

Marcia C. M. Marques  
Carlos E. V. Grelle *Editors*

# The Atlantic Forest

History, Biodiversity, Threats and  
Opportunities of the Mega-diverse  
Forest

 Springer

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Editors

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History, Biodiversity, Threats  
and Opportunities of the Mega-diverse Forest

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*To all the environmentalists who defended  
the Atlantic Forest*

# Foreword

For the past 30 years, the Atlantic Forest has been considered a global priority for biodiversity conservation, one of the top five Biodiversity Hotspots on our planet. Situated mostly within Brazil (but also in Argentina and Paraguay), which is one of the world's top two Megadiversity Countries (Mittermeier et al. 1997), the Atlantic Forest is truly a special part of the world, with exceptional levels of species diversity and endemism.

The numbers speak for themselves, more than 20,000 species of which at least 6,000 are endemic—a number higher than most countries. There are 2,645 non-fish vertebrates, including 384 mammal species, with at least 109 endemics, 1,025 birds with 215 endemics, 517 reptiles with 126 endemics, and 719 amphibians, of which a striking 504 are endemic (Figueiredo et al., this volume). Indeed, if the Atlantic Forest were a country, it would rank as a Megadiversity Country in its own right.

Diversity in certain groups of organisms is especially impressive. Tree diversity in certain parts of the region is among the very highest on Earth, with some early surveys stunning the scientific world, such as 454 arboreal species being surveyed in Bahia in a single hectare of forest (Thomas et al. 1998). This is a number that is matched only by a few sites on the eastern slope of the Tropical Andes, another Biodiversity Hotspot. In this volume, Zwiener et al. greatly expand on the magnificent tree diversity in the Atlantic Forest. Bromeliads and orchids are also exceptionally diverse. And, of course, our favorite group of animals, the non-human primates, are also extremely rich here, with 6 genera and 24 species, of which 21 are endemic, making this region one of the world's top primate conservation priorities.

Diversity and endemism per unit area are also exceptional in the Atlantic Forest, especially when we take into account how many species are packed into the relatively very small area that remains. Even without taking into account the widespread habitat loss that has taken place in the Atlantic Forest compared to Amazonia, its diversity in many groups of organisms is close to that of Amazonia, which is approximately five times larger.

As with the other hotspots, the Atlantic Forest has also suffered from widespread habitat loss over the centuries. It is where Brazil was first colonized and is today a major population center, not just for Brazil but for the entire continent, with São

Paulo being one of the two biggest cities in the Western Hemisphere. Going back to the 1980s, estimates of the remaining natural vegetation cover were as low as 7-10% (Fonseca 1985).

We usually refer to the Atlantic Forest as the Brazilian Atlantic Forest, but it is important to note that it also extends into the moist forests of eastern Paraguay and Misiones Province in northern Argentina. That said, more than 90% of the region is found within the borders of Brazil, making its conservation very largely a Brazilian concern.

Although the global importance of the Atlantic Forest is now recognized by everyone in the conservation world, that was not always the case. If one goes back just 50 years, Brazil and its vast extent of tropical rain forest wasn't even considered a high priority in our community. It was not until the early 1970s that Amazonia began to be recognized as of global significance, especially through the leadership of Dr. Thomas E. Lovejoy, then of the World Wildlife Fund – USA, as international attention focused on the impacts of the TransAmazonian Highway, popularized by Goodland and Irwin of the World Bank in 1975. The Atlantic Forest at this time was still nothing more than an afterthought, if it was discussed at all. One of the very first papers in an international journal that called attention to the plight of the Atlantic Forest was published by one of us (Fonseca 1985), as recognized by Marques et al. (this volume).

The origins of worldwide interest in the Atlantic Forest can be traced back to 1970, and it came about because of one little monkey, the Golden Lion Tamarin (*Leontopithecus rosalia*). Following a couple of short articles by Clyde Hill, Curator of Mammals at the San Diego Zoo, and John Perry, Assistant Director of the National Zoo in Washington, D.C., a number of people in the conservation community started to become concerned about the declining situation of this species and its habitat in the state of Rio de Janeiro. In July 1971, one of us (Mittermeier) travelled to Brazil and met with Prof. Ademar F. Coimbra-Filho, the pioneer of Brazilian primatology, and together with him started to publish on this species in international journals and also on the two other then-recognized species of lion tamarin, the Golden-headed Lion Tamarin (*Leontopithecus chrysomelas*) and the Black Lion Tamarin (*Leontopithecus chrysopygus*), which Coimbra had rediscovered in 1970 in the states of Bahia and São Paulo, respectively, after neither had been seen for almost 70 years. There followed a series of international conferences on these animals, the first at the National Zoo in Washington, D.C., in February 1972, with many others to follow.

At the end of the decade, Mittermeier began a decade-long survey of primates in protected areas of the Atlantic Forest, together with Coimbra, Prof. Célio Valle of the Universidade Federal de Minas Gerais (UFMG), and Almirante Ibsen de Gusmão Câmara of the Fundação Brasileira para a Conservação da Natureza (FBCN) in Rio de Janeiro, and with the active participation of one of us (Fonseca), then a graduate student working on primates – all of it funded by the World Wildlife Fund – USA. Early on, this program focused heavily on the two endemic genera, *Leontopithecus* and the muriquis (*Brachyteles*), turning them both into flagship species comparable in value to the giant panda of China, the gorillas of Africa, and the

orangutans of Southeast Asia. What is more, this research program recognized the importance of the Atlantic Forest region as a whole, with the result that Mittermeier introduced it as a priority region in the World Wildlife Fund's Global Campaign for Primates and Tropical Forests, which began in 1982.

There followed a series of scientific and popular publications, led by the two of us but in collaboration with many other partners, in which we highlighted repeatedly the importance of this region (Coimbra-Filho and Mittermeier 1973a, b; Coimbra-Filho et al. 1975; Mittermeier and Coimbra-Filho 1977; Mittermeier et al. 1982; Fonseca 1985; Tabarelli et al. 2005).

In 1983, at a meeting of senior staff from WWF-US to set priorities for its Latin America Program, the Atlantic Forest along with the Tropical Andes were recognized as the two highest priorities in the region. This meeting was in many ways a precursor to the Forest Hotspots analysis, first published by Dr. Norman Myers 1988, in which he recognized the Atlantic Forest as one of the top 10 on Earth. Following input from a number of us, he published an update in 1990, recognizing 18 of what were then called Biodiversity Hotspots. In July 1989, Mittermeier took the Hotspots concept to the fledgling Conservation International and made it the central focus of the organization for the next 20 years. Fonseca joined Conservation International in 1990 as Executive Director of its Brazil Program, with the Atlantic Forest as the top priority. In parallel, Fonseca led the establishment of the first graduate program in Ecology, Conservation and Wildlife Management at the UFMG focusing especially on the Atlantic Forest. One of the editors of this volume, C. E. V. Grelle, received his Master's degree from that program.

Thanks to the John D. and Catharine T. MacArthur Foundation, which also chose the hotspots as its central organizing principle for its new conservation program, Conservation International was able to secure a major grant for its work in the Atlantic Forest, along with grants to several young in-country conservation organizations (e.g., SOS Mata Atlântica in São Paulo, the Fundação Biodiversitas, Belo Horizonte, and the Sociedade de Pesquisa em Vida Selvagem (SPVS), in Curitiba, among many others).

Conservation International also began to publish a series of books, with support from the Mexican cement company CEMEX, highlighting a variety of different conservation issues. The first of these was entitled *Megadiversity* (Mittermeier et al. 1997), which recognized Brazil as one of the two top countries on Earth for its biodiversity, and this was followed by a number of others, two of them, *Hotspots* (Mittermeier et al. 1999) and *Hotspots Revisited* (Fonseca et al. 2004), prominently highlighting the Atlantic Forest. These also formed the basis of two major Conservation International fund-raising campaigns, "The Campaign to Save the Hotspots," which began in the mid-1990s, and "A Future for Life," which started with the new millennium. Together they raised approximately \$2 billion.

All of these activities were instrumental in increasing international recognition of the Atlantic Forest as a truly major global conservation priority, and this continues to the present day through a very wide range activities far too numerous to cover in this brief foreword.



What is especially gratifying to those of us who can trace our Atlantic Forest roots going back 40-50 years is the incredible growth of capacity in this region, including both the scientific research capacity and the conservation capacity to create and manage protected areas, at federal, state, and municipal levels, and even in terms of private protected areas (RPPNs). There is no doubt that the Atlantic Forest can be considered a conservation success story among the world's Biodiversity Hotspots, as exemplified by the recent publication, *The Atlantic Forest: Hotspot to Hopespot*, that documented an increase in forest cover to 28% percent, or 32 million hectares, of native vegetation cover (Rezende et al. 2018). The authors estimate that just the implementation of the existing legislative framework could boost the extent of forest cover to 35%.

To be sure, the region still faces many conservation challenges and we must always be cognizant of the old adage that “there are no final victories in conservation.” Nonetheless, we are confident that the large and growing cadre of Brazilian researchers and conservationists will succeed in their efforts. Indeed, there is no better indication of this than the truly amazing and highly competent group of young authors that have contributed to this historic and brilliant volume.

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# Preface

## Time to Rethink the Atlantic Forest

The object of curiosity and admiration of scientists and conservationists, the Brazilian Atlantic Forest is scientifically explored in this book. Over the 23 chapters written by 149 authors from 65 different institutions, the Atlantic Forest goes through a scanner again, updating some works already published in the last 25 years (Dean 1995; Morellato and Haddad 2000; Galindo-Leal and Câmara 2003; Metzger 2009; Eisenlohr et al. 2015). This re-reading is necessary, since both knowledge of the different dimensions of diversity and threats to biodiversity and ecosystem services remain current. Fortunately, in recent years, new tools have also been developed to map and manage the biome, opening up new opportunities for a future based on the conservation and sustainable use of nature.

The history of knowledge of the Atlantic Forest goes back to the end of the eighteenth century, with expeditions by European naturalists, and goes beyond the other centuries with a gradual structuring of research institutions in Brazil (Marques et al. 2000). Over time, a variation was also noticed in the ways of understanding the limits and sectors of the Atlantic Forest as well as the research topics, which include the most descriptive basic sciences (biogeography and systematics), ecology (populations and communities), and the most applied sciences (conservation and biodiversity) (Marques et al. 2021).

The Atlantic Forest has a long history of human interaction and transformation: the early human interactions in the Pleistocene, the actions of more modern native populations of farmers, the arrival of Portuguese colonizers and their large plantation systems, the urbanization and industrialization in mid-twentieth century, and the Anthropocene, from the twentieth century (Solórzano et al. 2021). Altogether, these activities dramatically affected the landscape of the Atlantic Forest, resulting in the highly threatened system. Considering the great environmental, biological, and occupational differences across regions of the Atlantic Forest, some particularities were marked. For example, in the northern Atlantic Forest, the vegetation was mainly converted into sugarcane fields, remaining only 13% of the original area

located mainly within particular properties (Lins-e-Silva et al. 2021). In the central Atlantic Forest, specifically the northern portion of Espírito Santo and southern Bahia states (the Hileia Baiana), 500 years of colonization and successive economic cycles (brazilwood, sugarcane, cassava flour, timber, cocoa) significantly reduced and degraded the native vegetation. However, these forests are still significant reservoirs of the regional biota that inhabits the few remaining forests and the complex mosaic of different land uses that comprise the dominant human-modified landscapes (Faria et al. 2021). In the southern Atlantic Forest (from south Doce river), characterized by tropical dense, seasonal, and mixed forests, the degradation was marked by strong land cover changes, but still some of the largest fragments along the Serra do Mar mountain remained (Carlucci et al. 2021).

One of the most striking features of the Atlantic Forest is its megadiversity, already documented in previous studies. The updating of these data in this book shows that the diversity of some groups of organisms may be even greater than that already reported, while for other groups, a large knowledge gap still exists. For terrestrial ecosystems, the analysis of data from inventories and herbarium revealed a greater richness of tree species in the central area of the biome, but data for most species is still scarce or not yet ready for use because of bias in data collection (Zwiener et al. 2021). Similarly, the richness of epiphytes is also biased by the collection, and a greater diversity and endemism is found in the south and southeast regions of Brazil (Ramos et al. 2021). For eusocial insects (ants, bees, wasps, and termites), the compilation made by Feitosa et al. (2021) found the impressive number of 1,401 species distributed in 189 genera occurring in the Atlantic Forest; the authors point to the many gaps for specific groups and regions. Finally, the compilation of Tetrapoda occurring in the Atlantic Forest identified 2,645 species, being 719 species of amphibians, 517 species of reptiles, 1,025 species of birds, and 384 species of mammals (Figueiredo et al. 2021). This impressive fauna represents 2.8% of world's Tetrapoda species, and considering that 157 new Tetrapoda species were described in the Atlantic Forest in the last decade, mostly from poorly sampled regions or environments, the importance of the region for global biodiversity can be still higher (Figueiredo et al. 2021). For freshwater ecosystems, understood as coastal and interior freshwaters distributed in 22 hydrographic basins along the Atlantic Forest, the diversity of fishes (and other vertebrates), macroinvertebrates, zooplankton, macrophytes, and microalgae is also astonishing (Padiál et al. 2021). The contrast between the demand for ecosystem services (especially drinking water and hydroelectric energy) and the susceptibility of aquatic organisms and trophic chains to environmental changes underscores the importance of increased ecological studies in these ecosystems.

Associated with this diversity in fauna and flora, a diversity of interactions between plant-pollinator, from generalist to specialist systems, represent part of the complexity of the ecosystems that compose the biome (Varassin et al. 2021).

Although it is one of the most important regions in the world in terms of biodiversity and ecosystem services, the Atlantic Forest has historically been the target of

numerous threats. As almost all regions in the world, the ongoing anthropogenic climate change is becoming one of the major threats to Atlantic Forest biodiversity. Vale et al. 2021 shows that, using the predictions of eight different climate models, it is possible to project a mean temperature increase of 4.8°C to 5.6°C under a business-as-usual scenario (RCP 8.5) whereas precipitation is expected decrease in the northern and increase in southern portion of the Atlantic Forest. In fact, there a good number of studies projecting high risk of biodiversity loss in terrestrial ecosystems, but a significant knowledge gap in altitudinal, freshwater, and coastal environments (Valle et al. 2021). At a regional (biome) scale, the land-cover changes along the last 520 years led the Atlantic Forest to the current situation of low forest cover mostly distributed in small and isolated fragments composed by forests of varying ages and degradation states (Lira et al. 2021). The introduction of non-native species, that led to biotic homogenization and species losses, showed a growing pattern in spatiotemporal records and richness in the last years. This pattern was specially marked by the increased number of non-native species of plants and fishes and the increased abundance of non-native insects, that directly alter community structure and ecosystem services, and indirectly affects public health and agriculture (Vitule et al. 2021). Also, the fauna of Atlantic Forest has been strongly affected and reduced, driven mainly by habitat loss, fragmentation and degradation in terrestrial populations. In general, apex predators, other carnivores, large-bodied mammals, large herbivores (Galetti et al. 2021) and pollinators (Varassin et al. 2021) were among the most defaunated functional groups, negatively affecting key ecosystem services.

In order to reverse the effects of these threats on the biodiversity of the Atlantic Forest, it is necessary to take advantage of the windows of opportunities that are now presented. One of these opportunities is centered on the concept of ecosystem services. Pires et al. (2021), argue that Atlantic Forest provides ecosystem services for over 60% of the Brazilian population and that promoting dialogue between multiple sectors that depend on these services could leverage a sustainability agenda. Creating alternatives to finance the conservation of the Atlantic Forest is also a possibility explored by Young & Castro (2021), who list several financial instruments that could be targeted for this purpose. Actions that include encouraging sustainable productive activities, such as agroforestry systems and large-scale ecological restoration are other alternatives. According to Tubenchlak et al. (2021), there are numerous initiatives already underway for agroforestry systems in the Atlantic forest, with great potential for restoring socioecological interactions. Similarly, de Siqueira et al. (2021) presents several ways to stimulate social engagement through ecological restoration, enabling conditions to organizing people in a common view project that significantly contribute to the success of the national restoration agenda. The engagement of people is also important for ecotourism (Viveiros-de-Castro et al. 2021), for conservation actions involving governments, organized civil society and universities (Grelle et al. 2021), and for the advancement of interdisciplinary

knowledge about biodiversity, as presented by Bergallo et al. (2021). Altogether, the threats, opportunities, as well as the weaknesses and strengths of the Atlantic Forest are addressed by Grelle, Rajão & Marques (2021), which discuss the possible future of the biome.

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**Part I**  
**Historical and Biogeographical Aspects**

# Chapter 1

## The Atlantic Forest: An Introduction to the Megadiverse Forest of South America



Marcia C. M. Marques, Weverton Trindade, Amabily Bohn,  
and Carlos E. V. Grelle

**Abstract** The Atlantic Forest, the second largest forest in South America and one of the most biodiverse biomes in the world, is also one of the most threatened and important for conservation. In this chapter, we introduce the Atlantic Forest focusing on describing the evolution of knowledge, the geographical limits, and the current proposals of sectorization in ecological units. The knowledge of the Atlantic Forest can be explained by three successive phases: (1) the science of naturalists (the late eighteenth century to the late nineteenth century), where the flora and fauna were described by European travelers; (2) the rise of science in Brazil, characterized by the organization of Atlantic Forest biodiversity in collections (1890–1985); and (3) the contemporary era (1985–2020), characterized by the publication of 8226 studies focused on 4 main topics – biogeography and systematics, conservation and biodiversity, plant-animal interaction, and populations and community. The understanding of the distribution limits of the Atlantic Forest biome (11 different proposals), as well as sectorization (4 different proposals), has been the subject of several studies and legislations, which are presented and discussed. Additionally, we present terminologies usually used to designate the Atlantic Forest as a whole, as well as its sectors, to facilitate understanding in future studies. We conclude that understanding the Atlantic Forest remains a long and endless exercise, given its complexity, increased knowledge, and continuous threats.

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