

# Chapter 1

## Biodiversity in the Gulf of Guinea Oceanic Islands: A Synthesis



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**Abstract** The Gulf of Guinea oceanic islands (Príncipe, São Tomé, and Annobón) are among the most endemic-rich regions of the planet. Historical scientific studies of the islands' unique biodiversity are scattered in a variety of publications, many of which are difficult to access. More recently, there has been a growing interest in the islands, which is reflected in a burst of new studies, reports, and ongoing projects.

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Here we aim to provide an updated and comprehensive synthesis, covering all the key information and references on the biodiversity of these islands. The goal of the book is to be a comprehensive reference for students, researchers, and conservationists dedicated to the study and preservation of this unique biodiversity. It also intends to serve as a basis for local stakeholders to make informed decisions, namely regarding conservation actions. The book is divided into three main sections: (1) a general overview of the islands and their biodiversity, including aspects of natural and human history (six chapters); (2) detailed accounts on different taxonomic groups (16 chapters); and (3) the conservation, environmental education, and research challenges that lie ahead (three chapters).

**Keywords** Biogeography · Conservation · Ecology · Endemics · History of science · Taxonomy

## Introduction

*É realmente notável a fauna da ilha de S. Tomé e mais notável é ainda a diferença que faz da sua irmã o Príncipe. No Príncipe os animais que se encontram são em grande parte do continente, enquanto que em S. Tome há uma forma especial com bastantes espécies que julgo serem privativas da ilha. A distância que há entre as duas ilhas é apenas de 90 milhas mas o cabo submarino lançado tem 120 milhas devido às ondulações de terreno no fundo do mar. Com relação à Atlântida, não serão as ilhas do Golpho da Guiné e mesmo as Canarias, Cabo verde, St<sup>a</sup> Helena, Assumpção etc, restos d'esse grande continente?*

*The fauna of S. Tome Island is truly remarkable, and it is even more remarkable the difference to its sister island of Príncipe. The animals that are found in Príncipe are mostly from the continent, while in S. Tomé there is a special form with several species that I believe are private to the island. The distance between the two islands is only 90 miles but the submarine cable has 120 miles due to the ruggedness of the sea floor. Regarding Atlantis, aren't the islands of the Gulf of Guinea, and even the Canaries, Cabo Verde, St. Helena, Ascension, etc., the remains of that large continent?*

Francisco Newton, letter from São Tomé Island  
23 January 1887

The Portuguese explorer Francisco Newton was one of the first naturalists to dedicate almost one decade to the study of the outstanding diversity of the Gulf of Guinea oceanic islands. The collections he made, in what was largely unexplored territory for science, allowed the description of dozens of new species and began to reveal intriguing biogeographic patterns. Gazing at the species he was collecting, many of which would turn out to be endemic, the naturalist found them so spectacular that he dared to suggest the islands could be the remains of the mythical continent of Atlantis. While this suggestion lacks any scientific basis, it is a perfect example of the sense of awe that the biodiversity of the Gulf of Guinea oceanic islands imparts to any naturalist who visits them. Although Newton's "Atlantis hypothesis" did not gain traction, other comparisons between these islands and other iconic places around the world have since been proposed. A quick search about these islands on the Internet, newspapers, popular magazines, or tourism advertisements will likely find them labeled as "a paradise on Earth" or "the Galapagos of Africa." The Galapagos archipelago in the Pacific Ocean is one of

the most famous group of islands for naturalists and wildlife enthusiasts, especially due to their role in British naturalist Charles Darwin's (1809–1882) genesis of the theory of evolution through natural selection. The observation of the diverse environments, unique species, and incredible adaptations of the Galapagos fauna and flora were fundamental to Darwin's growing body of evidence, forever linking the Galapagos to the theory of evolution. Darwin never set foot in the Gulf of Guinea but the type of evidence he found in the Galapagos is also abundantly available in these oceanic islands. Thus, the label "the Galapagos of Africa" is certainly fitting.

Since their emergence millions of years ago, due to the activity of the Cameroon Volcanic Line, the islands of Príncipe, São Tomé, and Annobón have been isolated from the African continent. Their prolonged isolation and complex geological history led to the evolution of unique species that sustain distinctive ecosystems. Humans arrived approximately 500 years ago, when Portuguese navigators found these uninhabited islands teeming with biodiversity. Since then, human impact on the islands has increased considerably, with lasting impacts to both the landscape and biodiversity. The human impact on the biota has been considerable, and a number of species and ecosystems are now threatened.

The islands' unique biodiversity has attracted several generations of researchers working in a wide diversity of taxonomic groups and biological topics. Biodiversity research in the region received a renewed focus when in June 1993 the Jersey Wildlife Preservation in Jersey (UK) organized a workshop on the biodiversity of the Gulf of Guinea islands. The aim of this meeting was to synthesize the data available at the time, and led to the establishment of a network of experts: the Gulf of Guinea Conservation Group. Managed by Angus Gascoigne (1962–2012), a passionate British amateur naturalist who was living in São Tomé, it supported many scientific endeavors. The results of the meeting were published in a special edition of the journal *Biodiversity and Conservation* (Juste and Fa 1994). This issue became the major reference for the biodiversity of the islands for more than two decades, serving as the main source of data and theoretical support for the new generation of island biologists and conservationists, many of whom are contributors to this volume.

On October 16, 2020, a virtual meeting brought together several dozen scientists, conservationists, educators, and local stakeholders, all with shared interests in the biodiversity of the Gulf of Guinea oceanic islands. This meeting aimed to set the foundation for the Gulf of Guinea Biodiversity Center, a collaboration to satisfy the urgent needs of an ever-growing community to have an institution fully dedicated to the biodiversity of the islands. This new generation is dedicated to surveying the islands to document biodiversity, to understand and mitigate the current threats, and to raise local and global awareness for this unique natural heritage. This book aims to represent this new wave of research and to set the stage for the next phase of biodiversity research and conservation.

## Historical Biodiversity Syntheses

Prior to the 1994 special issue of *Biodiversity and Conservation* (Jones 1994), efforts to synthesize knowledge on the biodiversity of the Gulf of Guinea islands were few and far between. Many tended to be taxonomically and geographically focused. In the early twentieth century, the Portuguese zoologist José Vicente Barbosa du Bocage (1823–1907) was the first to produce a synthesis on the land vertebrates of the Gulf of Guinea islands, based on the knowledge that had been amassed during the second half of the nineteenth century (Bocage 1903, 1905). According to him, the list of species for Príncipe included four mammals, 43 birds, ten reptiles, and two frogs, whereas that of São Tomé hosted 12 mammals, 64 birds, 11 reptiles, and five amphibians. For Annobón, the species list of Bocage (1903) recorded only two mammals, 14 birds, five reptiles, and no amphibians. Similar to Bocage's checklists of vertebrate fauna, the British botanist Arthur Wallis Exell (1901–1993) was the first to publish a checklist of the vascular flora of the Gulf of Guinea oceanic islands (Exell 1944). He benefited from the work of previous researchers, such as Júlio Henriques (1838–1928), former director of the herbarium of the University of Coimbra, providing an extensive series of publications (Exell 1956, 1958, 1959, 1963, 1973). By 1973 he had recorded 810 angiosperms for the islands (539 dicotyledons and 271 monocotyledons), of which 601 occurred on São Tomé, 314 on Príncipe, and 208 on Annobón (Exell 1973). Some taxonomic groups have received special attention in comparison to others. Birds, in particular, received regular syntheses through the years (Bocage 1889; Amadon 1953; Naurois 1994; Jones and Tye 2006; Lima and Melo 2021).

While many syntheses have been taxonomically oriented (vertebrates, angiosperms), others have focused on single islands. The work of Júlio Henriques on the natural history and agriculture of São Tomé (Henriques 1917) is a perfect example: across almost 300 pages, this monographic work aimed to cover all the aspects of the natural history of the island, listing its fauna, flora, geology, topography, agriculture, and even the organization of the local society. Other attempts to compile information on the biodiversity of the islands took place later on, including the bibliographic compilation of “pure and applied botany” of São Tomé and Príncipe by Fernandes (1982), and that on the fauna of the three oceanic islands by Gascoigne (1993, 1996).

Continuously updating species lists is vital for refining taxonomy, identifying knowledge gaps, recording changes in species composition, studying community ecology and biogeography, understanding ecosystem function, and supporting conservation decisions. Jones (1994) presented an updated overview of the number of vertebrate species and endemics on each island (Table 1.1). According to this compilation, the Príncipe species list of terrestrial vertebrates included four mammals, 35 birds, eight reptiles, and three frogs, that of São Tomé nine mammals, 49 birds, 14 reptiles, and six amphibians, and that of Annobón two mammals, nine birds, seven reptiles, and no amphibians (Table 1.1). Regarding plants, numbers would not be updated until the much more recent publication of bryophyte (Sérgio

**Table 1.1** Comparison between confirmed extant resident terrestrial vertebrates since the previous synthesis (Jones 1994), considering all species, single-island endemics, and all endemics. The percentage of endemic species is shown in parenthesis. The number of species currently thought to be introduced is shown in the last column. A few cells are blank because those figures were not available in the previous synthesis

	Island	Previous		Current		Previous Single-island endemics	Current		Previous All endemics	Current	
		Total		Total			Total	Introduced			
Amphibia	Príncipe	3		3		1 (33)	3 (100)	3 (100)	3 (100)	3 (100)	0
	São Tomé	6		6		4 (67)	6 (100)	6 (100)	6 (100)	6 (100)	0
	Annobón	0		0		0	0	0	0	0	0
	Total	7		9		5 (71)	9 (100)	7 (100)	9 (100)	9 (100)	0
Reptilia	Príncipe	8		14		2 (25)	8 (57)	7 (88)	10 (71)	10 (71)	2 (14)
	São Tomé	14		12		1 (7)	7 (58)	6 (43)	9 (75)	9 (75)	2 (17)
	Annobón	7		8		2 (29)	6 (75)	3 (43)	6 (75)	6 (75)	2 (25)
	Total			28		5	21 (75)	10	23 (82)	23 (82)	3 (11)
Aves	Príncipe	35		32		6 (17)	8 (25)	11 (31)	11 (34)	11 (34)	5 (16)
	São Tomé	49		50		15 (31)	17 (34)	20 (41)	20 (40)	20 (40)	17 (34)
	Annobón	9		11		2 (22)	1 (9)	3 (33)	2 (18)	2 (18)	3 (27)
	Total			66		23	26 (39)	28	29 (44)	29 (44)	17 (26)
Mammalia	Príncipe	9		12		1 (11)	2 (17)	1 (11)	2 (17)	2 (17)	5 (42)
	São Tomé	16		17		3 (19)	5 (29)	3 (19)	5 (29)	5 (29)	6 (35)
	Annobón			4		0	0 (0)	0	0 (0)	0 (0)	2 (50)
	Total			19		4	7 (37)	4	7 (37)	7 (37)	6 (32)
All	Príncipe	55		61		10 (18)	21 (34)	22 (40)	26 (43)	26 (43)	12 (20)
	São Tomé	85		85		23 (27)	35 (41)	35 (41)	40 (47)	40 (47)	25 (29)
	Annobón			23		4	7 (30)	6	8 (35)	8 (35)	7 (30)
	Total			122		37	63 (52)	49	68 (56)	68 (56)	26 (21)

and Gargia 2011), fern and lycophyte (Figueiredo 2002; Klopper and Figueiredo 2013), and angiosperm checklists (Figueiredo et al. 2011). There are noticeable differences in the number of species and endemics for taxa that have multiple checklists, reflecting the development of knowledge of the islands' biodiversity over the last century. New species continue to be added every year, even among the best studied groups, representing both species that are new to science and just newly recorded on the islands. Nevertheless, systematic and well-curated species checklists are still the exception for most taxa in the Gulf of Guinea oceanic islands. For many groups, notably terrestrial and marine invertebrates, there are still no comprehensive species checklists, or they were first published recently, highlighting how little is still known about the biodiversity of the islands (Lima 2016).

## A New Synthesis

The outputs of the long history of research in the oceanic islands of the Gulf of Guinea are scattered in hundreds of publications—scientific papers, reports, and books. Most works published since the late eighteenth century to the present day are very specific, focusing on few taxa and on a single island, or even a single species and particular regions of an island. Publications are available in several different languages—Portuguese, Spanish, English, French, German, Italian, Latin, Russian—and formats—from books to peer-review scientific journals, theses, unpublished reports, and more recently also in non-printed media, such as online images, audio, and video. Access to many historical works has greatly improved in recent years, especially due to important online platforms, such as the Biodiversity Heritage Library (Gwinn and Constance 2009). However, this immense diversity of sources also makes it challenging to gain a complete and updated view on the biodiversity of these islands. Similarly, thousands of scientific specimens are held in natural history collections around the world, providing the baseline to our present knowledge and enabling exciting new findings and research. Many of these collections have not been included in recent studies and some have only recently been rehabilitated and once more made accessible to the scientific community (e.g., Monteiro et al. 2016; Ceríaco et al. 2021). For such a small area, the Gulf of Guinea oceanic islands may be one of the most intensively studied parts of Africa (e.g., Droissart et al. 2018). However, most of the scientific output and associated data are not synthesized or readily available.

This book attempts to compile the key information and references regarding the past and current knowledge on the biodiversity of the Gulf of Guinea oceanic islands. The goal is to be a comprehensive reference for students, researchers, and conservationists dedicated to the study and preservation of this unique biodiversity. It also intends to serve as a basis for local stakeholders to make informed decisions, namely regarding conservation actions. Above all, it is an act of celebration of the scientific achievements of several generations of biologists and conservationists, a

manifest in support of the astonishing biodiversity of these islands, and a plea for its conservation.

## Book Structure

The book is divided into three main sections: (1) a general overview of the islands and their biodiversity, including aspects of natural and human history (six chapters); (2) detailed accounts on different taxonomic groups (16 chapters); and (3) the conservation, environmental education, and research challenges that lie ahead (three chapters).

Section one starts with an outline of the physical geography, geological history, climate, and sea level evolution of the study area, providing also its political boundaries and administrative divisions (Chap. 2; Ceríaco et al. 2022a). This is followed by a revision of the classification and cartography of the terrestrial ecosystems (Chap. 3; Dauby et al. 2022). Chapter 4 (Muñoz-Torrent et al. 2022) analyzes the five centuries of human presence on the better-known island of São Tomé, presenting demographic trends, cultural heritage, and how the history of the main economic activities has impacted biodiversity. Chapter 5 (Ceríaco et al. 2022b) reviews the history of scientific research, from mid-eighteenth century to the twenty-first century. The fascinating evolutionary patterns that shaped the biodiversity of the “Galapagos of Africa” are presented in Chap. 6 (Melo et al. 2022a). In Chap. 7 (Soares et al. 2022), our current understanding of island species ecology is synthesized, including information about species distributions, habitat preferences, species assemblages, and the interactions that maintain functioning ecosystems.

The second section constitutes the bulk of the book and corresponds to the taxonomic chapters. The level of detail varies between chapters, mostly reflecting disparities in knowledge across taxonomic groups. However, all chapters have a similar structure, including an introduction to the group, a brief review of the history of research on the islands, an account of the group’s diversity and endemism, an updated checklist, and a section on conservation. Most of these chapters also highlight important areas for future research.

Chapter 8 (Desjardin and Perry 2022) reports 260 species of mushrooms and allies of the Agaricomycetes lineages of the Basidiomycota in São Tomé and Príncipe. These correspond to 109 genera, 51 families, and 13 orders, and given how little scientific attention this group has received, species richness will likely increase with future work. Chapter 9 (Garcia et al. 2022) provides a review of the bryophytes of São Tomé and Príncipe, based on historical herbarium data complemented by the results of recent fieldwork. A preliminary list of 299 taxa (128 mosses, 171 liverworts and hornworts) is provided, and the authors note that several species likely remain undescribed or at least undocumented. Chapter 10 (Stévant et al. 2022) presents an updated checklist of vascular plants, combining data from historical material and bibliographic references with extensive new field surveys conducted since 2017. The current number of vascular plants includes

1285 taxa, with 164 endemics, of which at least 18 are new to science. A report on medicinal plants is also provided.

Six chapters focus on invertebrate groups. Chapter 11 (Crews and Esposito 2022) explores the diverse and little-known arachnid fauna of São Tomé and Príncipe, which includes 266 recorded species of six different orders. Chapter 12 (Nève et al. 2022) provides a first checklist for the beetles of the three oceanic islands, listing 403 species, of which 190 are endemic. The butterflies and skippers (Lepidoptera: Papilionoidea) are reviewed in Chap. 13 (Mendes and Bivar-de-Sousa 2022), with 91 confirmed taxa, and extensive discussion resolving previous doubtful records. Chapter 14 (Dijkstra and Tate 2022) notes the impoverished dragonfly and damselfly fauna of the islands, which includes only 22 confirmed records and one endemic species, from Príncipe. Chapter 15 (Loiseau et al. 2022) reviews the arthropod species that can act as vectors of diseases. Given the particularity of this group, the structure of this chapter is slightly different but its scientific relevance is undisputable due to the public health implications. The chapter also provides important insights into species interactions, and underscores the possibility of new vector-borne diseases arriving on the islands. Chapter 16 (Panisi et al. 2022) deals with the 96 species of land gastropods, of which 62 are endemic, providing new insights on the ecology, biogeography, and conservation of these species, including the famous endemic giant land snail *Archachatina bicarinata* Bruguière, 1792.

Regarding vertebrates, there are four taxonomic chapters for terrestrial groups and three for aquatic taxa. Chapter 17 (Costa et al. 2022) lists and discusses the more than 1000 species of fishes that potentially occur in the fresh and marine waters of the islands. Chapter 18 (Bell et al. 2022) deals with amphibians, which include three species on Príncipe and six on São Tomé, all of which are endemic (Annobón has no amphibians). The chapter provides a detailed overview of species biology, ecology, and biogeography. Chapter 19 (Ceríaco et al. 2022c) presents the 29 species of established terrestrial reptiles, reporting also historical and recent records of vagrant, doubtful, or introduced species. The five species of sea turtles that occur on the islands are reviewed in Chap. 20 (Ferreira-Airaud et al. 2022). All sea turtles are threatened, and this chapter includes extensive discussion of conservation successes and challenges. Chapter 21 (Melo et al. 2022b) revises information on birds, one of the best-known and most charismatic taxa from the islands that includes at least 29 endemic species. It summarizes historical data and provides updated insights into a group that has been at the forefront of research and conservation. Chapter 22 (Rainho et al. 2022) revises information on the 19 species of non-domesticated resident land mammals, including 11 bats, seven endemic species, and six introduced species. Finally, Chap. 23 (Carvalho et al. 2022) draws on new data collected since 2002 to present the updated list of the 12 cetaceans confirmed in the waters of the region, five of which are recent records. This chapter also provides a synthesis of the whaling history in the region.

The final section of the book focuses on the conservation, education, and future of research in the oceanic islands of the Gulf of Guinea. Chapter 24 (Lima et al. 2022) summarizes the state of conservation: from the cultural links to nature to the history of conservation initiatives. This chapter also lists priority species, sites, and actions.



Chapter 25 (Ayres et al. 2022) assesses recent strategies of formal and non-formal environmental education on São Tomé and Príncipe, which are vital to augment local capacity for conservation and scientific research. Chapter 26 (Bell et al. 2022) proposes a path toward biodiversity resilience for future naturalists, biologists, conservationists, and educators.

## Current Numbers, Current Biases

Comparing the number of species presented in previous compilations, such as Bocage (1903, 1905) or Jones (1994), with those recorded in this book is not a straightforward task. The coverage of previous syntheses was taxonomically more limited than the present work, and methods for counting endemic and non-endemic species varied. In comparing the number of vertebrate species and endemics provided by Jones (1994) with those in the current synthesis, however, one major trend stands out—our improved understanding led to an increase in endemism across most taxa (Table 1.1). In many cases, this was due to recognizing that each island had a distinct endemic species, and that shared endemics are rare. While it is likely that these numbers change little for vertebrate groups, they will certainly keep changing for less studied taxa, such as fungi, plants, invertebrates, and marine vertebrates.

There are several other biases in our knowledge of the biodiversity of these islands. Annobón is by far the least studied island. Most of the chapters focus on terrestrial habitats and species, and while several teams and projects are currently focusing on marine biodiversity and conservation, knowledge is still very limited. The study of marine biomes in the Gulf of Guinea oceanic islands is of critical importance, not only because the region is likely an important hotspot for marine biodiversity, but also because human residents depend heavily on marine resources. Another major gap is the limited number of ecological and natural history studies. While there is now a considerable amount of traditional and modern taxonomic research—describing, naming, and listing the several thousands of species known from the islands—there are very few studies on the ecology and natural history of these taxa. For most species, almost nothing is known besides the diagnosis and a few anecdotal pieces of information about its ecology. This lack of information hinders the development of effective conservation measures, which are increasingly necessary to ensure a thriving future for this unique archipelago.

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