

Gulf of Guinea Biodiversity: Proposal for Research and Conservation (2023-2030)

Version 1.1, November 2023

Contents (fast-tracked projects are CAPITALIZED)

1. Mission	7
2. Executive Summary	8
3. Motivation	12
4. Workplan	13
Pillar #1. Biodiversity knowledge: Surveys, DNA barcoding and database creation	14
I. Develop a framework for collaborative biodiversity research and conservation in the form of the “Gulf of Guinea Research Program”.	14
a. BUILD A WORLD-CLASS BIODIVERSITY CENTER (Príncipe).	14
b. BUILD A FIELD RESEARCH STATION IN PRÍNCIPE	14
c. Build a research station in the tropical rainforests of Mayombe National Forest (Cabinda).	15
II. Catalogue the ecological and genetic biodiversity of marine and terrestrial ecosystems in the Gulf of Guinea	15
a. DESIGN AND ROLL OUT A MARINE & TERRESTRIAL BIODIVERSITY DATABASE FOR THE GULF OF GUINEA	15
b. Develop a Marine & terrestrial DNA barcode library for the Gulf of Guinea.	16
III. Design and perform biodiversity surveys throughout the Gulf of Guinea.	16
a. Seabirds.	16
b. West African Manatee (Gulf of Guinea, 1PhD).	17
c. Sea turtles (Bioko, Annobon)	17
d. Seagrass meadows.	17
e. Marine forests of macroalgae.	17
d. Elephants, chimps, gorillas & vulnerable primates (Cabinda, Gabon, Mainland EG, Bioko).	18
e. Invasive plants (Príncipe, São Tomé).	18
f. Invertebrates (Príncipe, São Tomé, 1 PhD, 1MS).	18
g. Reptiles and amphibians (Maiombe National Park, Cabinda; 1 PhD, 1MS).	19
h. Landbirds (Príncipe, São Tomé, Bioko, Mainland EG).	19
i. Bats (All regions).	19
j. Freshwater turtles (Mainland EG, Gabon and Cabinda).	19
Pillar #2. Marine resources: sustainable use and conservation	21

I. Understand the spatial movements and distribution of marine megafauna using satellite technology.	21
a. Behavior and space-use of large pelagic sharks under threat from climate change (1PhD).	21
II. Unveiling the conservation status of important marine ecosystems.	22
a. Long-term monitoring of coastal temperature in the Atlantic.	22
b. Marine forests in the Gulf of Guinea: diversity and inter-forest connectivity	22
c. Assessing the Ecological Significance of Seagrass Meadows in the Gulf of Guinea: Implications for Biodiversity Conservation	23
Pillar #3. Forest ecosystem ecology, evolution and dynamics	24
I. Contribute to the global initiative of 30% of marine and land area protected by 2030 (AKA 30x30).	24
a. CREATE A NEW 100,000 NATIONAL PARK (Mainland EG).	24
b. Designing landscapes to support fully functional ecosystems (Gabon, Cameroon, mainland EG, 1PhD).	25
c. Leverage biological survey data to inform the design of new protected areas under 30x30 (All regions; 1 terrestrial PhD; 1 marine PhD).	26
II. Understand long-term patterns in biotic and abiotic processes that affect biodiversity in the Gulf of Guinea	27
a. Establish long-term monitoring plots for climate, carbon sequestration etc. (Príncipe, 1PhD, 1MS).	27
b. Long-term monitoring of rainforest bird populations (São Tomé, Príncipe, Bioko, Mainland EG, 1 PhD, 1MS)	28
c. Maintaining and expanding the project “Guardians of the Rainforest” (Bioko, Príncipe, São Tomé and Annobón islands)	28
III. Understand the critical ecological processes that shape biodiversity in the Gulf of Guinea	29
a. Dynamics of forest vegetation and seed dispersal (Príncipe and beyond, 1PhD, 1MS).	29
b. Ebony and Ivory: Essential dispersal of tree seeds by forest Elephants (Cameroon, Gabon, Cabinda).	30
c. Ecosystem engineers: Driver ants and their dependent fauna (Mainland EG, Bioko, Gabon; 2 PhDs: 1 birds, 1 ants).	30
d. Understanding the consequences of “defaunation” (loss of large mammals) in tropical rainforest (Mainland EG, Cabinda, Cameroon, Gabon; 2PhDs: 1 birds; 1 plants).	31
e. Revealing the mechanisms driving coexistence of resident and wintering migrant songbirds (Mainland EG, Cameroon,1PhD, 1MS).	32
IV. Understand evolutionary processes in the Gulf of Guinea	33

a.	Understand the evolutionary relationships among Gulf of Guinea Plants (Príncipe, São Tomé, Bioko, Mt. Cameroon; 1 PhD, 1 MS).	33
b.	Understanding evolutionary relationships among giant tree frogs (Príncipe, Cameroon, Mainland EG, Gabon; 1 PhD project, 1 MS project).	34
c.	Understanding evolutionary relationships among bats (all regions; 1 PhD & 1 MS).	34
d.	Evolution of bird diets on islands under climatic change (São Tomé, Príncipe, Mainland EG, 1 PhD)	35
e.	Ecology and evolution of avian malaria as a proxy for human malaria (Gabon, Mainland EG, Bioko, Annobon, Mt. Cameroon; 1 PhD)	36
f.	So close, yet so far: Molecular windows to the past in land-bridge island birds (Bioko, Príncipe, São Tomé, Mainland EG, Cameroon; 1 PhD).	37
g.	Community assembly and macroevolutionary impact of anthropogenic extinction on the vertebrates of the oceanic islands of the Gulf of Guinea (1 PhD).	37
Pillar #4.	Conservation biology of flagship, threatened and endemic species	39
I.	Understand hotspots for elephants, chimpanzee and gorillas (Cabinda, Gabon, Mainland EG)	39
a.	Camera traps, acoustic monitoring and DNA metabarcoding (Mainland EG, Cabinda, Gabon; 2 PhDs).	39
II.	Understand the distribution and population sizes of rare and endangered Island Endemics	40
a.	Monitoring and protecting Bioko Drill and Pennant's Red Colobus, including monitoring of bushmeat markets (Bioko, Mainland EG; 1 PhD).	40
III.	Understand and protect charismatic species	41
a.	Preserving Irreplaceable populations: population viability of western lowland gorillas (Mainland EG, Gabon, Cabinda; 2 PhDs).	41
b.	Forest elephants as stewards of carbon sequestration (Mainland EG, Cabinda, Gabon; 1 PhD).	42
c.	Picathartes (Bioko, Gabon, Mainland EG, Mt. Cameroon; 1 PhD).	43
d.	Grey parrots (Everywhere but Annobon; 1 PhD).	44
e.	In the Footsteps of Giants: A comparative analysis of forest elephant ecology across nations (Mainland EG, Gabon, Cabinda; 1 PhD, 1 MS).	45
IV.	Understanding and protecting threatened species with important ecological roles	45
a.	Aquatic ambassadors: Understanding freshwater turtle populations and their role in aquatic ecosystems across countries (all regions, 1 PhD, 2 MS).	45
Pillar #5.	Ecosystem services, invasive species and socioecology: Interactions of people and nature	47
I.	Understand the services that nature provides in agricultural systems	47

a.	Ecosystem services in cocoa and coffee: Using DNA metabarcoding to uncover pests and pollinators (Príncipe, São Tomé, Cameroon; 2 PhDs: 1 pests, 1 pollinators).	47
II.	Invasive species: Understanding their effect on Gulf of Guinea Ecosystems.	47
a.	How invasive rats affect agriculture (Príncipe, São Tomé, 1PhD).	48
b.	Evolutionary pathways and ecological impacts of an invasive, virus-transmitting Asian Tiger mosquito (<i>Aedes albopictus</i> ; São Tomé, 1PhD).	48
c.	Species interactions under biological invasion: an island model (Príncipe and São Tomé; 1 PhD).	49
II.	Understand which insectivores consume disease-carrying insects	50
a.	Insectivorous birds, bats and herps as predators of human disease vectors: Understanding an overlooked ecosystem service (Príncipe, Cameroon; 1PhD).	50
III.	Understand nature's value for humans	51
a.	Value generated assets (Bioko, Mainland EG; 1PhD, 2MS).	51
b.	Beekeeping as an alternative source of income that supports ecosystem function (Príncipe, 1 Ph.D, 1 MS)	51
c.	Buzzing for change: Promoting beekeeping and "buzzboxes" to reduce human-elephant conflict (Mainland EG, Cabinda, Gabon; 1PhD, 1MS).	52
Pillar #6.	Education, outreach, capacity building and local knowledge	54
I.	Contribute to the long-term sustainability of biological conservation through education and incorporation of local knowledge.	54
a.	Run educational experiences for schoolchildren and older students (Bioko, Príncipe, São Tomé; Mainland EG) -	54
b.	Develop environmental education programs for local communities (Bioko, Príncipe, São Tomé and Mainland EG)	54
c.	Contribute to training local and international researchers and graduate students in master's and doctoral programs	54
d.	Understand and incorporate local natural history and conservation practices (all regions; 1PhD, 2 MS).	55
II.	Develop educational capacity to support ecotourism	55
a.	Provide education in the ecotourism field (Bioko, Mainland EG, São Tomé, Príncipe).	55
III.	Support publications on the biodiversity of the Gulf of Guinea.	56
a.	PUBLISH A GUIDE TO THE BIRDS OF THE OCEANIC ISLANDS OF THE GULF OF GUINEA	56
b.	Support student and researcher publications.	56

IV. Outreach: Communicate and disseminate the work of the Gulf of Guinea Research Program to local and international audiences	56
a. Organize workshops for stakeholders in the region	56
b. Communication strategy and goals	57
c. Dissemination strategy and goals.	57
V. Fundraise for additional support for our programs	58
5. Timeline	59
6. Budget	60
7. Main Partner Organizations	60
8. Affiliate Organizations	60

Note: Version 1.0 of this proposal is the first version of this draft - it undoubtedly contains errors and the information is not comprehensive. This proposal is intended as a dynamic document that evolves over time.

Main Author: Luke L. Powell, CIBIO/Biopolis and the NGO Biodiversity Initiative

Other important Contributors: Martim Melo, Patricia Guedes, both of CIBIO/Biopolis. Many other contributing organizations are listed at the end under Affiliate Organizations.

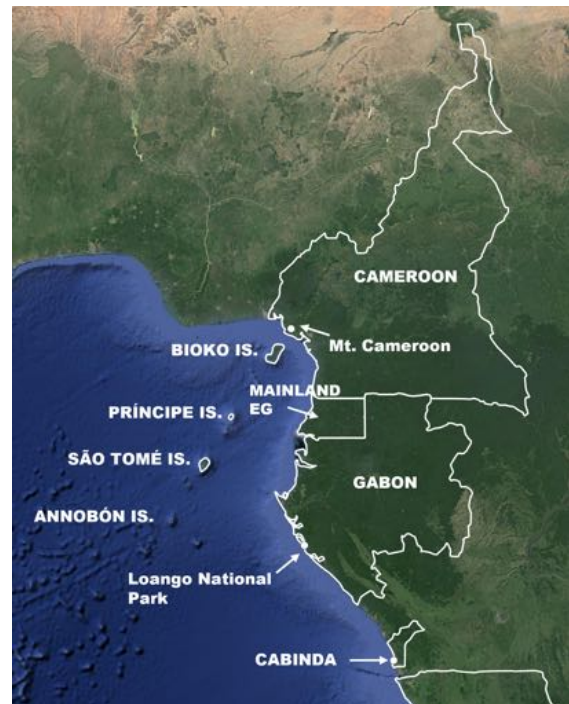
1. Mission

Our mission is to develop a research infrastructure and the necessary human resources to support biodiversity conservation and sustainable development in the Gulf of Guinea region, West Africa. This will be achieved through the creation of state-of-the-art research centers and the implementation of several dozen broad range marine, terrestrial and freshwater biodiversity and conservation research projects across the region. These projects and conservations actions will be supported by staff and by about 50 graduate students. The results of this research will directly contribute to conservation policy, strengthening the green economy including ecotourism, and supporting the creation and maintenance of protected areas.

Geographic Scope

The Gulf of Guinea Islands system and surrounding rainforests are a crucial region in West Africa that supports high levels of biodiversity and plays a critical role in global climate regulation. The region spans over 2,000 kilometers of coastline and includes several small islands, including Bioko, São Tomé, Príncipe, and Annobon. Mount Cameroon and the surrounding region are the natural extension (a “sky island”) that continues the Gulf of Guinea Island chain. These islands are characterized by lush forests, stunning coastlines, and a unique mix of plant and animal species, many of which are endemic to the region. The surrounding rainforests are part of the Congo Basin, which is the second-largest tropical forest in the world after the Amazon, and is known for its high levels of biodiversity and carbon storage capacity.

- Gulf of Guinea Island Systems
 - Mt. Cameroon & region
 - Bioko, Equatorial Guinea (EG)
 - Príncipe Island
 - São Tomé Island
 - Annobón, EG
- Loango National Park, Gabon
- Mainland EG
- Cabinda, Angola



2. Executive Summary

The goal of this effort is to undertake a vast research and conservation program in the Gulf of Guinea that will properly vault the region to the cutting edge of biodiversity research. The Gulf of Guinea is one of the most biodiverse regions in the world and is rich with endemism. However, the human population of the region is projected to quadruple by the year 2100, which coupled with climate change, habitat loss, and overexploitation, will continue to build enormous pressure on natural resources. The problem is, since the Gulf of Guinea's flora and fauna are so poorly studied, we lack the tools to properly conserve or manage biological resources—we don't understand the biodiversity well enough to effectively protect it. We will directly address this challenge through our five-year research and conservation program. The plan will bring together some of the world's leading experts in ecology, evolution and conservation biology, pairing them with about 50 graduate students and arming those researchers with the latest in infrastructure and facilities. After several years, we envision taking this region—one of the poorest studied in the world—and elevating it to among the best studied. Armed with this research, we will be in a strong position to protect the critical biological resources of the region—ecosystem services, flagship, endangered and endemic species—and to do so efficiently using the latest technology and data. Supernova Technologies and CIBIO/Biopolis will be at the forefront of this paradigm shift.

Here we have written a detailed proposal designed to tackle some of the most pressing needs for research and conservation in the region. The proposal is designed to guide the dozens of incoming graduate students and researchers to select the highest impact research projects—we have described those in detail throughout. Projects will pair one or more graduate students with an expert in the field at CIBIO. With guidance from leaders in the field, state of the art facilities, and the expertise of CIBIO, Supernova Technologies, and collaborators, these projects will be poised to make critical impacts in our understanding of and conservation of Gulf of Guinea Ecosystems.

This proposal is organized into **six Pillars**, with each pillar representing a series of projects and actions that together, coalesce the framework for our vision. In this executive summary, we summarize some of the highlights of those pillars.

Pillar #1: Biodiversity knowledge: Surveys, DNA barcoding, and database creation

This first pillar will build the critical physical, genetic and data-based frameworks that biologists need for their research. First, the program will create a world-class Biodiversity Center in Príncipe, a research station in Príncipe, and a research station in the tropical rainforests of Mayombe National Forest in Cabinda, Angola. The program will catalogue the ecological and genetic biodiversity of marine and terrestrial ecosystems in

the Gulf of Guinea through the development of a marine and terrestrial biodiversity database, as well as a marine and terrestrial DNA barcode library. Further, we will design and roll out an enormous number of biodiversity surveys throughout the Gulf of Guinea. Included in our surveys are (among other things): seabirds, fish, manatees, sea turtles, seagrass meadows, marine forests, elephants, chimpanzees, gorillas, invasive plants, invertebrates, reptiles, amphibians, landbirds, bats and freshwater turtles. These surveys will provide baseline levels of the state of populations and ecosystems, while synergistically providing data for dozens of graduate student research projects.

Pillar #2: Marine resources: sustainable use and conservation

Located in the middle of the Gulf of Guinea, the Biodiversity Center and research center situated on Principe Island are ideal locations to form a marine research program. Here we focus on the expertise of marine researchers at CIBIO, but we also leave room for the marine research program to grow with the input of donors. In addition to the vast marine survey work we propose in Pillar 1, we will focus here on the climate and on the movement of animals and resources between critical marine areas. Specifically, we will use satellite tracking technology to understand the movement of two charismatic megafauna (whale shark and tiger shark), to understand how they move about the Gulf of Guinea with respect to climate-induced deoxygenated zones. We will also study clustered marine resources that provide critical ecosystem function, referred to as marine forests; these include seagrass meadows, macroalgal forests and sessile invertebrate gardens. Such habitats are essential conservation hotspots as they include nurseries and reproduction sites for many animals, shelter for early life-stage organisms, major feeding sites for sea turtles, coastal protection, environmental quality improvement, and carbon sequestration. The maintenance of large, connected populations of marine flora and fauna contributes to conservation of biodiversity of such keystone marine habitats; here we propose to deeply understand pelagic sharks and marine forests to gain a deeper understanding of the Gulf of Guinea's marine ecosystems.

Pillar #3: Forest ecology and dynamics

This pillar focuses on ecology and conservation of the critical biological resources contained within the region's dominant terrestrial habitat: tropical rainforest. First, we will build towards the Global 30x30 initiative (protecting 30% of marine and land area by 2030) by creating a new 100,000ha national park in Equatorial Guinea. We will inform 30x30 by leveraging our vast survey data to help design marine and terrestrial reserves that will maximize the conservation of the Gulf of Guinea's biodiversity. We will build frameworks for long-term monitoring of climate, carbon, and forest birds (ideal ecosystem sentinels). Further, several projects are designed to understand the critical ecosystem functioning of Gulf of Guinea forests; among them are studies of seed dispersal and ecosystem engineers such as driver ants and forest elephants. Inspired by the model island system of Darwin's finches in the Galapagos, we will dive into the evolutionary relationships in the Gulf of Guinea's "natural laboratory"; these include projects on plants, frogs, bats, and birds. We also

propose cutting-edge research that will leverage recent molecular sequences to estimate how long it would take to recover the Gulf of Guinea's diversity of all the currently threatened and endangered species were to go extinct.

Pillar #4: Conservation biology of flagship, threatened and endemic species

This exciting pillar focuses on the fauna often featured in National Geographic nature documentaries: the charismatic megafauna and the endangered island fauna that inspire both public awe and on-the-ground conservation. This pillar starts with widespread deployment of camera traps, acoustic monitors and eDNA monitoring to understand the community of vertebrates in forests across the Gulf of Guinea. The combination of these three methods is novel and cutting edge and will lead to finely tuned maps of distribution and abundance of elephants, chimps, gorillas and other important fauna. On Bioko Island, we will work with two endangered taxa: Bioko Drill and Pennant's Red Colobus, to understand their distributions and how the bushmeat trade drives population declines. We'll study endangered forest elephants, both to understand their distributions and to understand how they sequester carbon. Finally, we'll work with two highly intelligent and breathtakingly beautiful birds with great cultural significance whose populations are of grave conservation concern: Grey-necked Rockfowl (*Picathartes*) and the Africa Grey Parrot.

Pillar #5: Ecosystem Services, invasive species and socioecology: Interactions of people and nature.

In this pillar we focus on the study of the interactions between human societies and the biodiversity the Gulf of Guinea, and how these interactions affect agriculture and human health through ecosystem services like pollination and pest control. Since the Gulf of Guinea islands are particularly susceptible to exotic, invasive animals and plants, we have several projects devoted to this issue, including: 1) how invasive rats affect agriculture, 2) how the disease-carrying Asian Tiger Mosquito affects humans and the ecosystem and 3) using cutting edge DNA metabarcoding to understand how invasive plants, birds, and mammals have fundamentally shifted food webs. We'll also quantify the value of biodiversity to humans in the region, including understanding savings provided by both pollinators and pest-eating birds and bats in cacao and coffee. We'll specifically quantify the value of nature to humans as part of an innovative framework known as "value generated assets". Finally, we'll explore the value of beekeeping and "Buzzboxes" (technology designed to detract elephants), both to keep elephants from raiding crops (on the mainland) and to provide alternative livelihoods for locals (on the islands).

Pillar #6: Education, outreach and capacity building

Biological research *per se* is essential in this age of anthropogenic disturbance of the natural world; but to maintain momentum generated by the work, both locals and students at CIBIO must be inspired through

education, outreach and capacity building. In this final pillar, we will contribute to long-term sustainability—the legacy—of the massive efforts described in this proposal. This pillar reinforces a two-way transfer of knowledge: to weave our biodiversity work into the fabric of Gulf of Guinea society whilst simultaneously weaving local biodiversity and conservation knowledge into the practices of international biologists working in the region. We will work with students of all levels, starting with educational experiences for schoolchildren, continuing with environmental education programs for local communities, publishing a book on the birds of the Gulf of Guinea, and finally providing training for local and international researchers and graduate students in master's and doctoral programs. We will fund research publications by students and researchers and will employ a professional fundraiser to procure funding beyond the years outlined in this proposal—thus ensuring financial sustainability. The project also intends to develop and implement ecotourism workshops that will build capacity for young Africans, providing them with the knowledge and skills necessary to develop and manage ecotourism ventures—additional efforts at financial sustainability. The workshops will focus on ecologically sustainable practices, emphasizing the importance of conservation and environmental stewardship in the development of tourism enterprises.

Overall, we will conduct a massive, ground-breaking research and conservation effort in the Gulf of Guinea to understand and address the threats posed by climate change, habitat loss, and overexploitation and to elevate the region's research and conservation into the 21st century and beyond. Overall, this proposal will help ensure the long-term sustainability of the Gulf of Guinea's biodiversity and the communities on which it relies.

3. Motivation

There are four key motivations for this proposed project:

First, there is the unique biodiversity of the Gulf of Guinea. The region is known for its rich biodiversity, with a variety of ecosystems including rainforests, mangroves, and coral reefs. These ecosystems provide important habitat for a wide variety of species, many endemic and/or rare, and also provide valuable ecosystem services, such as carbon sequestration and shoreline protection. The forests of the region host elephants, chimpanzees and gorillas, and the coastal ecosystems are home to West African manatees, sea turtles, and many species of sharks and rays. The oceanic islands hold some of the world's highest levels of endemism across several groups. Many areas are still relatively well preserved and have potentially enormous value for conservation and for the development of nature-related eco-enterprises such as ecotourism.

Our second motivation is the gaps in knowledge of biodiversity in the region. The biodiversity of the Gulf of Guinea has only been partially studied and there are still many gaps in our understanding of the region's ecosystems and species. Many areas of the region remain under-sampled or understudied and new species of vertebrates are still being discovered, such as the Príncipe Scops owl discovered by CIBIO researcher Martim Melo and colleagues in 2016. Filling these knowledge gaps will be essential for developing effective conservation policies, identifying areas for protection, improving conservation management and highlighting the enormous biological value of the region.

Thirdly, we are motivated by the threats to Biodiversity in the Gulf of Guinea. The rapid expansion of extractive industries, rapid human growth, unsustainable land use practices, and other anthropogenic activities pose significant threats to the ecological and cultural integrity of the region. It is critical to understand the importance of the Gulf of Guinea Islands and surrounding rainforests and work towards ensuring their sustainable management and conservation.

Our final motivation is the cultural and economic value of biodiversity. The Gulf of Guinea Islands and surrounding rainforests also hold significant cultural and economic value. The region is home to many indigenous communities that rely on the forests for their livelihoods and traditional practices, such as hunting, fishing, and gathering. Additionally, the region is rich in natural resources such as oil, minerals, and timber, making it a hub for economic activity in the region.

4. Workplan

There are six pillars of our workplan:

Pillar #1: Biodiversity knowledge: Surveys, DNA barcoding, and database creation

Pillar #2: Marine resources: sustainable use and conservation

Pillar #3: Forest ecology and dynamics

Pillar #4: Conservation biology of flagship, threatened and endemic species

Pillar #5: Socioecology, invasive species and ecosystem services: interactions of people and nature

Pillar #6: Education, outreach and capacity building

How this proposal is organized:

Within each **Pillar**, we describe *specific objectives* (blue; roman numerals).

Each *objective* contains individual **projects or specific actions** (red; lowercase letters) that are designed to meet those objectives.

For example:

Pillar #1

I. Objective I...

a. Project/action (location)...

II. Objective II...

a. Project/action (location)...

b. Project/action (location)... Etc...

Fast tracked projects:

We include several **FASTTRACKED PROJECTS**—these are designed to start immediately and produce results quickly; they are highlighted using **CAPITAL LETTERS**. Specifically, these **FASTTRACKED PROJECTS** include:

- **BUILDING A WORD-CLASS BIODIVERSITY HEADQUARTERS AND RESEARCH STATION ON PRÍNCIPE** (Pillar #1),
- **DESIGN AND ROLL OUT A MARINE & TERRESTRIAL BIODIVERSITY DATABASE FOR THE GULF OF GUINEA** (Pillar #1),
- **CREATING A NEW 100,000HA NATIONAL PARK IN EQUATORIAL GUINEA** (Pillar #1),
- **PUBLISHING A LONG-AWAITED BOOK ON THE BIRDS OF THE GULF OF GUINEA** (Pillar #6).

Pillar #1. Biodiversity knowledge: Surveys, DNA barcoding and database creation

The biodiversity of Africa is poorly known to science relative to other continents, and this is particularly evident in Sub-Saharan Africa, and in non-English speaking countries. Due to this and its sheer volume of biodiversity, Gulf of Guinea flora and fauna are particularly poorly known. To bridge this gap, biologists need a framework for their work. They need basic infrastructure (vehicles, research centers, labs), which is severely lacking, they need a baseline knowledge of the population's status and both the genetic and ecological diversity of the organisms, and they need a centralized repository to store information. In this pillar, we seek to bridge these critical gaps in the Gulf of Guinea by building the critical research framework—physical, virtual and genetic—upon which to build cutting edge research designed to mitigate the region's biodiversity crisis in the 21st century and beyond.

I. Develop a framework for collaborative biodiversity research and conservation in the form of the “Gulf of Guinea Research Program”. This objective provides the framework—both physically and academically—for research in the region. Here we seek to build the program's headquarters in Príncipe, together with the first two field research stations: one on Príncipe (upgrading the station at Belo Monte) and another in Cabinda (by converting a jungle ecolodge).

- a. **BUILD A WORLD-CLASS BIODIVERSITY CENTER (Príncipe).** In this FAST-TRACKED project, the headquarters for the Gulf of Guinea Research Program (GGRP) will be built outside of Supernova Technologies' property, to facilitate cooperation with third-party conservation agents and stakeholders. Porto Real would be a suitable location as it already hosts several institutions working on biodiversity related themes (Natural Park Management, Forestry Department, BirdLife International), allowing to create close synergies between GGRP and the local actors. The headquarters will act as a magnet for high quality research, education and outreach projects on the biodiversity of the region. They will include meeting and lecture rooms, interpretation centre/museum for the general public, biodiversity library and media center, accommodation, laboratories (specifics of which to be discussed beforehand among a wide range of potential users), and appropriate storage facilities (field equipment and samples).
- b. **BUILD A FIELD RESEARCH STATION IN PRÍNCIPE.** In parallel with the headquarters, the FAST-TRACKED GGRP base on Príncipe Island will include a field research station located in Supernova Technologies' Roça de Belo Monte. This station will be put to use almost immediately, by making use of the infra-structures already in place – which would only need minimal upgrading and eventually extension, together with some refurbishment. This station would be particularly suited for supporting marine work (and any upgrading should take this into account), whereas the research facilities in the headquarters could host the terrestrial

projects, such as those aimed at monitoring the impact and addressing the consequences of deforestation, forest degradation and climate change in the Gulf of Guinea.

- c. **Build a research station in the tropical rainforests of Mayombe National Forest (Cabinda).** Cabinda is an enclave of Angola that is isolated to the north of the rest of the country. As such, the ecosystem is distinct from the rest of Angola as it is tropical lowland rainforest—part of the greater Congo rainforest ecosystem. CIBIO researcher Pedro Vaz Pinto has made several recent pilot trips to the region (most recently in late March 2023), having connected with local stakeholders and government operators to develop a local network in which we can trust. Along with local stakeholders, he has determined that the Mayombe Lodge – a former ecotourism lodge located in the Mayombe National Forest—is an ideal location for a research station. Even for Cabinda – the lodge is in a remote location. It is nestled in the vast jungles of the Belize municipality, and the area contains the full complement of Central African fauna. Endangered megafauna such as forest elephants, gorillas and chimpanzees are common in the region, making fertile grounds for biological research on the fauna of the area. Because Cabinda, and specifically the Belize area, is so poorly known to science, the potential for discovery is enormous. The lodge will require rehabilitation, a research lab will need to be built and stable electricity and communications will need to be installed to make the research station functional. We will purchase a vehicle to support transportation within Cabinda. We will maintain the lodge’s ability to support ecotourists such that a local income can be generated beyond what biologists provide and to provide economic sustainability.

II. Catalogue the ecological and genetic biodiversity of marine and terrestrial ecosystems in the Gulf of Guinea.

The Gulf of Guinea’s biodiversity is rich, but poorly known and organized. Here we seek to organize the biodiversity data from the region into a database, and to build on that database by developing the DNA barcode library for the region.

- a. **DESIGN AND ROLL OUT A MARINE & TERRESTRIAL BIODIVERSITY DATABASE FOR THE GULF OF GUINEA.** To build a framework for the vast biological data that we are proposing to gather in this proposal, it will be critical to build a database to keep, store and organize the data and to make the data available and easily accessed. The organization of the database will depend on the taxa at hand and what databases are already available, and must be adaptive based on what information and databases already exist. For example, for bird observations, the existing, freely available website already exists (eBird); we can simply build our observations into this pre-existing platform. However, for plants, no regional database exists, so we will use a similar platform to flora-on.pt in collaboration with the Missouri Botanical Garden, which for years has been building a curated collection of the Gulf of Guinea flora. For the flora we would combine the slick interface and accessibility of flora-on.pt with the botanical expertise of the Missouri Botanical Garden in the Gulf of Guinea. We

will build in data from existing databases (e.g. Global Biodiversity Information Facility, GBIF) and collections into our centralized database efforts.

- b. **Develop a Marine & terrestrial DNA barcode library for the Gulf of Guinea.** Here our grand vision is to DNA barcode all life in the Gulf of Guinea. With the power of a comprehensive DNA barcode library, we could, for example, reconstruct the entire ecological network of Príncipe, or we could instantly understand which birds eat pests of cocoa, or which bee species pollinated a coffee plant. Embarking on this journey would create myriad advantages for research and for understanding biodiversity in the region. DNA barcoding is among the premiere, cutting edge tools for identifying organisms and CIBIO is at the forefront of this technological advance. Within a single sample of water from a stream, for example, hundreds of species that use the ecosystem can be identified simultaneously; however, without a decent “barcode library”—a database of known species DNA barcodes—biologists are not able to identify the DNA they collect from the environment. Biodiversity of the Gulf of Guinea region is particularly poorly represented in DNA barcode databases—hence the need to fill this gap. To do this, we will systematically search available DNA barcode databases (Genbank, Barcode of Life Database [BOLD]) and will determine the taxa that most urgently need DNA barcodes in the Gulf of Guinea. We will then cater sampling regimes towards capturing/collecting (see biodiversity surveys below) and identifying these taxa. We will systematically work to include charismatic species, species of economic importance (e.g. cocoa pests and pollinators) and species of conservation concern. DNA barcode sequences will be deposited into publicly accessible DNA barcode databases such as Genbank and Barcode of Life Library (BOLD), so that PhD students and researchers can freely access the information and easily identify the biodiversity of the region. We will coordinate this barcoding work with the biodiversity database(s) we create (see previous project).

III. Design and perform biodiversity surveys throughout the Gulf of Guinea. Many biodiversity survey efforts have been taking place by stakeholders in the region; thus we will make sure to integrate our work into ongoing efforts. Surveys will take particular emphasis on protected areas and future protected areas to facilitate conservation planning and protected area design (see [Pillar #3](#)).

Marine

- a. **Seabirds.** The Gulf of Guinea has the most important seabird colonies of the Eastern tropical Atlantic. Most are located in the Tinhosas islets offshore Príncipe, some on islets close to São Tomé and little is known of the situation in Annobón. Furthermore, a potential new species of storm-petrel is present in the Gulf of Guinea waters and it is known to breed with the forests

of São Tomé. Seabirds populations are threatened by fisheries bycatch and by the direct collection of chicks in the case of the Brown Bobbie. Fundação Príncipe has been monitoring the colonies at Tinhosas. A seabird conservation program should be established with the aims of i) assess the situation of the seabird colonies of São Tomé and Annobón & determine if a monitoring protocol should be implemented; ii) support Fundação Príncipe in its monitoring work in Tinhosas; iii) lead a study on seabird bycatch on the Gulf of Guinea waters.

- b. West African Manatee (Gulf of Guinea, 1PhD).** Here we aim to improve our understanding of these aquatic mammals and identify ways to protect them. Manatees are large, slow-moving mammals that live in coastal areas, rivers, and estuaries. They are threatened by habitat loss, hunting, and accidental entanglement in fishing gear. This project will use a combination of field surveys, interviews with local communities, and genetic analysis of samples collected from the animals. By studying the manatees' movements, behavior, and habitat use, the project will identify important areas for their conservation. The project will also work with local communities to raise awareness about the importance of manatee conservation and identify ways to reduce the impact of human activities on these animals. Ultimately, the goal of the project is to develop a conservation strategy that protects manatees while also meeting the needs of local communities.
- c. Sea turtles (Bioko, Annobon).** Green sea turtles (among others) play a critical role in maintaining the biodiversity and health of marine ecosystems. They maintain seagrasses meadows healthy by consuming seagrasses, preventing them from overgrowing and smothering other organisms. In addition, green sea turtles are also important prey for predators such as sharks, and their eggs and hatchlings are targeted by a range of terrestrial predators. Through field surveys, we will collect information that will allow us to understand the connectivity between populations of green sea turtles and their nesting and foraging grounds. This survey work will be synergistic with the “marine forests” project in [Pillar #2](#).
- d. Seagrass meadows.** This habitat is vital for ocean health as it provides food and shelter to a multitude of marine fauna (e.g. manatees, sea turtles, fishes, invertebrates, etc.), as well as acts as important nursery areas for fish, mollusks, crustaceans and other invertebrates. Additionally, the root system of seagrass meadows stabilizes the sea bottom and filters the water, improving its quality. Nonetheless, little is known about this habitat in the Gulf of Guinea. This project will change that (see details in [Pillar #2](#)).
- e. Marine forests of macroalgae.** Macroalgae forests provide several important ecosystems services, such as carbon sequestration, nutrient cycling and shoreline protection. They also act as shelter for several different marine taxa (e.g. fish, invertebrates, marine mammals, seaturtles) and are a valuable source of food for local communities. We will perform field

surveys which, combined with laboratory techniques, will generate important data for the management of this habitat. More details can be found in [Pillar #2](#).

Terrestrial

- d. **Elephants, chimps, gorillas & vulnerable primates (Cabinda, Gabon, Mainland EG, Bioko).** We will perform surveys for these charismatic, endangered species using integration of 3 different methods of cutting-edge technology: iDNA (e.g. DNA from carrion flies) along with both acoustic monitoring and camera traps armed with artificial intelligence (AI)-based identification of animals from photos and sound. Details of this project are provided in [Pillar #4](#).
- e. **Invasive plants (Príncipe, São Tomé).** Oceanic islands such as São Tomé and Príncipe are particularly vulnerable to the introduction of exotic invasive plants, because native ecosystems have been isolated for so many millennia that they lack natural defenses to balance the spread of invading flora. Here we will perform an inventory of the exotic plants in STP, with a particular emphasis on mapping the areas of expansion and replacement of native vegetation. We will also explore the feasibility of invasive species control and restoration. This work will be synergistic with the invasive species projects described in [Pillar #5](#); findings from those projects will help efficiently guide management action.
- f. **Invertebrates (Príncipe, São Tomé, 1 PhD, 1MS).** This project will describe the diversity of Gulf of Guinea Invertebrates. The invertebrates of the Gulf of Guinea are still poorly known, but harbor already a high number of endemic species. Groups as arachnids, beetles, butterflies and mollusks have been the focus of some attention, but they still hold many undescribed species and lack information regarding their conservation status and role in the ecosystems. Most orders, remain very poorly studied and need urgent field surveys and taxonomical work to document species distribution within islands, especially to identify the taxa that are unique from this region. Additionally, a smaller group of species are particularly important—among other things—as agricultural pests and pollinators as São Tomé, Príncipe rely heavily on agriculture (e.g. cocoa, coffee, etc.) to support their economies. Here we will continue the arthropod collecting work that we have started in São Tomé and Príncipe, using several arthropod collection techniques (sweep netting, malaise traps, sticky traps, pitfall, pan-traps, etc.) to collect representative samples of the islands' arthropod communities. We will work with taxonomists to identify and describe the organisms and will generate DNA barcodes for deposition in BOLD (see previous section on DNA barcoding). This will serve as a basis for further studies on the ecology of many species and to unveil the relationships between species using DNA metabarcoding methodologies. We will sample across the several ecosystems, but will particularly target agricultural systems, and will work with farmers and

local organizations to collect and identify pests and pollinators of economically important crops such as cocoa and coffee.

- g. Reptiles and amphibians (Maiombe National Park, Cabinda; 1 PhD, 1MS).** Angola is one of the most important herpetofaunal hotspots in Central/ Southern Africa, mostly due to the rapid growth of herpetological surveys within its territory over the last couple decades. Notwithstanding, some Angolan regions remain among the least explored areas in Africa, partly resulting from geographical isolation and ensuing political instability. This is the case of Maiombe National Park, in Cabinda. This national park holds important patches of tropical rainforest within the Gulf of Guinea broader region, corresponding to the southernmost reaches of western Atlantic forests that stretch from Gabon to Cabinda along a continuous chain of hills and mountains. The region has postulated as one of the most important African forest refuges in the Pleistocene, and a source of speciation and endemism, and yet little has been documented for Cabinda. The fact that most of the original Maiombe forests were extirpated in the neighboring DRC much increases the importance of the remnants still present in Maiombe NP. Currently, mining industry and human encroachment, are growing rapidly in Cabinda, threatening this unique and incredibly important African biodiversity hotspot. Consequently, the characterization of the herpetofaunal diversity (amphibians and reptiles) in Maiombe NP, must be a priority to shed light on its extant diversity and identify potential conservation threats for these highly threaten populations. This project, by compiling existing data and complementing it with dedicated surveys, may provide a better understanding of the extant herpetofaunal diversity in Maiombe NP, highlighting the important of centers of endemism in the region, to set the basis for future conservation plans in the broader region.
- h. Landbirds (Príncipe, São Tomé, Bioko, Mainland EG).** Small birds are ideal honest signals of rainforest health – sentinels – due to their sensitivity to disturbance and because unlike large mammals – are generally not hunted. Surveys for landbirds are detailed below in [Pillar #3](#).
- i. Bats (All regions).** Bats are critical to monitor as they both provide enormous benefits to humanity by consuming agricultural pests (e.g., pests of cocoa and coffee) as well as serve as reservoirs for disease. Bat research will be focused on taxa with poorly understood taxonomies (e.g., *Hipposideros* sp.) with the goal of discovering cryptic species, disentangling unresolved taxonomies, and understanding their rolls in pest suppression and in disease transmission. Details are provided below in [Pillar #3](#).
- j. Freshwater turtles (Mainland EG, Gabon and Cabinda).** Freshwater turtles play an important ecological role in the environment by transferring energy from aquatic to terrestrial environments, by scavenging decaying organisms, and by digging river and lake bottoms, which engineers the habitat; however, little is known about their biology and ecology in the



Gulf of Guinea. These turtles are also important in local cultural practices, as traditional medicine, a food source and as icons in popular culture. Despite their importance, more than half of the world's turtles are in need of conservation actions. Details on turtle surveys are provided below in [Pillar #4](#).

Pillar #2. Marine resources: sustainable use and conservation

The Gulf of Guinea is a region of high marine biodiversity and ecological significance. Despite its importance, the Gulf of Guinea faces many threats including overfishing, pollution, and climate change. This pillar aims to assess the current state of marine biodiversity in the Gulf of Guinea and uncover the ecological dynamics that will help us conserve and sustainably use the region's valuable marine resources. In this pillar, we will leverage much of the vast marine survey data that we compile in [Pillar #1](#).

1. Understand the spatial movements and distribution of marine megafauna using satellite technology.

- a. **Behavior and space-use of large pelagic sharks under threat from climate change (1PhD).** Climate-linked ocean warming and deoxygenation is expected to impact the movement and abundance of many pelagic species at a global scale. Ocean deoxygenation is one of the most important changes affecting marine ecosystems and has led to the geographic and vertical expansion of oxygen minimum zones (OMZs). This expansion is accompanied by shoaling of the upper boundaries, which acts to compress the vertical habitat extent of pelagic sharks to oxygenated surface waters (leading to higher fishing mortality or interactions with vessels). Permanent OMZs are present in the eastern tropical Atlantic (ETA), including in the northern portion of the Gulf of Guinea and off Angola. Crucially, how some shark species respond to climate-linked warming and deoxygenation remains unknown; these include whale and tiger sharks. In this context a major concern is how climate change will interact with increasing fishing/shipping levels to impact future conservation of these shark species in the general region of the Gulf of Guinea. Given these concerns, we will study the behavior and space use of Tiger Sharks and Whale Sharks using satellite tracking technology. In particular, we seek to understand how they move and migrate in the Gulf of Guinea with respect to temperature changes and the distribution of OMZs.



Whale shark (top) and tiger shark (second from bottom) shown with human diver.

II. Unveiling the conservation status of important marine ecosystems.

- a. **Long-term monitoring of coastal temperature in the Atlantic.** The Gulf of Guinea is characterized by a diverse and productive coastal ecosystem that supports important fisheries and other economic activities. However, the region is also facing significant environmental challenges, including rising sea temperatures due to climate change. This can cause shifts in species distributions, alter the timing of reproductive events, and increase the frequency and severity of harmful algal blooms. These changes can have negative impacts on the productivity of fisheries and other coastal industries, as well as the overall health of the marine ecosystem. Monitoring coastal temperatures will provide critical data for understanding these impacts and developing appropriate management strategies to mitigate them. The objectives of this project are to 1) Build a new, openly available, dataset of high resolution coastal temperatures; 2) Understand how environmental heterogeneity varies at global scales and how it determines biodiversity pattern; 3) Understand how upwelling areas buffer climate change, enhancing coastal biodiversity; and 4) Validating satellite-derived temperatures with in-situ data. We will achieve this by deploying several cutting-edge temperature loggers the intertidal zone in each sampling site. This project will be synergistic with the aforementioned pelagic shark project.
- b. **Marine forests in the Gulf of Guinea: diversity and inter-forest connectivity** (2 PhDs). Inter-population connectivity is an important process in conservation, supporting larger population sizes globally, thus reducing the high risks of genetic and demographic loss of small, isolated populations. In the marine environment however, the corridors and patterns of connectivity among populations are poorly understood. This is particularly the case for species that migrate passively, transported either by ocean currents or by biotic vectors such as migratory animals that carry propagules of marine species. For instance, this passive migration seems to be the leading hypothesis for green turtles transporting seagrass seeds along the coast of Atlantic Africa. However, along most of the Gulf of Guinea, there is a gap in information and understanding of the distribution, diversity and connectivity among populations that form the structural habitats known as marine forests, such as seagrass meadows, macroalgal forests and sessile invertebrate gardens. Such habitats are essential conservation hotspots for their multiple ecosystem functions, including sites for reproduction and nursery of many animal species like threatened elasmobranchs, shelter for early life-stages, major feeding sites for turtles, coastal protection, environmental quality improvement, and carbon sequestration. The maintenance of large, connected populations of marine flora and fauna contributes to conservation of biodiversity of such keystone marine habitats. This research line will focus on these objectives: 1) inferring patterns and vectors for inter-population connectivity in marine forests using oceanographic modelling and empirical genetic estimates based on population differentiation, linked to diet studies of potential biotic vectors, 2) comparing the functional composition and biodiversity of vegetated (seagrass, macroalgae,

coral and sponge gardens) versus unvegetated habitats to understand the ecological role of the habitat structure, 3) developing species distribution maps for marine keystone species and habitats, and predicting their vulnerability under realistic potential future habitat changes and range shifts, estimated as a function of thermal changes and sea level rise predictions under different greenhouse gas emissions scenarios. These approaches will apply a combination of field work with laboratory work and bioinformatics both for ecological modelling and genetic analyses. Methods will include field surveys of biodiversity using SCUBA-diving and underwater video tools, genotyping, eDNA, DNA barcoding, species distribution and oceanographic modelling, and local citizen-science work to integrate the local communities in the surveys to discover, map, sample and continue a long-term monitoring program for the target habitats. A second PhD project will assess the importance of marine forests and other marine resources in terms of priority for incorporation into marine protection areas (see [Pillar #3](#)).

- c. **Assessing the Ecological Significance of Seagrass Meadows in the Gulf of Guinea: Implications for Biodiversity Conservation** (1 PhD). Seagrass meadows are known for their role in supporting a diverse array of marine life, from small invertebrates to large mammals like manatees and sea turtles. However, despite their significance, seagrass meadows are often overlooked and face numerous threats. This project aims to dive into the importance of these unique ecosystems for biodiversity conservation by 1) performing surveys using remote sensing and GIS techniques to map the extent of seagrass meadows in the area alongside onsite validation through field surveys; 2) surveying the fauna associated with the seagrass meadows (e.g. fish, crustaceans and sea turtles); 3) develop predicative models for different climate change scenarios and discover how various levels of change can affect seagrass meadows and 4) investigate the effectiveness of marine protected areas in protecting seagrass meadows and their biodiversity. This project will produce valuable information for better suitable conservation policies and management practices of this invaluable habitats.

Pillar #3. Forest ecosystem ecology, evolution and dynamics

The rainforests of Central Africa and islands are among the least known in the world. However, they harbor impressive levels of endemism, biodiversity and carbon stocks—included is the second largest rainforest in the world: The Congo. Understanding the mechanisms that support a fully functioning ecosystem is critical to being able to meaningfully protect those ecosystems as climate change and forest degradation/deforestation reshape landscapes in the 21st century.

I. Contribute to the global initiative of 30% of marine and land area protected by 2030 (AKA 30x30). 30x30 is a global agreement signed on to by more than 100 nations at the COP15 meeting of the Convention of Biological Diversity in December 2022. To avoid ecological collapse, nations agreed to protect 30% of marine and terrestrial ecosystems by the year 2030. From the terrestrial perspective, São Tomé and Príncipe—at 29% protected—is a Global leader; however, to date the country has no marine protected areas. So, although all Gulf of Guinea countries have signed the agreement and some are at the forefront of 30x30, there is much work to be done. Given the rapid creation of protected areas that is projected to occur over the next seven years, we have a unique opportunity to contribute meaningfully through the strategic collection of biodiversity data and identify priority areas for protection, as well as more direct involvement in the creation of protected areas.

- a. **CREATE A NEW 100,000 NATIONAL PARK (Mainland EG).** This fast-tracked project has already had funding approved for 1.6 million dollars (~1.53 million euros) from Rainforest Trust. The funding will be used over the next five years to create a Parque Nacional de La Paz: a 100,000 ha park (about 5x the size of Amsterdam) adjacent to Equatorial Guinea's new capital city mainland. The Park will increase the percentage of Equatorial Guinea's terrestrial land surface from 19% to 23% protected. The grant includes the training and hiring of ecoguards, work with local communities to ensure the social sustainability of the park, and the construction of a management center along the northern edge of the park near the new capital city (see blue arrow in the map below). As part of this proposal, we would construct a small base camp near the town of Aconibe in order to access the southern portion of the park. The park's location supports the full complement of Central African megafauna including endangered forest elephants, chimpanzees and gorillas. Further, the park sits immediately adjacent to a newly established University: The Afro-American University of Central Africa (AAUCA), which presents innumerable opportunities for collaborative research and capacity building—and has the obvious advantage of providing housing working spaces for visiting researchers (this provision is specifically included in an MOU between AAUCA and CIBIO). The new park also sits adjacent to a five-star hotel: Hotel Djiblho, which presents many opportunities for Ecotourism in the area. Included throughout this proposal are various synergistic projects to study the biodiversity of the park and the surrounding region, including

elephants, chimps, gorillas, bats and birds. This project is in collaboration with Biodiversity Initiative and Bioko Biodiversity Protection Program.



Map of mainland Equatorial Guinea highlighting the new Parque Nacional la Paz (in pink) and existing protected areas (in yellow). The blue arrow indicates the new capital city of Equatorial Guinea, Cuidad de la Paz, which includes the new University, the Afro-American University of Central Africa (AAUCA) and the five-star Hotel Djibloho. The black arrow indicates the town of Aconibe, where we propose to build a small base for operations for the southern end of the park.

- b. **Designing landscapes to support fully functional ecosystems (Gabon, Cameroon, mainland EG, 1PhD).** Forests in Central Africa are being cut and fragmented at an alarming rate to support agricultural expansion and demand for timber—7.4 million hectares of net forest cover have been lost in the last two decades—about twice the size of the Netherlands. A serious problem associated with this is that the African rainforest ecosystem is so poorly studied that it remains unclear how to properly design protected areas – we don’t know how large the protected areas have to be to support critical wildlife populations and functioning ecosystems, nor do we know the maximum proportion protected areas that can support anthropogenic areas (e.g. agriculture, urban areas). For this project, we will study biodiversity on 40 landscapes (each ~49 km² or 7x7 km) with varying proportions of forest and anthropogenic areas. We will deploy camera traps, acoustic devices and will perform iDNA studies to compare among landscapes and determine which landscape configurations support rainforest ecosystems. This project will be integrated with biological surveys (Pillar #1) —also see Pillar #4 for methodological details on these techniques. Among other landscape-scale questions

we will address, we seek to determine the minimum forest-to-agriculture ratio necessary for the system to support critical ecological processes, i.e., a functioning ecosystem. To facilitate the landscape and analytical components of this and other projects, we will hire a technician that specialized in data analysis and geographic information systems (GIS).

- c. **Leverage biological survey data to inform the design of new protected areas under 30x30 (All regions; 1 terrestrial PhD; 1 marine PhD).** Here we seek to leverage the vast amounts of biodiversity survey data we will collect and curate in databases (see [Pillar #1](#) and [Pillar #4](#)) to inform priority areas for conservation. Specifically, we will design biological surveys such that they include areas likely to contain flora and fauna of conservation concern, and such that they cover unprotected areas in strategic places like areas rich in biodiversity and endemism and those that represent corridors between and buffers around protected areas. We will create country-specific maps of priority areas for protection that will help nations reach their 30x30 marine and terrestrial protection goals; we will present that map to local governments and stakeholders. To give one specific example, the southern part of Bioko Island is punctuated with two protected areas: Pico Basile National Park and the Caldera de San Carlos Scientific Reserve. Because of its remoteness, the Caldera Reserve has among the highest density of primates in the world and contains incredibly important endemic fauna (e.g., Bioko Red Colobus monkey, Bioko Red Colobus monkey, Bioko Drill, Bioko White-eye). The two reserves are only about 15km apart; however, encroachment of logging, hunting and agriculture is undercutting the integrity of biodiversity in the inter-reserve area. Restoring and protecting the land between the two areas would effectively create a biological corridor between the two critical PAs and effectively seal off the detrimental edge effects; it would also help Equatorial Guinea work towards its 30x30 goal. Armed with strong biological and sociological information, we could approach Rainforest Trust or other similar conservation groups to apply for funding to create a new reserve in this strategic location. Comparable strategies could be taken elsewhere that would follow a similar model.



Map of Bioko Island, Equatorial Guinea, showing the two protected areas. A natural fit for a place to add a protected area would be a corridor area between the two existing protected areas. Map from D.T. Cronin et al. 2015, PLoS ONE.

II. Understand long-term patterns in biotic and abiotic processes that affect biodiversity in the Gulf of Guinea.

Truly understanding biodiversity requires a long-term commitment to monitor patterns in both the biotic and abiotic (e.g. climate) patterns. Whereas there have been Global projects to tackle these gaps in data collection, these efforts are conspicuously absent in the Gulf of Guinea region. In other words, it is impossible to document how our world is changing if the appropriate kinds of data are not collected over time. In this objective we propose projects that establish the standardized monitoring of important biotic and abiotic processes in the Gulf of Guinea.

- a. **Establish long-term monitoring plots for climate, carbon sequestration etc. (Príncipe, 1PhD, 1MS).** Tropical forests play a vital role in mitigating climate change by sequestering carbon. However, climate change is affecting the growth, composition, and distribution of tropical forests, which can have significant impacts on global carbon cycles and climate. This is particularly important as tropical forests are 1) home to unique and endangered species of fauna & flora and 2) important source of food, fuel and other materials that ensure the sustenance of local communities. Therefore, if this delicate system changes there can be dire consequences for biodiversity and local communities. The project aims to establish long-term monitoring plots on Príncipe Island to study the effects of climate change and carbon sequestration in tropical forests. The monitoring plots will be established in collaboration with local communities and will be designed to measure changes in forest composition, structure, and carbon storage over time. The project will use remote sensing and data analysis techniques to measure changes in forest cover, biomass, and carbon stocks. The data collected from the monitoring plots will provide critical insights into the impacts of climate

change on tropical forests and the role of these forests in mitigating climate change by sequestering carbon. The project will also provide opportunities for capacity building and knowledge transfer to local stakeholders and communities and will contribute to the development of sustainable forest management practices on Príncipe Island.

- b. **Long-term monitoring of rainforest bird populations (São Tomé, Príncipe, Bioko, Mainland EG, 1 PhD, 1MS).** There is no coincidence that a bird was used as an indicator of environmental conditions in the classic expression “canary in a coal mine”. Small birds – which unlike most mammals, are rarely hunted with any meaningful consequences on their population sizes – are ideal indicators of rainforest health. They consume enormous numbers of forest fruits and invertebrates – including myriad agricultural pests – and are thus the sentinels with their “fingers on the pulse” of environmental change. Even in unbroken tropical rainforests in the world, some of the most sensitive rainforest bird specialists are disappearing (probably due to climate change altering forest dynamics), making it essential to monitor their populations. Here we propose to synchronize, expand and coordinate existing bird monitoring schemes around the Gulf of Guinea in order to have our finger on the pulse of the health of Gulf of Guinea forests—with birds as the sentinels. To achieve this, we plan to use a combination of mist netting arrays and autonomous recording units (ARUs). The mist netting arrays will be set up at strategic locations in each forest type to capture birds for identification and morphological measurements. The ARUs will be placed in each of the same forest types to record bird vocalizations, which will be used for species identification and to estimate the relative abundance of each species. This project will be carried out in association with Bioko Biodiversity Protection Program and Afro-American University of Central Africa (Mainland EG). This combination of sampling techniques will allow us to sample the entire bird community and provide detailed information on the diversity, distribution, and abundance of bird species across different forest types. The data generated by this study will be invaluable for conservation planning and management in this ecologically important region.
- c. **Maintaining and expanding the project “Guardians of the Rainforest” (Bioko, Príncipe, São Tomé and Annobón islands).** Endemism runs wild within the old-growth forests of the islands of Bioko, Príncipe, São Tomé, and Annobón. They hold the highest number of endemic bird species per unit area in the world, with the forests of the three oceanic islands of the Gulf of Guinea (Príncipe, São Tomé and Annobón) considered the third most important in the world from a bird conservation perspective (according to Buchanan *et al.*, PLoS One, 2011) These forests are so unique that together they form one independent ecoregion of the world. The most important action to support the conservation of such special biological heritage is quite simple: assuring that the protected areas created to protect these forests remain healthy and free from threats. As such, we will support and expand a program to train a local team of

'Guardians of the Rainforest' on each island. The aim will be to monitor protected areas on a regular basis and to long-term monitor the populations of selected flagship and indicator species and of reporting on any arising threats to the forests. The guardians will use a series of methodologies for their surveys, including the incorporation of standardized *SMART* technology (Spatial Monitoring and Reporting Tool), where they can input GPS and sightings data in real-time. The program was initially launched by BirdLife International under the ECOFAC 6 program for São Tomé. The Gulf of Guinea Biodiversity Centre (GGBC) will be responsible for coordinating this initiative when the ECOFAC funding ends. The GGRP can play a major role in this straightforward but essential initiative, by contributing to make it sustainable in the long-term in São Tomé and by extending it first to Príncipe and later, if feasible, to Bioko (in collaboration with the Forestry and Protected Areas Department, INDEFOR-AP, and the Bioko Biodiversity Protection Program, BBPP). The surveys will be complimentary to faunal surveys in [Pillar #1](#).

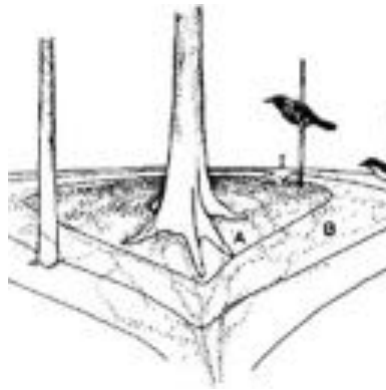
III. Understand the critical ecological processes that shape biodiversity in the Gulf of Guinea. Understanding the diversity and abundances of flora and fauna (e.g. through surveys, [Pillar #1](#)) is essential, but it provides only part of the picture of the ecosystem. Under this objective, we seek to understand the dynamics of the forest ecosystems—the ecological processes that shape the biological communities. In essence, anthropogenic change alters ecosystems in specific ways, and if we understand the nature of the complex relationships among organisms in the ecosystem, we can then predict how ecosystems will change as humans alter the natural world, and likewise design conservation actions with far more precision—thus conserving not only the flora and fauna per se, but the essential ecological processes (e.g. seed dispersal, keystone predation) that keep the ecosystem functioning.

- a. **Dynamics of forest vegetation and seed dispersal (Príncipe and beyond, 1PhD, 1MS).** The forest ecosystem is essential to both Príncipe and São Island islands ecology and economy, as it provides habitats for endemic species and is a vital source of timber for the local community. However, the island has experienced significant human disturbance, such as deforestation, which has led to a decline in forest vegetation and seed dispersal. The primary objective of this study is to investigate the dynamics of forest vegetation and seed dispersal in Príncipe Island through 1) analyzing the current state of forest vegetation and the factors affecting its growth and distribution through field surveys; 2) assessing the patterns of seed dispersal and the role of animal and wind dispersal agents in maintaining forest diversity through experimental manipulations (e.g. seed traps and animal exclusion experiments); and 3) developing a predictive model to estimate the long-term changes in the forest ecosystem under different scenarios of human impact. The results will allow for a better understanding of the ecological processes that drive forest diversity and resilience in small island ecosystems

and provide insights into for forest management and biodiversity conservation in other tropical regions.

- b. **Ebony and Ivory: Essential dispersal of tree seeds by forest Elephants (Cameroon, Gabon, Cabinda).** Many Afrotropical rainforest trees—such as the Ebony tree (*Dyospiros ebenus*)—produce large fruits and seeds that are dispersed at long distance by the critically endangered forest elephant (*Loxodonta cyclotis*). Illegal ivory trade has reduced forest elephant populations by more than 85% in 30 years, which should decouple their symbiotic relationship with the trees. Despite scant evidence pointing to a drop in tree regeneration in some cases the exact extent of the consequence for tree demography remains largely unknown. The identity of already impacted tree species and the precise mechanism at play still need to be assessed. Because of these gaps in knowledge conservation assessments do not consider the negative impact of elephant loss on tree regeneration and are likely over-optimistic. We will first quantify the regeneration success of elephant-dispersed tree species in forests with and without elephant. Then we will assess the importance of three key processes likely affected. First the increased mortality of seedlings due the reduced distance to their mother trees and its associated fungal and insect parasites, second the lack of elephant gut passage of seeds and finally the removal of the dung pile effect on the fate of seeds. Fieldwork will be conducted in Cameroon where extant populations of elephants remains at proximity of over-hunted forests. With this improved understanding of the consequence of elephant extinction we will be able to accurately predict tree populations trends and update their IUCN red list assessments. This project will be carried out in collaboration with the Congo Basin Institute.
- c. **Ecosystem engineers: Driver ants and their dependent fauna (Mainland EG, Bioko, Gabon; 2 PhDs: 1 birds, 1 ants).** Though their ecological importance to African rainforests is enormous, driver ants (*Dorylus* sp.) are among the most poorly understood ecosystem engineers on Earth. *Dorylus* colonies can contain more than *ten million individuals* and swarm over each inch of the forest floor every 8 weeks. *Dorylus* are considered the most important tropical insectivore, as their swarms create massive fronts of fleeing arthropods that provide a bounty for primates, pangolins, and specialized ant-following birds. By understanding the ecology of ecosystem engineers (*Dorylus*) and their dependents (birds), we can design sustainable landscapes that mitigate the effects of deforestation and degradation. Here we focus on the ecology of *Dorylus* driver ants and their accompanying ant-following birds, a guild about which we know little aside from a few studies suggesting their vulnerability to forest degradation. We suspect that Afrotropical ant-following birds are highly dependent on *Dorylus* ants and have enormous home ranges to track the nomadic ant colonies; however, these predictions remain effectively untested. Specifically, we will study *Dorylus* ant colonies to understand how they move about the rainforest in space and time: how sensitive they are to disturbance and

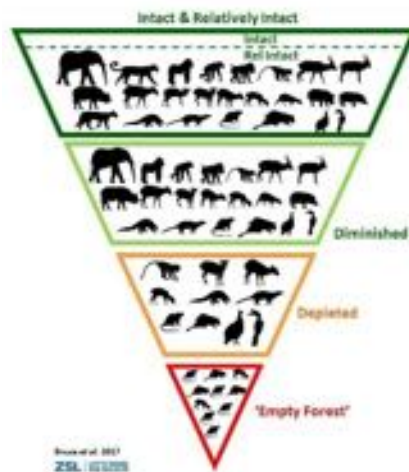
temperature shifts, how much area they cover, and how many colonies are there per hectare of forest. Concurrently, we will study the ecology of the many species of bird that depend on the ants: using miniature GPS tags to track their space use and home range size. With these data in hand, we will be able to parameterize a realistic agent-based model of how *Dorylus* ants and their dependent birds move about in space. We can then simulate realistic scenarios of deforestation and forest degradation, and allow the model to predict how and if the ant/bird system would respond. Armed with this realistic ecological model of space use, we will be in a strong position to design functional landscape that accommodate perhaps the most important ecosystem engineers in Afrotropical rainforests.



Depiction of ant-following birds congregating at the edge of a swarm of driver ants (*Dorylus*). A single colony of *Dorylus* can contain up to 20 million ants—their swarming behavior profoundly shapes the ecosystem. From Willis and Oniki 1978.

- d. **Understanding the consequences of “defaunation” (loss of large mammals) in tropical rainforest (Mainland EG, Cabinda, Cameroon, Gabon; 2PhDs: 1 birds; 1 plants).** Iconic megafauna of the tropical lowland rainforests of Africa are much more conspicuous ecosystem engineers (than ants): they literally shape the physical structure of rainforests. However, large expanses of forest across the Gulf of Guinea are becoming progressively “defaunated” as species like Forest Elephants, African Forest Buffalos, and Western Lowland Gorillas decline and are extirpated through hunting and habitat change. The compounding effects of defaunation, habitat change and degradation, and the creation and expansion of forest edge have trickle-down effects on the ability for tropical rainforests to maintain floristic diversity, effectively sequester carbon, harbor diverse animal communities and the variety of ecosystem services those species provide. This project aims to estimate the density of different megafauna species and quantify the forest’s physical characteristics. In doing so, we will establish whether forests with higher densities of megafauna support a greater diversity of fruiting and flowering trees and other woody plant species and whether that influences the diversity and diet of bird species that occur in those forests. Birds act as important purveyors

of ecosystem services within tropical rainforests, often being the primary seed dispersers for many tree species as well as important pollinators. To understand how changes in the physical characteristics of forests and diversity of trees impact the ability for birds to deliver these important services, we will quantify the diet of frugivorous birds with and without large herbivorous mammals. The resilience of tropical rainforests hinges upon the diversity of megafauna, who have a great influence on the physical structure of forests, as well as of seed dispersers and pollinators. This work would be among the first projects to investigate top-down relationships among key components of tropical animal communities and the implications those relationships have on woody plants.



Depiction of a gradient from intact to “empty forest” or defaunated. The abundance of large mammals can have profound effects on other parts of the ecosystem.

- e. **Revealing the mechanisms driving coexistence of resident and wintering migrant songbirds (Mainland EG, Cameroon, 1PhD, 1MS).** The Gulf of Guinea is an important region for millions of migratory birds. Migration is a very energetically demanding period in the annual cycle of birds, as they fly hundreds or thousands of miles between summer breeding and wintering grounds. Because of global climate change birds are experiencing rapid environmental changes that may cause phenological mismatches, such that they arrive outside times of peak food availability or have stop at different areas during their travels. Birds may have to switch to lower quality diets, which then may impact their reserves for further migration or lead to poorer condition during the breeding season, potentially having knock-on effects for reproductive success and population size. Further, when migratory birds arrive to their wintering areas they have to compete with resident species, often during times of the year when food availability is more limited. Thus, migratory birds are facing substantial dietary challenges, with consequences for their future persistence. In this project, the student will use

sophisticated DNA metabarcoding techniques to assess the diets of migratory birds at their wintering grounds in the Gulf of Guinea. The student will assess the diet and body condition of birds from a suite of migratory species arriving earlier vs later in the wintering season to understand the impacts of potential phenological mismatches. The student will further assess competition of migrant species with resident species and the relationship with body condition just before departure to European breeding sites. Beyond this, the project will also provide important insights into diets of resident bird species, who are also responding to environmental challenges related to global climate change. Overall, the project will provide training in cutting edge DNA sequencing, sophisticated bioinformatics, and rigorous statistical analyses.

IV. Understand evolutionary processes in the Gulf of Guinea. The fauna and flora of the Gulf of Guinea is extraordinary for including a wide array of species that occur nowhere else in the world. These endemic species are species that originated in the region. Hence the Gulf of Guinea constitutes an overlooked natural laboratory for the study of the processes that generate biodiversity – from local adaptations to that ‘mystery of mysteries’ (as Charles Darwin put it in his magnum opus): the origin of new species. The Gulf of Guinea islands can play a particularly important role in pushing our understanding of evolution forward because it is closer to the mainland than the remote archipelagos, such as Hawaii and the Galapagos, where most studies have taken place. This proximity adds a layer of complexity: the likelihood of gene flow between the mainland and the island populations increases. This allows to address one of the most active areas of research in evolutionary biology: the role of gene flow in driving forward (rather than hindering) differentiation. The Gulf of Guinea island system has an additional advantage, of great value, for the study of evolution and of the assembly of biological communities: it has three oceanic islands (born as bare rocks, never connected to the mainland or to each other), but also one land-bridge island (Bioko), which has been cyclically part of the African mainland. Bioko constitutes, therefore, not only a land bridge, but also an experimental bridge connecting the simplified worlds of oceanic islands with the complex systems of continental landmasses.

- a. **Understand the evolutionary relationships among Gulf of Guinea Plants (Príncipe, São Tomé, Bioko, Mt. Cameroon; 1 PhD, 1 MS).** The Gulf of Guinea is home to many unique plants that are found nowhere else in the world. Unfortunately, many of these species are now threatened with extinction due to habitat loss, climate change and anthropogenic pressures. Understanding their evolutionary history will provide valuable insights into their biology, ecology and conservation needs, which will allow for better suited conservation plans. Additionally, gaining insights into these species evolutionary relationships will open a window into the processes that have shaped plant diversity and explain which factors allowed for this region to be a hotspot of biodiversity. In collaboration with the Missouri Botanical Gardens and the University of Coimbra, we will combine existing samples in natural history collections with new sampling to conduct an unprecedented multi-island genetic sequencing and analysis study.

- b. **Understanding evolutionary relationships among giant tree frogs (Príncipe, Cameroon, Mainland EG, Gabon; 1 PhD project, 1 MS project).** Amphibians are the most imperiled vertebrate group with more than 30% of species considered threatened or endangered across the world. Although African tree frogs (genus *Leptopelis*) are a ubiquitous component of the continent's amphibian diversity, the number of species and their evolutionary relationships have not been comprehensively studied since the early 1970s, and then only with morphological data. Furthermore, many of these species occur in unprotected and rapidly diminishing habitats, and very little is known about their life history and ecology. These gaps in knowledge mean that conservation assessments are based on outdated taxonomy and an incomplete understanding of species' threats, and are thus of limited value for informing conservation management and policy. In collaboration with California Academy of Sciences, we will leverage existing samples in natural history collections (and will supplement with fieldwork as needed) to conduct a comprehensive genetic assessment of species-level diversity in African tree frogs in western Central Africa and the Gulf of Guinea archipelago. With this more complete understanding of diversity and distributions in the genus, we will be well-placed to update IUCN Red List assessments for these charismatic species and to identify key areas as candidates for formal protection and/or restoration and management.



Príncipe Giant Tree Frog, *Leptopelis palmatus*. Photo credit: Andrew Stanbridge.

- c. **Understanding evolutionary relationships among bats (all regions; 1 PhD & 1 MS).** Bats have a complicated relationship with humanity. On the one hand, they are primary consumers of enormous numbers of disease-carrying mosquitos and agricultural pests that save farmers billions of dollars per year; but on the other, they are perceived as feared and repudiated because of their tenuous link as agents in different diseases outbreaks (like Ebola or MERS). On balance, bats are of enormous benefit to humanity, but our ability to understand and hence benefit this is has been greatly hampered. Bats are difficult to study for two reasons. Firstly, they are small, nocturnal and difficult to observe, and capture. Second, bat taxonomy, the science of giving names to species, remains greatly unresolved. For example, the Gulf of Guinea is a global hotspot for bats; however, many of the species are part of cryptic species

complexes and cannot be readily identified in the field. African nose-leaf bats (genus *Hipposideros*) provide one example, where at least five genetically different types (probably unique cryptic species) of *Hipposideros ruber* exist in tropical Africa. This presents an enormous gap in our ability to conserve bats and address issues related to their interplay (both positive and negative) with humanity. For example, imagine that *Hipposideros ruber* suppresses the populations of a pest insect that destroys rice yields, therefore playing a key role in preventing human malnutrition. If we cannot actually identify *Hipposideros ruber*, this hampers our ability to study them, and conserve them to safeguard their pest control ecosystem services. The same problem holds true for crucially needed studies of disease surveillance, as many diseases rely on very specific hosts, often single bat species. Resolving the taxonomy of bats and progressing our ability to distinguish and study them is therefore of essential importance for accurate disease screening to prevent harmful outbreaks. Here will leverage existing sample collections with state-of-the-art lab work and will also sample bats broadly across the region to supplement the existing collections and contribute to biological surveys (Pillar #1). In collaboration with in collaboration with University of Eswatini, we will explore and describing bat in rural areas of the Gulf of Guinea and elaborate solid reference materials such as field guides and thus facilitate the creation of species-specific measures that maximize pest/mosquito control and minimize disease outbreaks. These materials would greatly assist local communities that do not have access to modern pesticides and thus rely on these natural ecosystem services for food security, and help in the prevention of spillovers events before they happen.



“*Hipposideros ruber*”: a species complex that is likely comprised of five or more cryptic species that aren’t possible to identify morphologically. *H. ruber* eats cocoa pests and *Anopheles* mosquitos (the genus that causes malaria), but without genetic and taxonomic work, it will remain unknown which specie(s) in the species complex provides these ecosystem services. Photo: Joxerra Aihartza.

- d. Evolution of bird diets on islands under climatic change (São Tomé, Príncipe, Mainland EG, 1PhD). Up to 90% of bird extinctions during historic times have occurred on islands—similar trends are likely to continue or worsen in the future. During the last decades, we have been

witnessing changes in global climate, like the increase in temperature and repeated droughts, that affect habitats, diet, phenology, and behavior of birds. There is growing concern that these changes might strongly affect island species, which are already vulnerable because of their reduced area of distribution and habitat available, the negative effects of further habitat loss to agricultural activity and the impact of invasive alien species (through increased competition, predation or introduced pathogens). The rapid climatic changes interaction with new invaders could force a rapid evolution of adaptive traits or otherwise lead to species extinction. In this context, a key question arises: are insular birds able to rapidly evolve new adaptive traits? This novel project aims to identify how endemic bird species evolve their diet under an increasing anthropogenic impact on islands, employing a multidisciplinary approach. In the first objective, the candidate will compare the trophic ecology of island birds (São Tomé and Príncipe) and their most related species on the mainland (Equatorial Guinea) to test the hypothesis that island organisms tend to be more generalist than continental ones. The second part of the project aims to assess how the continuing changing and species turnover (caused by the introduction of alien species) on islands currently affects and will affect in the future the diet and fitness of endemic birds. The second objective aims to compare the difference in diet between bird populations inhabiting native habitats or plantations by using state-of-the-art DNA diet metabarcoding techniques. In a third objective, the PhD candidate will assess the distribution trend of native and alien species that birds feed on under future global change by using new species distribution modelling approaches (SDM) to predict future resource availability for endemic bird species. As the fourth objective, we intend to develop a long-term study to assess differences in diet along the following years and relate them to a variation on alien species densities and climatic changes.

- e. **Ecology and evolution of avian malaria as a proxy for human malaria (Gabon, Mainland EG, Bioko, Annobon, Mt. Cameroon; 1 PhD):** Birds play important roles in maintaining healthy ecosystems, for instance by providing ecosystem services and serving as indicators of environmental health. Avian malaria also provides ideal unbiased proxy study systems for human malaria; birds do not use bed nets, DEET or environmental insecticides, so they serve as a natural, unmanipulated baseline for how malarial parasites evolve and spread. As such, we have much to learn about human malaria from studying this system in birds. Further, bird populations worldwide are under threat from various factors, including habitat loss, climate change, and diseases. Avian malaria is a disease that can severely impact bird populations, sometimes leading to mass mortality episodes—particular on tropical islands rich with endemics (e.g. Hawaii). Globally, it has led to a 7% decline in threatened bird species. The Gulf of Guinea, a biodiversity hotspot with an impressive diversity of birds—including many threatened and endemic species, has shown evidence of the impact of avian malaria on bird populations on a wide spatial scale. This study aims to investigate the seasonal variation of

endemic and migratory birds, and avian blood parasite lineage diversity across time and space, and to understand the population genetics of avian blood parasites in the Congo Basin. Field surveys will be supplemented with existing data to determine the diversity of avian blood parasites and the intensity of infection, and remote sensing tools will be used to map parasite spatial distribution as well as understand those factors that influence the spread of diseases and the risk of emerging infections in a rapidly changing environment. This study will provide valuable information on the seasonal variation of endemic and migratory birds in the Congo Basin, the diversity of avian blood parasite lineages, and the environmental factors that influence their infection rates. These new insights will help inform conservation strategies for these bird populations.

- f. **So close, yet so far: Molecular windows to the past in land-bridge island birds (Bioko, Príncipe, São Tomé, Mainland EG, Cameroon; 1 PhD).** Land-bridge islands (LBIs), islands that were connected to the continent during periods of low sea-level, have been overlooked in evolutionary and conservation studies. In birds, a lack of research on LBIs leads to an underappreciation of the conservation value of peripheral populations of bird species. In this project, we will identify and explore the added insights that LBI species can bring to biodiversity studies. We will focus on the Gulf of Guinea islands that include 2 LBIs (Bioko and Corisco) and three oceanic islands (OIs: Príncipe, São Tomé, Annobon). We will sequence thousands of genomic loci from multiple individuals from 20 bird species that co-occur in three geographical units: LBIs, OIs and continent. For each species, we will reconstruct phylogenetic trees, population structure and demographic history, allowing us to compare and contrast patterns within and among LBI, OI and mainland populations. We will also investigate whether Bioko's and Corisco's birds are sufficiently genetically unique to merit specific conservation efforts. Uncovering the effects of LBI formation on genetic divergence is a valuable step towards predicting consequences for conservation in LBIs but also in an increasingly fragmented world where nature reserves are like LBIs surrounded by "seas" of inhospitable habitat.
- g. **Community assembly and macroevolutionary impact of anthropogenic extinction on the vertebrates of the oceanic islands of the Gulf of Guinea (1 PhD).** Recent studies in Madagascar and New Zealand have shown that if species that are currently threatened on those islands go extinct, it would take several million years for diversity to recover back to today's diversity. In this project, we will estimate the rate of biodiversity recovery in the Gulf of Guinea islands, under the pessimistic scenario that all currently threatened species of vertebrates go extinct. We will produce new molecular phylogenies for all native species of terrestrial vertebrates (amphibians, squamates, birds, and mammals) based on existing molecular data (most species have already been sequenced) and complementing with new

molecular samples for the missing species. We will gather data on local threat status for all vertebrate species from the islands. We will fit the island biogeography model DAISIE to estimate natural rates of community assembly (speciation, colonisation, extinction). We will use the model to simulate into the future how long it would take (under natural rates) to recover diversity if currently threatened species go extinct. This study will provide the first evaluation of the amount of evolutionary history that is under threat in the Gulf of Guinea islands due to human activities, and will provide a new perspective on the impact of humans on these islands.

Pillar #4. Conservation biology of flagship, threatened and endemic species

The Gulf of Guinea has no shortage of both charismatic and threatened species, many of which have limited monitoring to date. Mainland spots in Cabinda and in Equatorial Guinea have the full complement of endangered Congo forest megafauna, including elephants, chimpanzees and gorillas, but populations and distributions of these animals are poorly understood. The islands are rich with endemic, range restricted species, many of which are poorly known. By understanding where these important animals are located and how many of them persist, we can design appropriate protected areas and cater management and conservation actions appropriately. These charismatic and/or threatened species are also ideal candidates for building support from the public.

I. Understand hotspots for elephants, chimpanzee and gorillas (Cabinda, Gabon, Mainland EG)

- a. **Camera traps, acoustic monitoring and DNA metabarcoding (Mainland EG, Cabinda, Gabon; 2 PhDs).** Over the last 15 years, technological advances have made it possible to widely monitor wildlife populations with relatively little effort. Cabinda, Gabon and Mainland EG all have significant populations of endangered chimpanzees, forest elephants and gorillas, but it is not clear how many persist on the landscape, or where hotspots of these charismatic species are located. Here we will use a combination of camera trapping, bioacoustics monitoring and iDNA (invertebrate-derived DNA) extracted from carrion flies, mosquitoes, and biting flies to monitor populations of large, charismatic mammals. Though camera trapping and bioacoustics monitoring (ie., use of remote audio recorders) are well known methods, recent advances in artificial intelligence (AI) have made it possible to much more efficiently identify animals recorded in images and sound. Further, the monitoring of animal populations through DNA metabarcoding is a recent development—and CIBIO is at the forefront of this movement. In this technique, bits of DNA are gathered from forest streams or from carrion flies—flies that feed on dead animals. The DNA are then extracted from these samples and matched to known DNA barcodes of African fauna. Each of these three methods separately have considerable biases that can mischaracterize the actual populations of these animals—but combined and if used with cutting edge statistical techniques (i.e., integrated Bayesian modelling), we would have the framework to estimate animal population sizes with great precision and accuracy. We will deploy dozens of camera traps and acoustic monitors in Gabon, Cabinda and mainland EG and will collect carrion flies at these locations as well. By combining camera traps and ARUs, we will obtain primate and elephant data as well as recordings of shotgun blasts—we will identify the animals and shotgun blasts from images and audio recordings using AI. Carefully chosen PhD students will curate the data and will integrate the three methods to produce population estimates as well as a map of the hotspots for these animals. This project will represent a collaboration with Michigan Technical

University. The data will be used to inform priority areas for conservation and expansion and creation of new protected areas (see [Pillar #3](#)). Overall, this project will provide unprecedented insights into the patterns of biodiversity in Guinean forests and will contribute to the development of effective conservation strategies.

II. Understand the distribution and population sizes of rare and endangered Island Endemics

- a. **Monitoring and protecting Bioko Drill and Pennant's Red Colobus, including monitoring of bushmeat markets (Bioko, Mainland EG; 1PhD).** Supporting a comprehensive research survey to update the population estimate and range for these two key primate species. It is known from previous work that Pennant's red colobus probably only can be found in a small region of the southwestern part of the Luba Caldera Scientific Reserve, yet carcasses of this species are still seen in the bushmeat market data indicating at least moderate levels of hunting. Drills are more widely distributed, and are seen the bushmeat data much more frequently, but there remain big gaps in our understanding of where they are still found on the island. In this project, a collaboration with Bioko Biodiversity Protection Program, we propose surveys for these two species throughout the Luba Reserve (Overlapping with [Pillar #1](#)) to understand hotspots for the two species. Further, we propose monitoring of the bushmeat markets in Equatorial Guinea to understand the supply chain for these animals. Finally, we will use DNA barcoding to understand which animals appear in bushmeat markets in Equatorial Guinea, and which are trafficked from the mainland to the island and vice versa. Understanding supply chains and demand for these species is an important step in forming conservation action.



Bioko Drill. An endangered subspecies of the Mandrill that is endemic to Bioko Island.

III. Understand and protect charismatic species

- a. **Preserving Irreplaceable populations: population viability of western lowland gorillas (Mainland EG, Gabon, Cabinda; 2 PhDs).** In 2014, the IUCN Species Survival Commission Primate Specialist Group, Great Ape Section, released the Regional Action Plan for the Conservation of Western Lowland Gorillas and Central Chimpanzees 2015-2025. This plan highlights priority landscapes and actions to ensure the conservation of these species. One of the sites of Exceptional Importance for gorilla conservation (i.e. holds more than 5% of the global population) is the Monte Alén-Monts de Cristal-Abanga Landscape, a transboundary region between Equatorial Guinea and Gabon. Various parts of Gabon are listed as well, and the Maiombe-Dimonika region (which includes Cabinda) is a priority area for surveys because populations are so poorly known.



Picture of Western lowland gorilla female with small baby captured in Equatorial Guinea. Photo Credit: Biodiversity Initiative.

In Equatorial Guinea, heart of the gorilla population is believed to be located in Monte Alén National Park (MANP). It is within a region also highlighted in the action plan for its high 'irreplaceability value', meaning its preservation is critical to effective conservation of great apes and that an equivalent conservation impact cannot easily be achieved elsewhere. Over the last 15 years, however, gorilla habitat has undergone rapid destruction and human encroachment. These changes can lead to interruption of gene flow, disruption of social dynamics, an increase in disease transmission to and from humans and domestic livestock or pets, and increase in hunting due to opening up previously inaccessible forest areas. The effects on gorillas, being a highly social species with large home ranges, are particularly pronounced, which is bringing these animals to the brink of extinction. Despite of that, today we still do not have a good understanding on the population density, distribution and viability

of gorilla populations, or how their social structure is being affected by human disturbance. As such, we are unable to develop specific, evidence-driven conservation actions that will ensure the survival of this species across the central African landscape. This project, a collaboration with University of West England and the Wilder Institute, will combine transect and nest surveys, genetic analysis and population modelling to determine (1) gorilla population size, density and distribution, (2) the effect of human activity on their social dynamics, and (3) the population viability of the species.

- b. **Forest elephants as stewards of carbon sequestration (Mainland EG, Cabinda, Gabon; 1 PhD).** The forests of Central Africa are identified as holding one of the largest reserves of “Irrecoverable carbon”, which if lost will preclude efforts to limit global warming to $<1.5^{\circ}$. Yet these forests are being the subject of rapid infrastructure development, particularly road construction driven by foreign investment. This negatively affects wildlife - particularly large-bodied animals - in various ways, including changes in animal density, disruption of gene flow and migratory routes, and increase in mortality. Furthermore, as these animals play a critical role shaping forest function (e.g., biogeochemical cycles) and structure (e.g., tree density) and therefore forests’ carbon sequestration potential, their disappearance would also have significant and long-lasting changes in the environment. For example, each forest elephant, a critically endangered species endemic to Central Africa, promotes a net increase in carbon capture by 9,000 metric tons of CO₂. As such, the International Monetary Fund identifies conservation of forest elephants as a nature-based solution to climate change. This project aims to study the effect of habitat destruction and hunting on the Critically Endangered forest elephant to develop evidence driven conservation strategies that will prevent the decline of this species and hence contribute to the preservation of the countries’ forests’ carbon stocks. Equatorial Guinea has been identified as a priority for their conservation given its relatively well-preserved forests and their transboundary landscapes with Cameroon and Gabon. Populations of forest elephant are also thought to be quite high in recent preliminary surveys. The project, which is a collaboration with The University of West England, has three specific objectives (1) examining elephant population genetic structure, genetic diversity and phylogenetic history, (2) identify corridors and areas ecological importance for the species, and (3) determine connectivity levels among populations. The project will use a multidisciplinary approach, combined forest transects, DNA extraction and analysis, and satellite imagery.



Picture of Forest elephant captured in Equatorial Guinea.

Photo Credit: Biodiversity Initiative.

- c. **Picathartes** (Bioko, Gabon, Mainland EG, Mt. Cameroon; 1 PhD). *Picathartes oreas* (AKA Grey-necked Rockfowl) is probably Central Africa's most iconic bird. Due to this and its cultural importance, its striking Porsche red and royal blue head skin graces the cover of several bird books and stamps of Central African countries (see below). *Picathartes* was also featured in the first television appearance by Sir. David Attenborough in 1954. The species' range stretches from southwest Nigerian to Gabon, where there are thought to be only roughly 3000-10,000 individuals scattered about the rockiest regions of the jungle. *Picathartes* nests only in boulders or caves within rainforest, so it is very much threatened by the many hunters who also use these shelters from jungle downpours and would gladly enjoy a breakfast of *Picathartes* eggs or chicks. Further, its long legs get caught in hunter's ground snares designed for duiker and porcupine. Despite its iconic status, the species' habits, population size and ecology are poorly known because it makes practically no noise and inhabits rugged, remote regions, making it difficult to study. We don't know what priority areas are for the species, we don't know how much area of rainforest the species requires, and we know if individuals on Bioko Island represent a distinct species or subspecies. Further, we don't know what priority areas are for the species' conservation because most satellite layers don't have high enough resolution (e.g., Landsat, 30m) to detect the kinds of boulders where the species nests. Fortunately, cutting edge satellite imagery and genetic techniques provide a solution to several of these problems. High resolution, satellite-based 3D LiDAR (light detection and

ranging) scans of the Earth's surface are now available globally at the resolution of 0.5m, meaning that we can detect *Picathartes*' preferred boulder habitat at a fine scale. Likewise, modern genetics techniques allow us to extract DNA from feathers found at *Picathartes* nests, allowing us to calculate the effective population size, as well as to detect population trends that would allow the species to be globally listed, e.g. as endangered. Here we will use LiDAR to produce a high-resolution map of the species' priority nesting habitats and we will estimate population size and trend in order to facilitate conservation planning and action for the species. We will attach satellite-GPS tags to individuals to calculate the amount of rainforest the species requires around boulders where it nests. Further, we will perform environmental outreach on the species (see [Pillar #6](#)) to educate young people on the importance of this cultural icon.



- d. **Grey parrots (Everywhere but Annobon; 1 PhD)**. Arguably the most intelligent bird in the world, this endangered species has gone functionally extinct in Togo, Benin, and large swaths of Ghana due to agricultural expansion and persecution for the pet trade. The species—which ranges throughout much of west and Central Africa, is undergoing a steep population decline, with somewhere between 50 and 80% of the species lost in the last 40 years. Fortunately, Bioko, Principe and parts of Cameroon remain strongholds for the species, where its robot-like chirps and whistles can still be heard overhead in the dawn light when family groups are flying from roosts to foraging grounds. Here we will design a monitoring program for Grey Parrots in collaboration with World Parrot Trust to establish baseline population sizes and establish precise population trends. We will integrate these data with existing databases (e.g. eBird) to create a map of species distribution and hotspots. We will work with local communities to provide education on the importance of this species (see [Pillar #6](#)). Further,

we will work with locals to understand the dynamics of the wild bird trade and will design conservation actions accordingly.

- e. **In the Footsteps of Giants: A comparative analysis of forest elephant ecology across nations (Mainland EG, Gabon, Cabinda; 1 PhD, 1MS).** Forest elephants play a vital role in the forest as they 1) maintain the biodiversity of the forest ecosystem; 2) disperse seeds and help to maintain forest structure, which benefits other wildlife species and contributes to the overall health of the forest; 3) play an important role in carbon storage by dispersing seeds of large trees that store significant amounts of carbon. They are also an important cultural symbol in many African countries, playing a significant role in local folklore, art, and traditional practices. Unfortunately, forest elephants are listed as critically endangered on the IUCN Red List, and their populations have declined significantly due to habitat loss, poaching for ivory, and human-elephant conflicts. This PhD will combine several approaches to give a holistic view on forest elephants in mainland Equatorial Guinea, Gabon and Cabinda. The project will include using survey data to create Maps of Biogeographical Ignorance (MoBIs), an innovative method developed by CIBIO researchers, that account for survey completeness and quality of data in each areas to identify where data is robust and to support conservation prioritization; the use of bioacoustics (with automated detection using artificial intelligence) and other methodologies to study forest elephant populations; conduct social surveys to understand local perception, beliefs and folklore about forest elephants; and study poaching pressure on this iconic species, allowing to develop informed conservation strategies for protecting forest elephants and maintain a healthy forest ecosystem.

IV. Understanding and protecting threatened species with important ecological roles

- a. **Aquatic ambassadors: Understanding freshwater turtle populations and their role in aquatic ecosystems across countries (all regions, 1 PhD, 2MS).** In the Gulf of Guinea, freshwater turtles play an important role as both predator as prey in aquatic systems and as an indicator of habitat quality and ecosystem health. Through a combination of visual encounter surveys, trapping (e.g., baited hoop traps, funnel traps, box traps), mark-recapture studies and monitoring of reproductive effort, we will be able to study their behavior, population dynamics and distribution. Genetic samples will also be collected to study phylogenetic relations and Biogeographical Ignorance (MoBIs), which will enable the identification of areas where species distribution data is reliable and can be used to prioritize conservation efforts. Combined with social surveys to understand the different cultural and economic roles freshwater turtles play in local communities (e.g., as a food source, traditional medicine, pet trade, etc.), the PhD student will be having a holistic understanding of the threats to these

species and will be able to make informed suggestions on conservation actions additionally to providing new information about these species.



*Picture of West African Mud Turtle captured in São Tomé.
Photo Credit: Ricardo Rocha.*

Pillar #5. Ecosystem services, invasive species and socioecology: Interactions of people and nature

Here we focus on the study of the interactions between human societies and the natural environment in the Gulf of Guinea, and how these interactions affect the provision of ecosystem services such as crops, water, and climate regulation. Understanding these interactions is critical for developing sustainable development strategies and conserving the unique biodiversity of the Gulf of Guinea.

I. Understand the services that nature provides in agricultural systems. Ecosystem services are services provided (for free) by nature such as pollination and pest consumption. Understanding and quantifying these services is important for humanity—particularly in agricultural systems imbedded in a forest landscape as is common in the Gulf of Guinea. Equipped with an understanding of nature’s services, farmers can manage biodiversity to co-exist with them and indeed help yields and wellbeing.

- a. **Ecosystem services in cocoa and coffee: Using DNA metabarcoding to uncover pests and pollinators (Príncipe, São Tomé, Cameroon; 2 PhDs: 1 pests, 1 pollinators).** Cocoa and coffee are two of the most important commodity crops in the Gulf of Guinea, and consumption of both is increasing globally as the middle class of populous countries like India and China expand. Both crops are greatly aided by natural ecosystems: insects pollinate both crops, and insectivorous birds and bats eat pests of both coffee and cocoa. Despite conventional wisdom in this system, we really have a poor understanding of how to leverage ecosystem services provided by nature to increase crop yields and farmer wellbeing. Specifically, we still do not know which insects pollinate cocoa (because cocoa flowers and their pollinators are impossibly tiny), nor do we know which birds and bats consume cocoa and coffee pests, or how much this saves farmers. Here we will leverage cutting edge DNA metabarcoding technology to 1) isolate pollinator DNA from cacao trees and 2) sequence insect DNA from bird and bat feces. This project, in collaboration with Durham University, will tell us both 1) the cocoa pollinator insect(s) and 2) the birds and bats that eat pests of cocoa. We will then study the habitats of these critical ecosystem providers, specifically by determining the native shade trees in cocoa that benefit pest-eating birds and bats, and by determining the vegetation and management conditions that benefit pollinator insects. By understanding the species that benefit agricultural systems, we can design farms that include habitat for these animals, thus increasing crop yields and farmer wellbeing.

- II. *Invasive species: Understanding their effect on Gulf of Guinea Ecosystems.* Invasive species—both plants and animals—are a growing problem on Gulf of Guinea islands, where they can cause significant ecological and economic damage. The introduction of non-native plant and animal species can displace native species and alter entire ecosystems, leading to a loss of biodiversity and

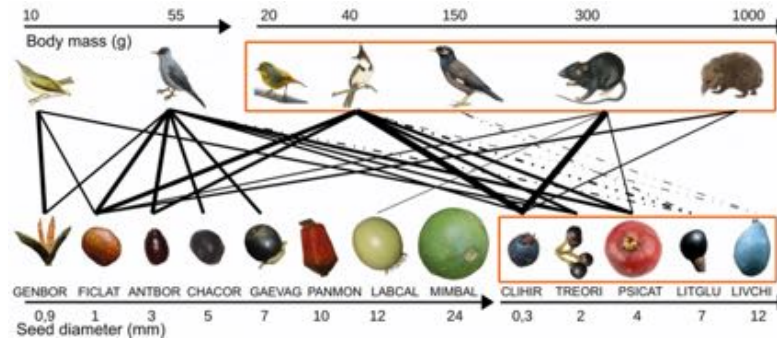
ecosystem services. In addition, invasive species can also have negative impacts on human health, agriculture, and infrastructure. The unique geography and climate of the Gulf of Guinea islands make them particularly vulnerable to the spread of invasive species, highlighting the urgent need for effective management and control measures.

- a. **How invasive rats affect agriculture (Príncipe, São Tomé, 1PhD).** Because Gulf of Guinea island ecosystems have been isolated for so many millennia, they are then ill equipped to support the arrival of exotic species—they haven't evolved in the presence of the new species, so the ecological balance becomes unsustainable. As such, rats and other mammalian predators can particularly decimate both endemic native species (e.g., naïve nesting birds) and agricultural systems. In São Tomé and Príncipe, where cocoa farming has been practiced for over two centuries, invasive species are serious issues with considerable economic consequences posing complex challenges to its future. Indeed, apart from the limited access to global value chains, suboptimal management practices and crop damage by exotic species might synergistically be affecting productivity. As such, we will focus on the Black Rat (*Rattus rattus*), the most damaging exotic species in the islands for both biodiversity and cocoa production, destroying up to 40% of the annual production. We therefore propose to assess the drivers of both rat abundance and cocoa production in both São Tomé and Príncipe islands, disentangling the effects of both agricultural management and the damage caused by the rat. Specifically, we will evaluate how both practices such as the management of the soil and vegetation and the abundance of the exotic rat affect cocoa production. To do so, we will establish 1-ha plots in 40 cocoa farms, representing the diversity of management intensity and landscape contexts (e.g., distance to forest, town or rivers, rainfall, slope, soil type). Surveys will be carried out for two years, to accommodate seasonal variation in the rat abundance which will be estimated by monthly trapping sessions using Tomahawk live-traps during five consecutive nights. Between August and October, the fruiting season of the cocoa tree, species interactions with cocoa fruits will be further examined. Aiming to understand cocoa management practices, we will give questionnaires to farm managers and an index of management intensity will be calculated. Structural equation models will be used to distinguish the direct influence of (i) management intensity and (ii) crop damage on productivity; in addition to (iii) that of the landscape context. The overall goal of this project will be to develop an evidence-based protocol to maximise cocoa production while minimising the ecological impacts caused by augmented rat abundances.
- b. **Evolutionary pathways and ecological impacts of an invasive, virus-transmitting Asian Tiger mosquito (*Aedes albopictus*; São Tomé, 1PhD).** *Aedes albopictus* is major invasive mosquito that is now found throughout the world. This mosquito was first reported on São Tomé in 2017 and since then has become one of the most common mosquito species in urban areas.

Because *Aedes albopictus* is an important vector of deadly human arboviruses (e.g., dengue fever) its presence in São Tomé is a major public health concern. Establishing routes of invasion and origin populations will contribute to a better understanding of the impact of this new introduction in disease transmission in São Tomé. Furthermore, the introduction of this new species may also have an ecological impact on the local fauna. For example, recently introduced *Aedes albopictus* seems to be able to outcompete a different, already established mosquito, the Yellow fever mosquito (*Aedes aegypti*) in places where the species co-occur—it is not clear how this affects human disease transmission. This project aims at: i) establishing the origins and invasion routes of *Aedes albopictus* in São Tomé island through DNA sequencing of island and origin populations; ii) assess the impact of *Aedes albopictus* on *Aedes aegypti* fitness at the larval stage by conducting field surveys and microcosm experiments; iii) Determine the role of *Aedes albopictus* in the diets of insectivorous predators (aquatic macroinvertebrates, birds and bats) using DNA metabarcoding. This project will run in collaboration with University of California Malaria Initiative and will complement the project “*Insectivorous birds, bats and herps as predators of human disease vectors...*” described below.

- c. **Species interactions under biological invasion: an island model (Príncipe and São Tomé; 1 PhD).** Biological invasion of plants and animals is a key threat to biodiversity, but its impacts are often assessed at species level, halting a deeper understanding of ecological consequences. Ecological networks are an important tool to explore interaction patterns at the community level, which have regained attention in recent years due to the development of powerful technologies and data-intensive analyses. We will use these networks to explore how biological invasion is changing species interactions and functional traits, to infer ecological consequences using the endemic rich tropical islands of São Tomé and Príncipe (STP) as models. To provide a holistic perspective on the impacts of biological invasion on species interactions, the PhD student will 1) complement conventional visual methods with diet DNA metabarcoding to reconstruct ecological networks and to study vertebrate trophic interactions with native and exotic plants in STP, which will provide insights into how biological invasion can affect trophic interactions and ecosystem functioning, allowing to develop evidence-based guidance to manage introduced species in extinction-prone oceanic island and in wider contexts; 2) use ecological networks to explore the effects of introduced species on vertebrate seed dispersal interactions, by evaluating network topology and how species traits determine their trophic roles and 3) study how introduced species affect seed dispersal along the gradient of forest degradation in STP providing a valuable opportunity to decipher how biological invasions and anthropogenic land-use intensification interact. This project will

be developed with the support of experts from cE3c and will use survey data from exotic plants described in [Pillar #1](#).



Example of a seed dispersal network connecting fauna to the flora that they disperse.

Thickness of the line indicates frequency of the interaction. Figure credit: Albert Sebastien.

II. Understand which insectivores consume disease-carrying insects. A single bat, for example, can consume more than 600 mosquitoes in an hour. As such, insectivorous birds and bats almost certainly provide a service to humans by consuming disease-carrying mosquitoes, but DNA barcoding technology has only just emerged—allowing us to make headway into understanding this field.

- a. **Insectivorous birds, bats and herps as predators of human disease vectors: Understanding an overlooked ecosystem service (Principe, Cameroon;1PhD).** An often-overlooked ecosystem service that animals may provide is the consumption of insect disease vectors, such as mosquitoes. Mosquitoes are the deadliest animals on the planet, due to their role in the spread of diseases such as malaria, dengue fever, and yellow fever, which account for more than 600,000 human deaths every year. Insecticides have been used to control mosquitoes, however, these can have negative impacts, for example on pollinators or insectivorous predators. Further, mosquitoes have begun to evolve insecticide resistance. The role of natural predators in controlling mosquito populations (especially of adults) is poorly understood. For example, bats are voracious consumers of mosquitoes, potentially removing up to 600 from the environment every hour, but because of morphological similarity of mosquitoes, we don't know if they consume disease vectors. Our DNA sequence data from bird and bat fecal samples from Cameroon show that at least 15 species of bats and birds consume mosquitoes from five different genera, including *Anopheles*, *Culex*, *Coquillettidia*, *Eretmapodites*, and *Mansonia*—all of which include important human disease vectors. On Principe, for example, the recent arrival and spread of the mosquito *Aedes albopictus* has likely driven an outbreak of the deadly Dengue fever. The aim of this project, which would represent a collaboration with Durham University and University of California's Malaria

Initiative, is designed to understand how mosquito (especially vectors) fit in food webs in rural and more urban landscapes by using sophisticated DNA metabarcoding techniques to survey diets of various animal groups, including birds, bats, amphibians, and reptiles. If possible, we will also include arthropod predators, as they also play an important role in pest control. Network analyses will be used to explore species interactions. Because of ongoing work to remove some mosquitoes completely (e.g. genetic modifications of *Anopheles gambiae* using *CRISPR technology*), as well as shifting distributions of organisms due to global climate change, the student will conduct sensitivity analyses to investigate how changes in the community (either for mosquitoes or predators) will impact population dynamics.

III. Understand nature's value for humans. Evaluation of value generating practices (VGPs) in protected areas across the study region. VGPs are any activity that creates value (economic or cultural) for individuals, communities and societies. Critically, VGPs are based on interactions with natural or human assets which can be invested in to increase the contribution of protected areas to human wellbeing and quality of life. Demonstrating such value is important to ensure ongoing political support and to safeguard protected areas against development interests.

- a. **Value generated assets (Bioko, Mainland EG; 1PhD, 2MS).** Protected areas are widely regarded as the most important tool for protecting biodiversity, though it is increasingly understood that by providing opportunities for livelihood generation, relaxation, research and many other human activities, they also generate an enormous amount of tangible and intangible value for individuals, communities and institutions. In conjunction with Oxford University (UK) and the Federal University of Alagoas (Brazil) we have developed an innovative approach, the PA Asset Framework (PAAF), that is exceedingly well suited to multiscale assessment of the contributions made by natural areas to human societies. The aim of this PhD will be to evaluate the cultural value of the biodiversity and biophysical assets of the new Parque Nacional de La Paz on mainland EG (see **Pillar #1**), based on PAAF. Specifically, the student will use a combination of social survey and desk-based analysis to identify key assets, value generating practices and the values they generate for a diverse range of stakeholders, including local communities, international tourists, researchers and park managers. This information will be used to attract further investment into the park and to strengthen the conservation and governance of natural resources.
- b. **Beekeeping as an alternative source of income that supports ecosystem function (Príncipe, 1 Ph.D, 1 MS)** – Bees play a crucial role in pollinating crops and wildflowers, making them essential to our food supply and ecosystem. Without bees, many of our favorite fruits, vegetables, and nuts would be in short supply or disappear altogether. Bees also help to sustain biodiversity by pollinating wildflowers that provide food and habitat for other wildlife. Not a lot is known about the bees in Príncipe, however, there is a high probability that these

species are endemic. This makes them particularly important as they have evolved to fill specific ecological niches within the environment, meaning that they are often better adapted to pollinate the plants that are unique to that island, which may not be effectively pollinated by other bees. Unfortunately, they face several threats to their survival, making it imperative to understand their conservation status. In the last few years, there has been an increase in the local population's use of honey and honey sub-products, with demand steadily increasing. Studying beekeeping as an alternative source of income would create several benefits, including: 1) diversification of income and higher economic stability for local households; 2) promote sustainable forms of agriculture that promote conservation and natural habitats; 3) educational opportunities for local people to engage in, both through learning skills or knowledge but also by opening the door for entrepreneurial opportunities and 4) conservation of the endemic bee species of Príncipe. We will collect specimens for identification through metabarcoding, study species abundance and study possible threats, as well as assessing market demands, investment costs, honey and subproducts production yield, marketing strategy and risks and pests. This project will be in collaboration with Fundação Príncipe.

- c. **Buzzing for change: Promoting beekeeping and “buzzboxes” to reduce human-elephant conflict (Mainland EG, Cabinda, Gabon; 1PhD, 1MS).** The project aims to research the considerable conflict between critically endangered forest elephants and rural people, particularly the impacts on local livelihoods and agriculture. Forest elephants can kill villagers (and vice versa), and can wipe out a year of crops in less than an hour, so they present a considerable management challenge. Elephants are demonstrably scared of bees, so beekeeping (“living fences”) along the edges of agricultural areas can be an ideal alternative livelihood for communities. By providing training and equipment, the project hopes to create a sustainable source of income that does not rely on agriculture and decreases the need for encroaching on elephant habitat. Furthermore, the project plans to test the effectiveness of buzzboxes, a device that detects the approach of elephants (using technology similar to camera traps) and then emits recorded bee sounds to deter elephants from entering crop fields. The buzzboxes, like live bees, are placed around crop fields, and when elephants approach, they are scared away by the sound of swarming bees, which they instinctively avoid. The project will measure the impact of the buzzboxes and beekeeping on crop damage and elephant behavior, as well as the acceptance and adoption of the technology among local communities. The project will collect data on elephant movements and crop damage through camera trapping, acoustic surveys and iDNA (see surveys in [Pillar #3](#)), interviews with farmers, and conduct surveys to assess the effectiveness of the beekeeping training and buzzboxes. The findings of the research will be used to inform policies and interventions to reduce human-elephant conflict in the region and support sustainable livelihoods for local communities.



Pillar #6. Education, outreach, capacity building and local knowledge

Education, dissemination of our work, and working with local people to build capacity are absolutely critical to ensure that the work described in this proposal is sustainable. Without learning from locals and without passing the torch to young researchers and conservation biologists in the Gulf of Guinea, we risk doing “parachute science”—providing a very short-term research impact and then departing. Ideally, the work described in this proposal will inspire and integrate local people into research and conservation programs, while simultaneously learning and integrating local natural history knowledge and conservation practices.

I. Contribute to the long-term sustainability of biological conservation through education and incorporation of local knowledge. This objective is designed to achieve two-way knowledge transfer between local communities in the Gulf of Guinea and the partners of this proposal.

- a. **Run educational experiences for schoolchildren and older students (Bioko, Príncipe, São Tomé; Mainland EG)** - Natural history education for the next generation of Gulf of Guineans is critical to ensuring the sustainability of biodiversity. Here we propose a series of educational activities for schoolchildren in the region. We propose to have 2 activities per region per year, including fieldtrips (e.g. a visit to a bird ringing station; a visit to see nesting sea turtles), workshops, festivals and viewings of nature documentaries.
- b. **Develop environmental education programs for local communities (Bioko, Príncipe, São Tomé and Mainland EG)** – Local communities hold the power to make changes *in situ* that protect biodiversity. Our local communities education program will: 1) raise awareness about environmental issues around the community and show how everyday activities might affect the environment and provide helpful alternatives; 2) empower the communities by giving them knowledge to make informed decisions about the environment, which will lead to more sustainable practices and policies that promote conservation and environmental protection; 3) promote behavioral change that benefits biodiversity conservation and 4) create a culture of sustainability by promoting a sense of responsibility, pride and stewardship towards biodiversity and the environment. Each program will be tailored to each region, focusing on the specific conservation needs of the area. We propose to conduct at least 2 activities per year per location. It is also expected that PhD students develop educational programs related to their theme with local communities.
- c. **Contribute to training local and international researchers and graduate students in master's and doctoral programs.** Throughout this proposal, we have incorporated dozens of fellowships for PhD and master's students. These students will receive their degrees at CIBIO through fellowships from FCT—funding for the associated thesis research projects will be provided by the partners of this proposal. PhD fellowships will be open to applicants from any country, but

those from Gulf of Guinea countries will be particularly encouraged (~10 minimum). Master's fellowships will be primarily reserved for students from countries in the Global South, as opportunities for higher education are especially challenging in Gulf of Guinea countries, so masters degrees are often a more appropriate educational stepping stone. Throughout the duration of their projects, graduate students and their collaborators will follow CIBIO's code of ethics for working in the Global South.

- d. **Understand and incorporate local natural history and conservation practices (all regions; 1PhD, 2 MS).** Throughout the Gulf of Guinea region, researchers and conservation practitioners stand to benefit greatly from local knowledge of natural history and conservation practices. Knowledge of medicinal plants, ethnobotany, and how to manage resources such as shifting agriculture and wild fish and game vary regionally and are only understood through interaction with locals. Here we propose a project designed to understand and study local practices involving biodiversity, and for managing natural resources. This project will be integrated with the project on value generating practices (VGPs) described above (**Pillar #5**), but the precise nature of this work is intended to be adaptive based on the students' interactions with local people. As a key deliverable of their program, the PhD student will summarize the work and that of the Masters students, and present a report on the findings such that the work can be continued and the local practices can be incorporated into the ongoing research and conservation work by CIBIO and partners.

II. Develop educational capacity to support ecotourism

- a. **Provide education in the ecotourism field (Bioko, Mainland EG, São Tomé, Príncipe).** Our proposed project aims to unlock the ecotourism potential in the Lower Guinean Forests region by developing contemporary ecotourism workshops that will build capacity for young Africans. We plan to partner with the National University of Equatorial Guinea, The University of São Tomé and Príncipe and the Afro-American University of Central Africa to design and deliver training programs that will provide local youth with the knowledge and skills necessary to develop and manage ecotourism ventures. These workshops will focus on ecologically sustainable practices, emphasizing the importance of conservation and environmental stewardship in the development of tourism enterprises. By building capacity in the local population, we aim to foster economic growth while also protecting the region's natural resources and unique cultural heritage. This project will provide valuable training opportunities for young Africans, enabling them to develop successful and sustainable ecotourism businesses and contribute to the development of their communities.

III. Support publications on the biodiversity of the Gulf of Guinea. Here we propose to provide funding for a long-awaited bird book on the region as well as a series of scientific publications generated by the student-led research.

- a. **PUBLISH A GUIDE TO THE BIRDS OF THE OCEANIC ISLANDS OF THE GULF OF GUINEA (FAST-TRACKED project).** Birds have for long constituted the main ambassadors for the natural wonders of the oceanic islands of the Gulf of Guinea. Not only are they in the coat of arms and on the stamps and currency of São Tomé and Príncipe, as they are the main magnet for nature tourism, with regular birding tours taking place several times a year by different operators, which rely on local eco-guides. Nevertheless, there is no bird guide available for these islands, sought after for having the highest number of endemic birds in the world in relation to their area. A team of two writers (researchers that will not ask for a fee) and two scientific illustrators (with experience of the islands and its birds) is ready to produce such a guide, with original illustrations and the most updated information, within a 2 year period.
- b. **Support student and researcher publications.** Here we will provide funding for what we expect will be dozens of scientific research papers that will emerge from the projects described in this proposal. We provide financial support for these publications.

IV. Outreach: Communicate and disseminate the work of the Gulf of Guinea Research Program to local and international audiences. A well-defined Communication and Dissemination strategy is essential to achieve the main goals of this project and to maximize the visibility of the project among the national and international community. We will adopt an integrated approach to planning Communication and Dissemination activities, given that these activities are largely complementary, interdependent, and need to be understood as “horizontal issues” that run alongside and complement research and innovation activities throughout the project’s lifetime. These strategies will be reviewed on a regular basis to verify whether they are fulfilling their objectives and to improve on any aspects that are underperforming.

- a. **Organize workshops for stakeholders in the region** (i.e., research institutions, local NGOs, local communities etc.) designed to create a united framework for research and conservation in the region. Workshops are designed to bring together the network of stakeholders in the region (including the dozens of CIBIO graduate students that will be involved so that they are 1) aware each other’s efforts and 2) are united in common goals, protocols and a code of conduct. The initial 2-day workshop will take place at the Gulf of Guinea Biodiversity Center and will include a hybrid virtual and in-person format. Subsequent workshops will be primarily virtual and will occur yearly.

- b. **Communication strategy and goals.** The main strategic goal of the communication strategy is to promote *Gulf of Guinea Research Program*, its results and achievements, through the implementation of a variety of activities targeted at multiple audiences. Achieving these goals will require the implementation of a number of activities, including:
- Defining an identity (logo/brand) to improve recognition among participants and to foster a sense of identity among members of the *Gulf of Guinea Research Program* (Action 1: Identity creation);
 - Create and maintain a *Gulf of Guinea Research Program* webpage to showcase strategies and achievements, act as a point of entry for research and corporate partners, among other functions (Action 2: *Gulf of Guinea Research Program* webpage);
 - Use online media, including YouTube, Twitter, Instagram and other social media platforms, to communicate *Gulf of Guinea Research Program* to the wider community through vlogs, educational videos, etc. (Action 3: Social media);
 - Develop exhibitions and activities for the general public (Action 4: Exhibitions and related activities);
 - Encourage publication of non-technical papers to document research results with relevance to the wider society (Action 5: Publication of non-technical papers);
 - Communicate *Gulf of Guinea Research Program* to schools through printed materials and seminars, targeted at both teachers and school children (Action 6: Media and public engagement);
 - Promote citizen science and other forms of citizen engagement, through for instance online platforms such as eBird and iNaturalist, and linking to research projects (Action 7: Media and public engagement);
- c. **Dissemination strategy and goals.** The main strategic goal of the dissemination strategy is to document and showcase the results of Gulf of Guinea Research Program, thereby ensuring that they are available and in a form that others can use, both during and after the implementation of the project. The aim is to enable and facilitate stakeholders to use the results/products thereby maximising the project's impact. Specifically, effective dissemination ensures that the knowledge and results generated are easily available for others to use, either for developing new research, for improving policies and management of natural resources and agrobiodiversity, or for commercial exploitation. Thus, dissemination activities make the results/products generated by Gulf of Guinea Research Program widely available to stakeholders, leading to their exploitation. The main targets include not only the scientific

community, but also stakeholders that can benefit from Gulf of Guinea Research Program results, such as partners, policymakers, the organisms of the public administration at national, regional and local levels, and NGOs. Achieving these strategic goals require the development of a wide range of activities, including:

- Publication of open access, high impact scientific papers in international journals, thus making the results widely available to the scientific community (Dissemination Action 1: Publication of open access scientific papers);
- Presentation of results in scientific and technical seminars, conferences and workshops, with financial support awarded for young and outstanding researchers (Dissemination Action 2: Presentation of results in scientific meetings).

V. Fundraise for additional support for our programs. To ensure appropriate support for our research and conservation programs beyond this five year proposal (i.e. financial sustainability), we will hire a professional fundraiser who will work with us to submit proposals to various trusts and foundations (e.g. the São Tomé Conservation Trust Fund) and will help us develop relationships with donors and partners.

5. Timeline

The execution of the work program detailed here will run for 5 years, though the program will undoubtedly last longer. A basic timeline can be found below, but we will produce a detailed schedule of the work plan based on the present proposal after discussion and agreement among the institutions involved. Three FASTTRACKED projects are highlighted with red arrows.

Pillar #	Quarter	Year One				Year Two				Year Three				Year Four				Year Five				
		1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	
1	Construct Principe Research Station & HQ																					
	Build a field research station in Principe																					
	Build a research station in Cabinda																					
	Vehicle Purchase																					
	Stakeholder workshop																					
	Design and launch a marine & terrestrial biodiversity database																					
	Develop a Marine & terrestrial DNA barcode library																					
	Design and perform biodiversity surveys																					
2	Create new park in Equatorial Guinea																					
	Weather and climate monitoring																					
3	Educational experiences																					
	Ecotourism trainings																					
	Publish a book on the Gulf of Guinea Birds																					
	Scientific publications																					
	Dissemination & communication																					
	Fundraising for medium to long term																					
2 - 3	PhD fellowships																					
	PhD research																					
	MS fellowships																					
	MS research																					

We will produce an annual report describing the work carried out, as well as a report after 5 years. The Work Program may be adjusted annually, after agreement of participating institutions if there are new opportunities or challenges.

6. Budget

The total budget of this project is approximately 12 million euros. The Budget is included as a separate spreadsheet.

7. Main Partner Organizations

CIBIO - Centro de Investigação em Biodiversidade e Recursos Genéticos, with host institution **Associação BIOPOLIS**. Cibio is a biodiversity and genetics research institute in Varão, Portugal, which is part of the University of Porto System. It specializes in biodiversity and genetic resource research, contributing to the understanding and conservation of the Earth's biodiversity. CIBIO's multidisciplinary approach and collaboration with national and international partners make it a vital hub for biodiversity research in Portugal. **Associação BIOPOLIS** is the (financial) managing entity for CIBIO.

Supernova Technologies is a private company in the energy sector that is based in the Netherlands. Supernova Technologies has generously agreed to do provide infrastructure and logistical support for the GGRP. The company holds properties in the Gulf of Guinea, including Roça de Belo Monte in Principe, and is investing in GGRP infrastructure projects in, among other locations Gabon, Principe, and Cabinda, Angola.

8. Affiliate Organizations

Dozens of paragraphs in the preceding sections describe potential PhD research projects that represent excellent matches for Biopolis and the GGRP. Depending on the students that we recruit and the projects that are eventually selected, specific organizations will then be recruited as collaborators on the work described in this proposal as collaborators (with MOUs developed as needed) because they provide specific expertise. Although these organizations may not be directly involved in the actions described here, and resources may not be directly allocated to them, they will likely be important on-the-ground collaborators as the work rolls out. This list of affiliated organizations is thus intended as a non-binding and dynamic list of likely partners based on the research projects described above. Actual partner organizations will be added on a case-by-case basis as PhD students are recruited and their specific projects chosen.

Afro-American University of Central Africa (AAUCA), Equatorial Guinea: created in 2019, AAUCA aims to become a University of academic and research excellence, committed to the scientific, technological and cultural domain, oriented to the formation of people of high professional quality, leadership and competitiveness and based on the excellence of its academic staff in exchanges with other universities,

through scientific networks, promotion and cooperation at national and international level. AAUCA can provide logistical support for researchers working in the Parque Nacional de La Paz (Pillar #3, objective I, action a) and be a partner in the long-term monitoring of rainforest bird populations (Pillar #3, objective II, action b)

Biodiversity Initiative, USA: is a global effort to conserve and protect Earth's biodiversity. Its director is Luke L. Powell, also of CIBIO/Biopolis. It aims to address the ongoing loss of biodiversity caused by human activities, such as habitat destruction, climate change, pollution, and overexploitation of natural resources. The initiative involves the development and implementation of policies, programs, and projects that promote sustainable practices, preserve natural habitats, and protect endangered species. Biodiversity Initiative involves collaboration between governments, conservation organizations, scientists, and local communities to promote conservation and sustainable development. BI has worked extensively in EG and will provide support in EG related projects.

Bioko Biodiversity Protection Program, Equatorial Guinea. BBPP is a conservation initiative focused on preserving the unique biodiversity of Bioko Island, Equatorial Guinea. Its director is David Montgomery of the TROPICO program at CIBIO/Biopolis. The program aims to protect the island's critically endangered primates, such as the Bioko drill and the Bioko black colobus monkey, as well as other threatened species and their habitats. BBPP also supports local communities through education and sustainable development projects, promoting conservation awareness and improving livelihoods. The program is a collaboration between the government of Equatorial Guinea, CIBIO/Biopolis, and the conservation organization Proyecto Primates. BBPP will be a partner in the long-term monitoring of rainforest bird populations (Pillar #3, objective II, action b), in the "Guardians of the Forest" project to be established in Bioko (Pillar #3, objective II, action c) and in the "Monitoring and Protecting Bioko Drill and Pennant's Red Colobus, including monitoring of bushmeat markets (Pillar #4, objective II, action b). Note that BBPP is soon to be renamed Equatorial Guinea Biodiversity Project (EGBP).

Birdlife International, São Tomé: BirdLife International is a global partnership of conservation organizations focused on the protection of birds and their habitats. The BirdLife International branch in São Tomé and Príncipe is dedicated to conserving the unique bird species found in these two small islands off the coast of West Africa. The branch works to protect critical habitats for birds, including rainforests, wetlands, and coastal areas. It also conducts research on the biology and behavior of endemic bird species, such as the São Tomé olive pigeon, the São Tomé grosbeak, and the Príncipe weaver. BirdLife International can be involved in the "Guardians of the Forest" project (Pillar #3, objective II, action c) in São Tomé and Príncipe, as well as coordinate with INDEFOR-AP and BBPP to expand the project to Bioko.

California Academy of Sciences (CAS), USA: is a natural history museum, planetarium, and research institution located in San Francisco, California. The museum's mission is to explore, explain, and sustain life on Earth through scientific research, education, and public engagement. It houses over 46 million specimens, including plants, animals, fossils, and minerals, and features exhibits that showcase the biodiversity and

geology of the planet, as well as its past and current environmental challenges. The CAS can collaborate in the “Understanding evolutionary relationships among giant tree frogs” project (Pillar #3, objective IV, action b).

cE3c - The Centre for Ecology, Evolution and Environmental Changes is a large R&D unit based at the Science Faculty of Lisbon University. cE3c’s vision and strategy evolved expanding its research to address science and societal challenges in ecology, evolution and the environment (the three Es in the Centre’s name). Its geographic scopes were broadened to encompass tropical and insular ecosystems, and innovative methodologies and collaborative approaches were expanded. cE3c can provide support in the “Species interactions under biological invasion: an island model” (Pillar #3, objective III, action f).

Congo Basin Institute, Cameroon: Research and education institution located in Central Africa, with campuses in Cameroon, the Democratic Republic of Congo, and the Republic of Congo. Its mission is to advance scientific knowledge and promote sustainable development in the Congo Basin region, which is home to some of the world’s most important tropical forests and wildlife. The institute focuses on a range of topics, including biodiversity conservation, climate change, public health, and community development. CBI also provides training and education opportunities for students, researchers, and practitioners from across the region, working to build local capacity for scientific research and sustainable development. The Congo Basin Institute can collaborate with the “Ebony and Ivory” project (Pillar #3, objective III, action b).

Direção Geral do Ambiente (DGA), São Tomé and Príncipe: it is the government agency responsible for coordinating the country’s environmental action and handling the state environmental policies. Its objective is to balance economical and social development with preservation and equilibrium of the environment, as well as establishing criteria and standards of environmental quality. The DGA, alongside the DGFB (see below), can grant authorization for all research in São Tomé and Príncipe.

Direção Geral das Florestas e Biodiversidade (DGFB), São Tomé and Príncipe: the DGFB is the government agency responsible for the management and protection of forests and biodiversity in São Tomé and Príncipe. DGFB is responsible for developing policies and regulations related to forestry and biodiversity, as well as overseeing the implementation of programs and projects aimed at promoting conservation and sustainable development. The DGFB, alongside the DGA (see above), can grant authorization for all research in São Tomé and Príncipe.

Drexel University, USA: private research university, founded in 1891, offers undergraduate and graduate programs in a wide range of fields, including engineering, business, medicine, law, and the arts and sciences. Drexel is known for its co-operative education program, which integrates classroom learning with practical work experience. The university has a strong focus on research and innovation, with faculty and students conducting research in areas such as biomedical engineering, information science, and environmental science. Drexel University has worked extensively in EG (in collaboration with BI, BBPP and INDEFOR-AP) and can provide support in EG related projects.

Durham University, UK: public research university founded in 1832. The university offers undergraduate and graduate programs in a wide range of subjects, including arts, humanities, social sciences, sciences, and engineering. The university has a strong research profile, with research areas including astronomy, physics, and biosciences, among others. Durham University, specifically Dr. Andreanna Welch, can collaborate with the “Ecosystem services in cocoa and coffee: using DNA metabarcoding to uncover pests & pollinators” project (Pillar #5, objective I, action a) and with the “Insectivorous birds, bats and herps as predators of disease vectors: Understanding an overlooked ecosystem service” project (Pillar #5, objective II, action a).

Fundação Príncipe: non-profit organization created in 2015. The foundation's mission is to promote sustainable development and conservation in Príncipe by supporting local initiatives, developing innovative solutions, and raising awareness about the island's unique biodiversity and cultural heritage. The foundation focuses on a range of areas, including sustainable agriculture, fisheries, and tourism, as well as conservation of the island's forests, marine ecosystems, and endangered species such as sea turtles and humpback whales. The foundation also runs a number of community-based programs, such as education and health initiatives, to improve the well-being of the island's residents. Fundação Príncipe collaborates with a range of partners, including local communities, government agencies, and international organizations, to achieve its goals. Fundação Príncipe can provide support in seabird monitoring (Pillar #1, objective III, action a), in the “Understand how beekeeping can be an alternative source of income and assess bee’s conservation status” project (Pillar #5, objective III, action b).

Gulf of Guinea Biodiversity Center, São Tomé: regional research and conservation center that focuses on the conservation and management of biodiversity in the Gulf of Guinea islands. The center conducts focus in facilitating research, education and conservation of the unique diversity of plants and animals of the islands. The GGBC can coordinate the “Guardians of the Forest” project (Pillar #3, objective II, action c) in São Tomé and Príncipe, as well as with INDEFOR-AP and BBPP in Bioko, after funding from ECOFAC ends.

INDEFOR-AP (Instituto Nacional de Desarrollo Forestal y de la Fauna, Áreas Protegidas y su Entorno), Equatorial Guinea: is the National Institute of Forestry and Wildlife Development, Protected Areas and their Environment in Equatorial Guinea. It is a government agency responsible for the management and conservation of the country's forests, wildlife, and protected areas. INDEFOR-AP oversees the implementation of policies and programs related to sustainable forest management, biodiversity conservation, and environmental protection. Its work includes developing and enforcing regulations for timber and wildlife trade, establishing and managing protected areas, conducting research and monitoring, and providing technical assistance to local communities and stakeholders. INDEFOR-AP can be involved in all projects conducted in protected areas in Equatorial Guinea.

Michigan Technological University, USA: public research university that offers undergraduate and graduate programs in engineering, natural sciences, business, humanities, and social sciences. Michigan Tech is known for its strong focus on engineering and technology, and a significant research presence, with faculty and

students conducting research in fields such as environmental science, materials science, and applied physics. The Michigan Technological University, specifically Dr. Jared Wolfe and Dr. Kristin Brzeski, can contribute to the “Camera traps, acoustic monitoring and DNA metabarcoding” project (Pillar #4, objective I, action a).

Missouri Botanical Gardens, USA: founded in 1859, is one of the oldest botanical institutions in the country. The Missouri Botanical Garden is a leading center for botanical research, conservation, and education. It has partnerships with institutions around the world to support the study and preservation of plant diversity. The Missouri Botanical Gardens can contribute to the flora biodiversity database (Pillar #1, objective II, action a) and to the “Understand the evolutionary relationships among Gulf of Guinea Plants (Pillar #3, objective IV, action a).

Natural History and Science Museum from the University of Porto (MHNC-UP), Porto: founded in 1837 the museum's collections include over 15,000 specimens, ranging from fossils and minerals to live animals and plants. The exhibits cover a wide range of scientific disciplines, including geology, paleontology, zoology, botany, and anthropology. The MHNC-UP is also home to a planetarium and an aquarium, which offer educational programs and activities for visitors of all ages. The museum is committed to scientific research and education, with a focus on promoting awareness and understanding of the natural world and its conservation. MHNC-UP researchers have worked extensively in the islands of the Gulf of Guinea and can provide support in island related projects.

Naturalis Biodiversity Centre, Leiden, The Netherlands: research institution and natural history museum where collaborator Dr. Luís Valente is based. The center's mission is to promote the understanding and appreciation of biodiversity through research, education, and public engagement. Its collection includes over 42 million specimens of plants, animals, fossils, and minerals from around the world, making it one of the largest natural history collections in the world. Naturalis conducts research in a range of disciplines, including taxonomy, evolution, ecology, and conservation biology, and is involved in a number of international research collaborations. Luís Valente can collaborate is several of the evolutionary studies.

Rainforest Trust, USA: non-profit conservation organization that works to protect threatened tropical forests and endangered wildlife around the world. The organization's mission is to purchase and protect the most threatened tropical forests, saving endangered wildlife and endangered habitats. It accomplishes this through partnerships with local organizations and communities to identify and prioritize areas for protection, and then working to secure legal protection for those areas. Rainforest Trust also provides sustainable economic opportunities to local communities to ensure their continued support for conservation efforts. Since its founding in 1988, Rainforest Trust has helped protect over 33 million acres of tropical forests and the species that depend on them. Rainforest Trust has approved funding 1.6 million dollars for the establishment of Parque Nacional de La Paz (Pillar #3, objective I, action a).

Universidad Nacional de Guinea Ecuatorial (UNGE), Equatorial Guinea: established in 1995, UNGE has several campuses located in the capital city of Malabo and other parts of the country. UNGE offers undergraduate and graduate programs in a variety of fields, including law, economics, education, engineering, humanities, natural sciences, and social sciences. The university is committed to promoting research and innovation in Equatorial Guinea and the wider African region, with a focus on addressing the development challenges facing the country. UNGE also has a strong community outreach program, which provides services and resources to local communities and aims to improve the social and economic well-being of the people of Equatorial Guinea. UNGE researchers and students can collaborate in projects developed in Equatorial Guinea.

University of California Malaria Initiative (UCMI), California: collaborative research program aimed at combating malaria, a mosquito-borne infectious disease that affects millions of people worldwide. The initiative is a partnership between the University of California, San Francisco (UCSF), the University of California, Berkeley (UCB), and the Malaria Elimination Initiative at the University of California, San Diego (UCSD). The UCMI's research focuses on understanding the biology of the malaria parasite and the mosquito vector, as well as developing new tools and strategies for disease prevention, diagnosis, and treatment. The initiative also works closely with national and international partners to promote malaria control and elimination efforts in endemic regions, with a particular focus on sub-Saharan Africa and Southeast Asia. UCMI can collaborate in the "Insectivorous birds, bats and herps as predators of disease vectors: Understanding an overlooked ecosystem service" project (Pillar #5, objective II, action a).

University of Coimbra: public research university, founded in 1290. The university offers undergraduate and graduate programs in a variety of fields, including arts, humanities, social sciences, natural sciences, and engineering. It is particularly well-known for its programs in law, medicine, and humanities. The University of Coimbra has a strong research presence, with faculty and students conducting research in fields such as biotechnology, renewable energy, and digital humanities. UC can contribute to the "Understand the evolutionary relationships among Gulf of Guinea Plants (Pillar #3, objective IV, action a).

University of Eswatini (Formerly Swaziland) (UNESWA): established in 1982 as a merger of the University of Botswana, Lesotho and Eswatini, currently has three campuses located in the towns of Kwaluseni, Luyengo, and Mbabane. UNESWA offers undergraduate and graduate programs in a variety of fields, including business, education, engineering, health sciences, humanities, law, and natural sciences. The university is committed to promoting research and innovation in Eswatini and the wider African region, with a focus on addressing the development challenges facing the continent. UNESWA can collaborate in the "Understanding evolutionary relationships among bats" project (Pillar #3, objective IV, action c).

University of São Tomé and Príncipe (USTP), São Tomé and Príncipe: established in 2016, it is the only public university in the island nation of São Tomé and Príncipe. USTP currently offers degree programs in several disciplines including economics, law, computer science, and education, among others. Its mission is

to contribute to the development of São Tomé and Príncipe by providing high-quality education, conducting research, and promoting innovation. Despite its recent establishment, the University of São Tomé and Príncipe has already made significant contributions to the country's education and research landscape. USTP can be a collaborator in projects developed in the country.

University of West England (UWE), Bristol, UK: public research university that offers a wide range of undergraduate and postgraduate programs, including business, engineering, healthcare, law, and creative arts. UWE Bristol has a strong emphasis on sustainability, and its sustainability initiatives have won numerous awards. UWE can collaborate in the “Preserving Irreplaceable populations: population viability of western lowland gorillas” project (Pillar #4, objective III, action a) and in the “Forest elephants as stewards of carbon sequestration” project (Pillar #4, objective III, action b).

Wilder Institute, Calgary, Canada: research and policy institute part of the Mount Royal University with focus on conducting research and analysis on social and public policy issues affecting communities in Alberta and beyond. The institute aims to promote evidence-based decision-making and informed public discourse, with a particular focus on issues related to social justice, health, and education. The Wilder Institute can collaborate in the “Preserving Irreplaceable populations: population viability of western lowland gorillas” project (Pillar #4, objective III, action a).

World Parrot Trust (WPT): international conservation organization dedicated to the protection and welfare of parrots, which are among the most threatened bird groups in the world. Founded in 1989, the WPT works to raise awareness about the threats facing parrots, such as habitat loss, poaching, and the pet trade, and to develop and implement conservation strategies to address these threats. The organization conducts scientific research on parrot populations and habitats, works to establish protected areas for parrots, and supports conservation efforts through education and outreach programs. The WPT also promotes responsible parrot ownership and works to combat illegal trade in parrots through advocacy and lobbying efforts. The organization has partnerships with other conservation organizations, governments, and local communities to achieve its conservation goals. WPT can collaborate in the “Grey Parrot” project (Pillar #4, objective III, action d).