term *genres endémiques* (endemic taxa) in a biogeographical context (Fig. 1.1). He adapted the term from the medical meaning, where *endemic* described diseases that are present continuously in a certain area, to refer to the analogous concept of taxon restricted to a particular geographic region. If a disease is spreading through human populations across large regions then the disease becomes a *pandemic* disease (from Greek *pan demos* = across peoples) (Photo 1.1).

As the antonym to endemic taxa in biogeography, De Candolle used the term *genres sporadiques* for the more wide-spread taxa. He felt that locally or regionally restricted taxa normally occur in higher densities than wide-spread taxa with a more scattered distribution – which occasionally is observed (e.g. Rabinowitz et al. 1986).

Endemism is a function of spatial scale (cf. Laffan and Crisp 2003, and many others). Many small regions do not harbour any endemic taxon but solely non-endemics. At the scale of the earth, all taxa are of course endemic (Lu et al. 2007; Hobohm 2003). The necessary spatial context means that for every taxon, one can find a geographical unit where it exists as non-endemic (except when the taxon has become reduced to a last individual) and another larger area where it is endemic. Today, there are two general groups of biogeographic definitions of *endemism* or *endemic taxon*, and within each group the differences in practice are

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Parmi les phénomènes généraux que présente l'habitation des plantes, il en est un qui me paroît plus inexplicable encore que tous les autres : c'est qu'il est certains genres, certaines familles, dont toutes les espèces croissent dans un seul pays (je les appellerai, par analogie avec le langage médical, *genres endémiques*), et d'autres dont les espèces sont réparties sur le monde entier (je les appellerai, par un motif analogue, *genres sporadiques*).

Fig. 1.1 First book section with a definition of the term *genres endémiques* (endemic taxa) in a biogeographical context (De Candolle 1820: 54)

small. In the first group, endemism refers to taxa restricted to a certain sized area (e.g. 10,000 km^2) or number of cells within a geographic grid. The second group of definitions, which are independent of any artificial maximum size of a region, refer to taxa restricted to a defined geographic area or habitat type. Henceforth we will use the term endemic to correspond to the second group of definitions. This makes analyses such as Endemics-Area-Relationships (EARs), which include taxa with a variety of range sizes, possible.

What is the difference between endemism and rarity? Rabinowitz et al. (1986) noted that plants may be rare in several ways. They distinguished three traits that all species possess – a geographic range (broad area vs. endemic to a particular small area), habitat specificity (occurs in a variety of habitats vs. restricted to one or a few sites with special environmental characteristics) and local population size (large populations somewhere within its range vs. only small populations). According to Rabinowitz et al. (1986) a taxon can be rare in a region without being endemic (it has populations outside the region). It could also be endemic to the region but not rare, having large population sizes and/or broad habitat tolerance within its restricted range.

Cowling and Lombard (2002) stated that rarity or endemism *"is associated with the early (post-speciation) and late (pre-extinction) phases of the taxon cycle"*, which means that an obligatory stage in the distribution patterns of every taxon must be a phase of local endemic existence both at the beginning and the end of the taxon's existence. This would mean that every taxon originates and ends as endemic. Is this theoretically necessary? One could imagine special cases in which a wide-spread species is dividing into two species by long-term diverging genomes which ultimately are genetically isolated; the new taxa could each occupy half of the former range. In this case both "new" species do not start the taxon cycle in a small region or with a few individuals only. However, it is perhaps more likely that speciation events initially involve new taxa that are limited to only small portions of the original range, or to small areas of new habitat, and thus are endemic.

Regions that are rich in endemic taxa are referred to as having *high endemism*. The global distribution of regions with high and low endemism is incompletely

Photo 1.1 *Alstroemeria magnifica* near La Serena, Chile (photographed by Marinus Werger). Almost all c. 120 *Alstroemeria* spp. are restricted to one of two centres, one in central Chile, the other in E Brazil

recorded and the causes not fully understood. Yet, it is recognized that these designations are important to conservation planning and activities. Though we have not fully explained how and why regions of high endemicity arise, and how they are maintained, we know many processes and conditions in the past and present that are likely to be relevant. Current hypotheses and models on endemism are useful even in the face of this uncertainty: as Gentry (1986) showed, different explanations for diversity patterns may have very different implications for nature conservation strategies and practices. For example: the *habitat specialisation model* explains distribution patterns of local endemics by differences in soil, water or microclimate parameters (soft boundaries), whereas the *refugia model* relates endemism to a strong relationship between the location of (Pleistocene) refugia. The implication of the habitat specialisation model would be to protect landscapes, including all different habitat types, whereas the refugia model would primarily mean that as many of the refugial centers as possible should be protected by establishing reserves. We do not know much about distribution patterns of local endemics (e.g. in diverse tropical forest zones), and thus we must rely on the theories available. As a consequence, as many representative regions as possible of both habitat types and refugia should be protected.

The species concept that is mainly based on morphological, phenotypic similarities and on the idea of a putative reproduction barrier that disrupts gene-flow between distinct taxa was largely contradicted by data obtained from molecular analyses (genome analyses, allozyme analyses). Several phylogenetic studies have shown that speciation is to be understood as a more continuous process rather than a process which occurs at a discrete specific moment in time.

A comprehensive assessment which applied methods of morphological and genetical analyses (DNA barcoding) to species numbers of Madagascar's amphibian inventory, for example, resulted in an almost two-fold increase in species numbers (Vieitesa et al. 2009). Authors found large genetic variations that could no longer be interpreted as simple intraspecific genetic variations. In the light of modern genetic analyses it becomes clear that evaluating endemism is also a matter of the underlying species concept (see e.g. Hawksworth and Kalin-Arroyo 1995; Bruchmann 2011).

1.2 The Increasing Importance of Endemism in the Media

The growing attention on *endemism* and *endemic species* can be visualized based on the rising number of scientific publications including these terms. Though in 1820 De Candolle defined endemism in a biogeographical context, the term was not regularly used before the beginning of the twentieth century. Since that time the words *endemism* and *endemic* taxa began to occur more or less regularly in scientific publications, particularly in relation to the scientific description of new species with a restricted distribution or to the recognition of threats. In the last quarter of the twentieth century, especially in the late 1980s and 1990s, the term endemism began exploding. Many taxa in checklists and Red Lists became labeled as endemics. For scientists and students in the field of ecology and biogeography, endemism became a central issue.

The concept of *Biodiversity Hotspots* was coined by Norman Myers in 1988 and 1990. Biodiversity hotspots are regions of the highest conservation priority, based on a number of characteristics determining their contribution to global diversity and the level of threat they face: one requirement is that these regions have high endemism. Today these biodiversity hotspots play a leading role in international and national nature conservation strategies. In 1988, the United Nations Environmental Programme (UNEP) convened an Ad Hoc Working Group of Experts on Biological Diversity to explore the need for an international Convention on Biological Diversity (CBD). As a result this Convention was opened for signing in 1992 at the United Nations Conference on Environment and Development in Rio de Janeiro. The concepts of endemism and endemic species were included within this declaration (see e.g. Annex I of the CBD). Today endemism and endemic species are part of an uncountable number of scientific publications, national and international laws and conventions, internet sites (e.g. www.iucn.org), and many documentary films on TV, that use these terms for characterizing globally rare and threatened animals and plants. The terms endemism and endemic, in former times only used in science, are now becoming more and more common to non-scientists in many countries, many languages, environmental protection laws and nature conservation measures all over the world.

Furthermore, endemics are not only entities in nature conservation, scientific or political efforts. Endemism in general or particular endemic plants and animals are topics included for advertisement in tourism industry, especially in ecotourism.

Endemic plants may be used regionally as ornamental and medicinal plants (cf. El-Darier and El-Mogaspi 2009; Latheef et al. 2008). We saw different endemics used as ornamental plants in gardens, e.g. *Adansonia* and *Aloe* spp. on Madagascar, orchids in Colombia, *Proteas* in South Africa, and palms on Mauritius. Many plants widely if not globally used in horticulture, such as *Rhododendron* spp., *Metasequoia glyptostroboides* or *Ginkgo biloba*, were once restricted to small regions (cf. Zhao 2003). In a few cases, some plant families such as Cactaceae are almost completely represented in botanic gardens, many others, e.g. Orchidaceae, Asteraceae or Melastomataceae, are only represented by a small proportion of their total number of species (cf. Rauer et al. 2000).

Where endemic species have economic value, there can be positive or negative consequences. Endemic plants, e.g. cultivars of *Argyranthemum* spp. which are native on Canary Islands, are legally traded by florists on markets in Europe. Additionally, illegal trade in plants and animals is a serious and growing crime, and affects endemic as well as non-endemic species. The revenues generated by trafficking in endangered species (including, but not limited to endemic species) are estimated at 18–26 billion dollars per year (Europol 2011; Alacs and Georges 2008; Flores-Palacios and Valencia-Diaz 2007, see also Maggs et al. 1998).

1.3 Endemism, Responsibility and Education

Though the meaning of endemic species for nature conservation management is well recognized, it is also recognized that there is a paucity of information about diversity and endemism: *"educational value of biological diversity"* and the *"general lack of information and knowledge regarding biological diversity"* is pronounced in different chapters of the Convention on Biological Diversity (see e.g. Preamble). According to Article 13 – *Public Education and Awareness* – of the CBD

> The Contracting Parties shall:
>
> (a) Promote and encourage understanding of the importance of, and the measures required for, the conservation of biological diversity, as well as its propagation through media, and the inclusion of these topics in educational programmes; and
> (b) Cooperate, as appropriate, with other States and international organizations in developing educational and public awareness programmes, with respect to conservation and sustainable use of biological diversity.

Public preferences play an important role in prioritizing species for nature conservation activities. Stating that species with small ranges are important indicators and subject to the risk of extinction should be picked out as central theme in the education of children at schools and curricula. Meuser et al. (2009) found a preference of the public for endemism over other conservation-related species-attributes such as economic importance, regionally at risk but common elsewhere, cultural and traditional importance.

Endemism, the risk of extinction, and our responsibility in halting the loss of biodiversity might be topics in school subjects such as biology, philosophy, geography, economy, social studies. However, the reality seems to be far away from the education-related goals of the CBD. The term *biodiversity* has entered the schoolbooks in biology in different languages and countries (e.g. in Europe and North America). Furthermore, it is very easy to find teaching concepts on biodiversity on the internet in different languages. However, the term "biodiversity" does not automatically imply the meaning *halting the loss of biodiversity, nature conservation* or *sustainability* as is stated by the CBD. One can talk and teach about the diversity of life without any connection to questions of nature conservation.

Since children are responsible for tomorrow, it is clear that the discussion about how endemism is linked to aspects of species' survival and nature conservation policies and that this discussion should be intensified in schools and other programs (cf. Meuser et al. 2009; Ugulu et al. 2008). Teaching material about endemism, endemic species, the risk of extinction and/or histories of species which have been rescued, might easily be prepared for all types of school. For example, stories of species which were rescued from extinction due to activities in zoos or botanical gardens can result in positive outlooks on conservation by children at primary schools. More complex situations, including economic, social and ecological constraints, might be discussed in secondary schools or universities.

And in any case, there should be a focus at all levels on the target of halting the loss of biodiversity by protecting landscapes and habitats that harbour endemics.

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Chapter 2
How to Quantify Endemism

Carsten Hobohm and Caroline M. Tucker

2.1 Number of Individuals (N)

Counting or estimating the number of individuals in a population is only possible if the whole population is rather small and well documented. Because of the high extinction risk faced by small populations, the number of individuals should be continuously monitored. The IUCN Red List of threatened plants (Baillie et al. 2004; Walter and Gillett 1998, see also IUCN on the internet) uses information about the number of individuals to categorize level of threat experienced. In practice, as the examples that follow will show, almost all taxa with low numbers of individuals are categorized as critically endangered. Some spectacular examples of plant species which at the moment are represented by only a few individuals have been published, and we detail some of these below. Many but not all examples of plant species represented only by few individuals are restricted to marine islands. Unfortunately, some other plant taxa recently disappeared altogether from the globe – no longer having a single living individual. Avoiding extinction cannot be guaranteed, regardless how intensive the efforts to rejuvenate the species are.

The following examples are primarily in 2011 and 2012 adopted from the very important IUCN Red List (www.iucnredlist.org). However, some of the assessments are 10 or 20 years old and, therefore, cannot be assumed to represent recent conditions and should be updated. These examples are ordered in a geographical manner: from west to east and/or north to south, beginning with North America.

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2.1.1 California

Cercocarpus traskiae is a shrub or small tree, living on Catalina Island. Only a single wild population still exists, consisting of seven individuals in a canyon covering an area of approximately 250 km^2 (World Conservation Monitoring Centre 1998; Oldfield et al. 1998).

2.1.2 Mexico

Diospyros johnstoniana (*syn. D. xolocotzii*) is endemic to Michoacan de Ocampo, Mexico (Madrigal Sánchez and Guridi Gómez 2002; Madrigal Sánchez and Rzedowski 1988). It is known only from an area of 25 ha. Despite many surveys since 1998, no other locations have been found. In 2005, a census for this species found 36 trees, but in 2006 only 34 individuals remained. One was felled for agricultural expansion, and the other was severely damaged by human-caused fire in 2006 and died in the same year. The remaining population is fragmented.

D. johnstoniana grows in subtropical dry forest and woodland. It is a plant with a low number of fruits observed and a low rate of pollination success. It reaches sexual maturity at the age of about 25 years old. There is no trade in this species. But, the fruit is commonly eaten, and the species can be used as an ornamental plant. The plant can also be used for the genetic improvement of other species in the same genus. The species is severely impacted by habitat loss through agriculture, which directly threatens the remaining trees. Clear-cutting in the area is common practice to open new areas for agriculture. Furthermore, the presence of cattle and goats in the area threatens the remaining trees: livestock eat young plants and near-ground level foliage, severely affecting the surrounding habitat and compacting the ground. The human population is increasing in the area, and urban expansion is ongoing. This has several impacts on *D. johnstoniana*, as there is an increase in solid waste, human-caused fire, wood collecting, and the introduction of alien plant species, e.g. *Eucalyptus* trees. The species is included in Mexico's official list of species at risk, in the category of Special Protection. However, this is not enforced for this species and there is still no specific programme to protect this species (Villaseñor Gómez 2005; www.iucnredlist.org).

Mammillaria sanchez-mejoradae is a critically endangered cactus endemic to a single area in Mexico. Since the discovery of the species more than 20 years ago, the population has diminished by an estimated 75 %. The wild population currently is estimated at less than 500 plants and, despite legal protection of the species, the population continues to be highly threatened by illegal collecting (www.iucnredlist.org).

Acharagma aguirreanum is a cactus which occurs in semi-desert on calcareous rocks at an altitude of about 1,500 m in Sierra de la Paila over a range of 1 km^2, in Coahuila, Mexico. The total population numbers less than 100 individuals. Illegal collecting is a major threat (Anderson et al. 2002; Anderson 2001; Hunt 1999; Glass 1998).

2.1.3 Costa Rica

The present adult population of the palm *Cryosophila cookii* is estimated to number less than 100 individuals. The species is living in atlantic lowland rainforest near Limon, Costa Rica. Habitat conversion to arable land has caused a major population decline. Logging, increasing settlements and decline in the populations of dispersal/pollination agents have also contributed to losses. The palm heart is eaten locally for medicinal purposes (Evans 1998; Oldfield et al. 1998).

2.1.4 Ecuador

Centropogon cazaletii is an endemic herb or subshrub in Ecuador where it occurs in high Andean forest (3,500–4,000 m). It is known from two collections in Napo Province, both made inside the Reserva Ecológica Cayambe-Coca. One was in the surroundings of the Laguna de San Marcos; another from Oyacachi. After two field trips of experts to search for the species in 1998, no individual was recorded around the Laguna and only four individuals were found in Oyacachi.

Although the taxon occurs inside a protected area, it might be threatened by fire set by humans around the Laguna de San Marcos and deforestation around Oyacachi.

Another species of the same genus, *Centropogon pilalensis* is also endemic to Ecuador. It is known only from one population of less than 50 individuals in Cotopaxi province where it is living in high Andean forest and dry paramos (Moreno and Pitman 2003; Valencia et al. 2000).

In the Red List of the IUCN (www.iucnredlist.org) many critically endangered species of Ecuador are only known from the type collection and nobody knows how many of them have meanwhile become extinct (cf. Valencia et al. 2000).

2.1.5 Juan Fernandez Islands, Chile

In the following (Fig. 2.1), Skottsberg tells the story about a journey to the last living individual of *Santalum fernandezianum* which he saw and photographed on Robinson Crusoe Island (also known as Masatierra) in the year 1908.

2.1.6 Cerrado, Brazil

Dimorphandra wilsonii is a critically endangered tree, found only in Minas Gerais State in southeast Brazil. Before 2010 (last assessment 2006), there were only some ten mature trees and six juveniles growing in the wild, in the middle of pastures of *Brachiaria*, an alien invasive grass species, in a strongly deforested and fragmented

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IN MEMORY OF
ALEXANDER SELKIRK,
Mariner,
A native of Largo in the county of
Fife, Scotland.
Who lived on this island in complete solitude, for four years
and four months.
He was landed from the Cinque
Ports galley, 96 tons, 16 guns, a.d.
1704, and was taken off in the
Duke, privateer, 12th Feb. 1709.
He died lieutenant of H.M.S. Weymouth, a.d. 1723, aged 47 years.
This tablet is erected
near Selkirk's lookout by
Commodore Powell and the
officers of H.M.S. Topaze, a.d. 1868.

This is the historical basis of Defoe's work. It may look somewhat meagre, but one can understand that poor Selkirk had to work to preserve his life. What a mental trial, not to hear a word spoken by another, not to see a human soul for four years and four months! Thus his fate was pretty adventurous even if told without embellishment. On the other hand, he left his ship at his own request, discontented with the life on board. Besides, he might have chosen a worse place. The climate is very mild, it rains just enough, snow or frost is unknown. A few plants are edible, and the goats, which were much more numerous in Selkirk's time than they are now, provided him with fresh meat.

Through a walk lined with marvellous trees and precious ferns we pass the natural gate and are on the south side of the island. Down it goes, almost as precipitous as on the other side. We have a magnificent view of the coast and Santa Clara, where a tremendous surf roars. Soon we came out of the forest,

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and continued on to the barren slopes near the sea. The vegetation here is more like that of a steppe, with short grass and some heath-plants; only along the streams is there a bright green strip, a mosaic of gigantic pangue-leaves. And we bent the thick stalks at the side and drank to the health of Masatierra and Robinson and the whole world. There is only one way back, the way we had come; it was getting dark and we hurried on through showers of rain; large drops splashed on the heads of the rosette-trees, the soil emitted strong, peculiar scents. The last part of the way we slid down in the slippery clay.

Above I happened to mention the sandal-wood. The discovery of this kind of wood, famous since the days of Solomon, on Juan Fernandez most surely attracted notice. We have no reports of it previous to 1624, when, according to Burney, L'Heremite reported sandal-trees in great number. According to another authority ships used to visit the place as early as 1664 to bring the valuable wood to the coast, where it was highly appreciated. One did not think of preserving anything; a hundred years later it was hardly possible to find a living tree, and in the beginning of last century it was regarded as extinct. No botanist had ever seen the leaves or flowers. Suddenly F. Philippi in Santiago got some fresh twigs brought to him in 1888; he found them to belong to the genus *Santalum*; the species being new, it received the name of *S. fernandezianum*. The general interest in the tree was increased, but nobody told where the branches came from; a living tree was still unknown. Only in 1892 did Johow

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get news of one; a colonist had found it in Puerto Ingles, high up in the valley. He was the first botanist who saw this plant. It is easily understood that I was anxious to become the second. How many people had looked for other specimens! All their efforts were fruitless; as far as we knew Johow's tree was the very last. If it were still there!

The man who brought Johow to the spot still lived, and after we had explained our purely scientific interest he promised to send his son with us. It would have been more than uncertain for us alone to look for a single tree in a valley clad with virgin forest.

It is possible to climb across the ridge that separates Cumberland Bay from the English Harbour, but we preferred to go there with a well-manned boat. The landing is, as in most places on the islands, performed with some risk; one must jump just at the right moment, and there has to be a good crew in the yawl, or the boat would be thrown on the rocks and capsized. Perhaps I ought to mention that the place in question only has the *name* of a harbour. We walked up the valley and made an ascent of the western side; the place is so steep that one is forced to grasp the trees and shrubs to get a foothold. Our guide stopped, looked round for a minute, down a few hundred yards, and we had reached our destination. The last sandal-tree. Absolutely the last descendant of *Santalum fernandezianum*. It is so queer to stand at the death-bed of a species; probably we were the last scientists who saw it living. We look at the old tree with a religious respect, touch the stem and the firm, dark green leaves—it is not only

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an individual, it is a species that is dying. It cannot last very long. There is only one little branch left fresh and green; the others are dead. We cut a piece to get specimens of the peculiar red, strongly scented wood. A photo was taken, I made some observations on the place, and we said good-bye. Should I happen to go there once more I shall not see the sandal-tree; it will be dead and its body cut up into precious pieces—curiosities taken away by every stranger.

Fig. 2.1 Travelogue of Skottsberg about a journey to Robinson Crusoe Island where he visited the last individual of *Santalum fernandezianum* (Skottsberg 1911: 140–143) region. The species is threatened by deforestation for charcoal production, which is the most important threat to the Cerrado Biome. There is also deforestation for pasture establishment and any seedlings face competition from *Brachiaria*. People also deliberately eradicate this species because its seeds can be harmful to pregnant cattle (cf. Moreira Fernandez 2006; Alves 2004, Mendonça).

2.1.7 Puerto Rico

Some ten trees of *Auerodendron pauciflorum* are recorded on Puerto Rico where a single small population is found in woodland on a limestone cliff. Most individuals occur on land owned by a development company. The trees have not been seen to seed but efforts are being made to cultivate the plant from tissue culture. Information needs to be updated because the last year assessed was 1998 (cf. World Conservation Monitoring Centre 1998; Oldfield et al. 1998).

2.1.8 Anegada, Virgin Islands

Anegada belongs to the British Virgin Islands and is located northwest of Puerto Rico. The population of *Acacia anegadensis*, endemic to Anegada, has been reduced by past exploitation for resin. The potential extent for *A. anegadensis* is approximately 25 km^2 because fieldwork has determined that the species is found primarily on limestone and scattered in sand dune habitats. Different numbers of individuals have been recorded, from a few mature trees to locally common (Baillie et al. 2004; Clubbe et al. 2003). However, many human and natural effects such as habitat destruction, livestock, invasive species, or hurricanes cause a risk of extinction. Anegada is under severe development pressure resulting in both loss of habitat to residential and tourism infrastructure, and further fragmentation due to upgrading and construction of new roads. Loose cattle, goats and donkeys roam the island and damage the habitat through trampling and grazing. Natural disasters are a current and on-going threat e.g., hurricanes and coastal inundation (Clubbe et al. 2003; Smith-Abbott et al. 2002; Proctor and Fleming 1999; D'Arcy 1971).

2.1.9 St. Helena

Trochetiopsis erythroxylon (Redwood) is a tree endemic to St. Helena and is extinct in the wild. After settlers arrived, the species was extensively exploited for its excellent timber and bark which was used for tanning hides. By 1718, the species was already extremely rare. Further losses occurred when flax plantations began in the late 1800s. By the mid of the twentieth century, only one redwood individual survived and this single tree is the source of all the St. Helena's Redwoods known in cultivation today. Inbreeding depression and a depauperate gene pool are the most serious threat to the future survival of this species.

Trochetiopsis ebenus, called Saint Helena Ebony, is a critically endangered shrub found only on this island. The species declined sharply in the eighteenth century, mainly due to overgrazing by goats, and was once thought to be extinct. In 1980, two shrubs were rediscovered on the island. All existing material in cultivation is derived from these two individuals. This species was previously burned to produce mortar. The wood was also used in the nineteenth century for turnery and ornament making and was introduced to British gardens around 1800.

The hybrid of cultivated plants of *Trochetiopsis erythroxylon* × *ebenus* may provide the only chance of survival for this part of the gene pool (Cairns-Wicks 2003).

Also *Mellissia begoniifolia* is a critically endangered shrub found on St. Helena Island. The wild population currently numbers some 16 individuals. The size of this population fluctuates year by year, largely depending on weather conditions, but also on predation pressure. Currently only one plant in the population can be considered mature and it is from this that the majority of seeds has been collected to establish plants in cultivation. Threats include attacks from aphids and caterpillars, mice and rabbits. Growing in such a dry environment, the plants are also prone to drought (www.iucnredlist.org).

Nesiota elliptica was a small endemic tree on St. Helena that grew on the highest parts of the island's eastern central ridge. It became very rare in the nineteenth century and by 1875 only 12–15 trees were recorded. The species had been thought to become extinct until a single tree was discovered in 1977. This tree was found to suffer from fungal infections which might have been exacerbated by damage sustained during attempts to conserve it. Because cuttings were difficult to root, because the species very rarely set good seed as it was almost completely self-incompatible, and because of fungal infections the species died in the wild in 1994 and became globally extinct in 2003. No other live material, plants, seeds or tissues, remain in local or international collections. The extinction of this plant has been attributed to habitat loss through felling for timber and to make way for plantations.

2.1.10 Germany

Oenanthe conioides is an annual or biannual pioneer herb living at the Elbe river in and nearby Hamburg. The number of individuals is fluctuating from year to year; normally some hundred individuals are counted. A serious problem for the survival of this species is the destruction of habitat including alteration of water depth, currents and tides, caused by governmental authorities of the harbour of Hamburg and river traffic. Different neophytes inhabit the remaining natural habitats which in this case obviously do not cause any problem to *Oenanthe conioides*. Fortunately, the species is building a soil seed bank in muddy substrates (Below et al. 1996).

2.1.11 Alborán, Spain

The annual herb *Diplotaxis siettiana* was last seen in 1974 in the wild. At that time seeds were fortunately collected on the island of Alborán, south of Spain's mainland, where the plant was growing in a tiny area around a helicopter platform. The seeds were multiplied at the University of Madrid, and distributed to some botanical gardens. Under cultivation conditions high germination rates can fortunately be achieved. A re-introduction programme has been started and has become more and more successful since 1999 (Montmollin and Strahm 2005).

2.1.12 Sicily Archipelago, Italy

Some 30 trees of *Abies nebrodensis* grow at an altitude of 1,500 m altitude on limestone soil. The Madonie Mountains, Sicily, rising to 1,980 m, were once covered by *Abies nebrodensis*. Degraded natural habitat, the poor health of specimens propagated in tree nurseries, the limited population size, and threat from fire represent the biggest threats to the species. Hybridization with non-native firs results in genetic contamination.

Foresters immediately initiated conservation measures. However, soil degradation in the natural habitat has made re-introduction difficult. Researchers from Palermo University are currently investigating the species' ideal growth conditions. The species has grown well in several European botanic gardens. An EU LIFE-financed project is being carried out to conserve the existing population. The project includes implementing an action plan which would include forest management, conservation, and the gradual elimination of non-indigenous fir species. The goal is to stabilize the current population and improve the survival rate based on natural reproduction. Their location within the Madonie Regional Park guarantees some level of protection. In 1978, following seed collection, the forestry service cultivated 110,000 young trees in a nursery. Since the survival rate in nature is extremely low, an adoption programme was set up in parallel. 40,000 young plants have been planted in the Botanical Garden of Palermo, Sicily, as well as in gardens and second homes in the Madonie Mountains, slightly away from their natural area of distribution. Several mature trees also grow in botanic gardens and arboreta elsewhere in Europe. For *ex situ* cultivation of *A. nebrodensis*, areas should be selected that are not home to other fir trees to prevent genetic contamination (Farjon et al. 2006; Montmollin and Strahm 2005; Virgilio et al. 2000; Ducci et al. 1999).

Bupleurum dianthifolium, a small shrub, is endemic to the island of Marettimo, part of the Egadi archipelago, west of Sicily, Italy. It grows in only a few locations on the northern side of the island in an area of 5 km^2. It is estimated that approximately 300–500 individuals remain. The small, cushion-shaped perennial shrub grows on calcareous cliffs at an altitude of 20–600 m, preferring north-facing slopes and growing in the cracks of limestone rock faces.