# The Gamba Complex of Protected Areas: An Illustration of Gabon's Biodiversity

Michelle E. LEE[1], Alfonso ALONSO[2], Francisco DALLMEIER[2], Patrick CAMPBELL[2] and Olivier S.G. PAUWELS[1,3]

## 1 Introduction

The Republic of Gabon lies on the central west coast of Africa, traversed by the equator and bordered by Equatorial Guinea and Cameroon to the north, Republic of the Congo to the east and south, and 885 km of Atlantic Ocean coastline to the west. Its surface area, 267,667 km$^2$ - roughly the size of Italy - may be divided into three topographical zones: a narrow coastal alluvial plain; an extensive, hilly inland plateau; and several low-elevation mountain zones (max. 1575 m).

Central Africa's tropical moist forests cover 1.8 million km$^2$, the second largest contiguous block in the world, traversing boundaries of Gabon, Equatorial Guinea, Congo, Democratic Republic of Congo, Cameroon, and Central African Republic (Wilkie and Laporte 2001). Gabon harbors an important part of that block, with roughly 80% of the country covered by moist tropical forest. This flora is classified in the Guineo-Congolian regional center of endemism (White 1983), and its lowland diversity is among the richest in Africa (Breteler 1996). Extensive wetlands – rivers, swamps, lakes and lagoons – sustain dynamic forest and coastal ecosystems, with the country's largest river, the Ogooué, traversing some 800 kilometers over much of the country to reach the ocean. Savannas are found in the south, center, and east of Gabon, and along the coast. Two major mountain chains, the Monts de Cristal and Massif du Chaillu, bring rugged relief to the north and central-south of Gabon, respectively, and two minor chains, Mayombe and Ikoundou, are found nearer the coast in the south.

These forest, savanna, coast, and mountain landscapes harbor some of the continent's most remarkable and uncharted species diversity. Current knowledge includes about 198 species of mammals (Emmons *et al.* 1983), 680 species of birds, 98 species of amphibians (Burger *et al*. this volume), an estimated 95-160 species of reptiles (Pauwels *et al*. this volume), 184 freshwater fish species in the Ogooué River basin alone (Christy *et al*. 2003), and an estimated 6,000-10,000 species of plants (Letouzey 1968) – with numbers increasing for nearly every taxonomic group with each biodiversity research field trip. Gabon is also home to important populations of species of conservation concern, such as sea turtles, African forest elephants, humpback whales and great apes. Its abundance of these globally-rare species and its biological diversity make Gabon's wildland systems valuable for conservation at an international level (Kamdem-Toham *et al.* 2003).

Considering that Gabon's forests and biodiversity have evolved over geologic time, human influence on this forest system is relatively recent and radical (White 2001). Hunter-gatherer history from the middle Ogooué region of Gabon dates to the Early Stone Age (ca. 400,000 – 120,000 years BP), shifting as agriculturalist Bantu tribes immigrated to the area in the past 5,000 years (Oslisly 2001). European explorers, missionaries, and traders arrived in 1472, seeking timber, forest products, ivory, and slaves, beginning an era of resource exportation to international markets. Gabon was part of French Congo, then French Equatorial Africa until 1910, eventually gaining independence in 1960. Since then timber, oil, manganese, and uranium exports have supported the 1.2 million population, which is largely concen-

[1] Monitoring and Assessment of Biodiversity Program, National Zoological Park, Smithsonian Institution, S/C Shell Gabon, BP 48, Gamba, Gabon. Email: LeeMi@si.edu

[2] Monitoring and Assessment of Biodiversity Program, National Zoological Park, Smithsonian Institution, 1100 Jefferson Drive SW #3123, Washington DC 20560-0705, USA. Emails: aalonso@si.edu, fdallmeier@si.edu, pcampbell@si.edu

[3] Mail address: Department of Recent Vertebrates, Institut Royal des Sciences Naturelles de Belgique, Rue Vautier 29, 1000 Brussels, Belgium. Email: osgpauwels@yahoo.fr

trated in major cities and along transport lines. Although vast areas in Gabon remain uninhabited and ecologically intact, these valuable forest sites are under threat as the territory and offshore are increasingly being zoned for commercial extraction (Collomb *et al*. 2000**,** Walsh *et al.* 2003, Laurance *et al*. in press).

To protect Gabon's natural heritage and develop an ecotourism industry, a National Park System was created by Presidential decree in August 2002, setting 10.8% of the national territory under full protection (Anonymous 2002). This landmark decision was precipitated by a high-profile, science-based conservation campaign for the region (Quammen and Nichols 2002, 2003) and priority-setting ecological research in key areas of the country (Fisher 2004a, L. White, pers. comm.). The Gabonese government and NGO community are working together to establish parks and regulations, build capacity for conservation personnel, and spread awareness in the country and beyond (Anonymous 2002, Ward *et al*. 2003, Fay and Nichols 2004, Ross 2004, Ward and Lee 2004) for ecotourism and conservation. Never before has central African forest conservation received equal attention or support (CBFP.org, CARPE.umd.edu) from the rest of the world.

## 2 The Gamba Complex of Protected Areas

Gabon's recent commitment to national parks marks a new stage in protected area management for the country. In 1956, Petit Loango National Park and the Ngové-Ndogo hunting area were created on the southwest coast; they were modified to a faunal reserve in 1962. In 1962 and 1966, several contiguous partially-protected zones were created around it, bound under title the Gamba Complex of Protected Areas. They included the four hunting areas of Iguéla, Ngové-Ndogo, Setté Cama and Moukalaba – used for elite sports hunting until its closure in 1981 – three faunal reserves of Petit Loango, Plaine Ouanga, and Moukalaba-Dougoua – set aside to restock the hunting areas – and one sustainable use faunal reserve, Monts Doudou. The Gamba Complex (1˚50'-3˚10'S; 9˚15'-10˚50'E) is the largest protected area in the country, covering 11,320 km$^2$ (see map on page xxxii) in a remote area – its conservation largely due to inaccessibility.

### 2.1 Geography and wildlife

A coastal sedimentary basin covers the western two-thirds of the Gamba Complex, with wave action along the coast exposing localized parts of the beach to its rock surface. Soils in the coastal sediment are largely ferralitic sandy clays (Environmental Resources Management 1999). The eastern third is characterized by a low mountain ridge (max. 820 m) of metamorphic rock, part of the Mayombe mountain chain, which extends 450 km by 30 km and dates back 2.7 million years. Eastern soils are considered terrestrial crystalline, and although the richest soils in the Gamba Complex, they are characterized by poor mineral content and fragile, erodable structure, like most of Gabon (Thibault *et al*. 2004).

Hydrology is divided into three main watersheds: the Nyanga River (watershed in Gabon 19,500 km$^2$), the Ndogo Lagoon (surface area 487 km$^2$; watershed 1587 km$^2$), and the N'gové Lagoon (surface area 195 km$^2$). Numerous minor rivers, streams, lagoons and swamps form a complex hydrological network with significant areas of lowland forest temporarily or permanently inundated. Waters drain to the Atlantic Ocean, which can display a tidal amplitude of 1.3m. Petit Loango and Setté Cama are RAMSAR sites, Wetlands of International Importance.

The equatorial climate is hot and humid, with average temperature in the Gamba Complex a relatively constant 24-28°C (Shell Gabon unpublished data), and annual rainfall averaging 2300 mm (1985 – 2002) inland at Rabi, and 2093 mm (1984 – 2002) on the coast at Gamba (Shell Gabon unpublished data). Compared to other rain forests of the world, it is relatively dry (White 1983). A short dry season often occurs in January and a long dry season extends from June to August, with wet weather otherwise, though rainfall patterns vary highly between years. Relative humidity in the study area is around 85%, giving a rate of annual evaporation around 1200 mm or nearly half the annual precipitation (Lemoalle and Albaret 1995).

The Gamba Complex supports a mosaic of habitat types – coastal beaches and dunes, mangrove forests, littoral forests, coastal scrub, freshwater and brackish swamps, lowland permanently- and seasonally-inundated forest, upland forest, rocky outcrops, various stages of secondary forest, prairie, papyrus and *Raphia* marshes, and extensive freshwater and brackish wetlands. This varied assemblage of habitat

types – probably the most diverse protected area in Gabon – leads to high species diversity in the area. Its inaccessibility has allowed wildlife that is often threatened elsewhere to exist in relative abundance. The Complex is thought to hold some of Gabon's most significant populations of African forest elephant (*Loxodonta cyclotis)*, western lowland gorilla (*Gorilla gorilla gorilla*), chimpanzee (*Pan troglodytes)*, hippopotamus (*Hippopotamus amphibius*), sitatunga (*Tragelaphus spekii gratus*), Nile crocodile (*Crocodylus niloticus),* and other animals that are threatened elsewhere. The diverse habitat types also allow a great variety of biodiversity, as presented in this volume, much of which is believed to occur in other similar parts of Gabon. It has been said that the Gamba Complex is an ecological microcosm of Gabon – a place whose species and habitats represent the range of the country's wildlife systems in relative intactness.

Previous ecological studies in the area include vegetation collections by the National Herbarium of Gabon (summarized for Monts Doudou in Sosef *et al*. 2004), De Bie and Geerling (1989), Reitsma (1988, 1991), Wieringa (1999); large mammal studies (Lahm 2000, Walsh and White 1999, Morgan 2000); small mammal studies (Goodman and Hutterer 2004, Nicolas *et al*. 2004); birds (Christy and Goodman 2004, WIWO 1993, Sargeant 1993); amphibians and reptiles (Burger *et al*. 2004); arthropods (van Noort 2004a and b, Prendini 2004, Fisher 2004b). Several of those studies were conducted simultaneously in the Monts Doudou region (Fisher 2004a), and other Environmental Impact Assessments conducted in oil areas (Basquin *et al*. 1991, Gabon Vert 2002, Shell Gabon 1993, de Bie and Geerling 1989).

### 2.2 Human influence

Gabon's southern coast was primarily settled by groups from present-day Congo who subsisted by hunting, fishing, gathering, and agriculture, thus playing a long-standing, important, but often "invisible" historical role in shaping the landscapes of today. Selective logging over the last century has left a matrix of secondary forest patches, especially along the coast and where access to okoumé trees was possible. Extensive seismic exploration since the 1950's led to major oil finds in 1963 and 1985, with old fields still active today and new ones under exploration. The town of Gamba arose from a tiny fishing village to support the oil industry and its support services, standing today at 7,000 inhabitants, with another 2,000 in 35 villages throughout the Gamba Complex. Infrastructure is limited, and with a few poor roads joining the rest of the country, much transport is by air and water.

Human demands on natural resources threaten the biodiversity of the Gamba Complex. Major identified threats include illegal hunting (commercial hunting of protected species or in restricted zones like national parks), offshore trawler fishing within the illegal limit of the coast, onshore fishing using illegal techniques or quotas, logging and related hunting pressures, low-standard oil operations and poor pollution response on shore and off, lack of land use planning, and lack of sustainable development strategies to provide economic alternatives to natural resource extraction (WWF 2003). Managing these threats is the work of the government, assisted by non-governmental organizations and private companies though a variety of actions including law enforcement, ecotourism, education, and research.

In 2002 the Gabonese government created two national parks in the Gamba Complex: Moukalaba-Doudou (4500 $km^2$), containing mountains rich in "refuge" biodiversity and great ape populations; and Loango (1550 $ha^2$), known for its coastal megafauna (terrestrial and marine), habitat mosaics, and ecotourism potential. Between the parks lies an original 'hunting area' (3585 $km^2$), considered an Industrial Corridor because it holds several important oil concessions (active exploitation permits cover 723 $km^2$) and associated towns and villages. With its highly natural value and intense, multiple land uses, the Gamba Complex exemplifies the conservation challenges found throughout central Africa, with great potential to realize long-term security of its forests for its people.

## 3 The Gabon Biodiversity Program

The Smithsonian Institution's Monitoring and Assessment of Biodiversity Program (SI/MAB) and Royal Dutch/Shell Group are working to encourage industry-research partnerships that promote research and conservation of biodiversity, especially in areas that require environmentally-responsible approaches to resource development and extraction (Dallmeier *et al*. this volume). In 2000, the Gabon Biodiversity

Program was initiated to provide scientific evaluation of the Gamba Complex of Protected Areas to further research in the country, and assist local oil industry and land management. In Gabon there was a need to collect fundamental science and conservation information – what species exist, and where – for many taxonomic groups that had never been surveyed. Designing the Program required assessing biodiversity knowledge and issues in the area, and building links with government, community, industry, scientific, and conservation partners. A stakeholder consultation workshop held in November 2000 aligned these perspectives with the objectives of SI/MAB and the Royal Dutch/Shell Group, and established goals for the Program:

- Increase knowledge of biodiversity within Gabon and regionally.
- Build strong links among stakeholders in Gabon, researchers, conservation scientists and industry.
- Increase in-country technical capacity for continued biodiversity work.
- Disseminate scientific findings to a wide audience.
- Advance the model for conservation and resource development through partnerships among local stakeholders, scientists and industry.

Specific study sites and issues were also determined in the workshop based on stakeholder priority. It was decided to focus half of the studies in oil concessions and half in pristine areas, with one coastal and one forest site each, in order to make statements about diversity in and out of oil development zones, and perhaps draw conclusions or make recommendations for better environmental management to the industrial sector. A literature review was conducted, remote sensing imagery analyzed, taxonomic focus groups determined, and standardized protocols defined, given the Program goals, timeline, and cost considerations. In collaboration with many national and international partners, biodiversity assessments were conducted in the Gamba Complex in 2001-2003 (Table 1). These intensive field inventories combined pure and applied research in vegetation, large and small mammals, amphibians, reptiles, aquatic systems, birds, and arthropods, resulting in the most comprehensive biodiversity assessment yet for the country, and a robust biotic baseline for long-term ecological monitoring.

To serve as a scientific base and a repository for natural history reference collections for the country, a natural history laboratory was established in Gamba – one of the few such centers for insect parataxonomy in the world (Basset *et al*. 2004 a, b). The center houses over 2200 biological reference specimens representing roughly 200 vertebrate species and 200 arthropod families, and is used for scientific research, training, and environmental education. Environmental education programs were launched in schools in collaboration with local counterparts, and technical training of local staff was incorporated throughout. Data management and analysis were largely but not exclusively handled from the U.S. In 2004-5, the Program shifted its focus from biological inventories to applied ecological research with a view to assist oil field and protected area management. Results are soon forthcoming for studies on forest fragmentation impacts (effects of logging) on biodiversity, bushmeat hunting impacts (effects of roads and management poli-

Table 1. Summary of Smithsonian-led biodiversity assessments indicating site, date and taxa studied, conducted in the Gamba Complex of Protected Areas. (Research described in the book conducted by partner organizations not included).

| Site | Date | Taxa studied |
|---|---|---|
| Greater Gamba area | Jul-Aug 2001 | large mammals, birds, amphibians, reptiles |
| Rabi | Feb-Mar 2002 | vegetation, large mammals, small mammals, birds, amphibians, reptiles |
| Toucan | Apr-May 2002 | vegetation, large mammals, small mammals, birds, amphibians, reptiles |
| Industrial corridor | Jun-Jul 2002 | aquatic vertebrates (mostly fish) |
| Greater Gamba area | July 2001-July 2002 | arthropods |
| Loango NP | Sep-Nov 2002 | vegetation, large mammals, small mammals, birds, amphibians, reptiles |
| Greater Gamba area | Nov-Dec 2002 | small mammals, amphibians, reptiles, birds |
| Greater Gamba area | Feb-Mar 2003 | fishes |
| Rabi | Mar 2003 | vegetation |
| Moukalaba-Doudou NP | Apr-Jun 2003 | vegetation, large mammals, small mammals, birds, amphibians, reptiles |

cies), the ecological connectivity of the Gamba Complex (using elephants as an indicator species), and oil field decommissioning scenarios. Results are assisting the ecological monitoring and management of the area.

The present study presents results from biodiversity assessments conducted in the Gamba Complex of Protected Areas in southwest Gabon, 2001-2003. Twenty-nine scientists and 32 technical staff from various disciplines and agencies participated in several expeditions led by Smithsonian Institution in partnership with Shell Foundation and Shell Gabon. A few chapters explain work done by colleagues or collaborators outside of the Gabon Biodiversity Program in the same period, included to document our collective state-of-knowledge of the biodiversity of the Gamba Complex. The approach was modeled in part on SI/MAB projects in Peru (Alonso *et al*. 2001, Dallmeier *et al.* 2002) and Cameroon (Comiskey *et al*. 2003), adapted for Gabon.

## 4 Study areas

Within the Gamba Complex of Protected Areas, our team of researchers investigated in detail the following study locations (see map on page xxxii, Table 1).

### 4.1 Greater Gamba Area

The greater Gamba area extends along the coastal basin from Setté Cama to the Nyanga River, including the Ndogo Lagoon. Much of the area is characterized by a prairie-woodland mosaic on white sands. Secondary forests persist in various successional stages due to historic land use along the coast, and recent forest use for plantations, fuelwood, and timber to support Gamba and surrounding villages. Bunchgrass prairies line the coast and upland hills on the southeast edge of the lagoon, maintained by annual burning, interspersed with forest blocks. The coast stretches roughly 80 km between the mouths of the Ndogo Lagoon and Nyanga River, with numerous smaller lagoons, both temporary and permanent, opening to the ocean. The Ndogo Lagoon is a large water body draining the Ndogo River and containing numerous small islands, one of which produces natural gas for local use. The area has been extensively surveyed for oil and gas by seismic campaigns. Gamba is a population center for southwest Gabon, with a community of 7,000 people, an oil facility over 40 years old, and related pressure on its natural resources. Scientific work was based at the Smithsonian biodiversity laboratory in Gamba. A network of tarmac, sand, and laterite tracks provided wider access for scientists to field locations than at other study sites.

### 4.2 Rabi

The Rabi area is a mature forest site in the north-center of the Gamba Complex, in the headwaters of the Rabi River. Its swamp and hill geography results in distinct wet and dry forest types. The area has been selectively logged since around the 1920's, mostly for okoumé wood. It was also explored extensively by seismic activity, with evidence today of a vast network of secondary forest gaps, tracks, transects, helipads, fuse wire, and concrete markers. The Rabi oil field covers a 17 km x 8 km block, intensively developed by platforms, infrastructure, and laterite roads since 1985. No communities occur in the immediate vicinity of Rabi, nor are historic communities known, and oil field workers are accommodated in an off-shore model relying heavily on air transport. An extensive road network includes a 'ring road' around the field and numerous roads accessing wellheads and work sites. This road access allowed intensive biodiversity sampling of the oil field area, and additional sampling occurred both in and out of the oil concession at further locations. Oil concession regulations restrict access, vehicle speed, hunting, and other resource uses that may influence biodiversity, while areas adjacent to the oil field are largely public lands or logging concessions.

### 4.3 Toucan

The Toucan oil field is located northeast and abutting the Rabi field, and was under oil exploration during the time of study. Since then the field has become productive and is currently being developed. A year prior to the study, a 12 km road was opened to connect Rabi to Toucan. At the time of the study, a 5 km extension was being added north of the Calao well site. No oil infrastructure existed except a test well. Although drier than Rabi because it does not contain the headwaters of a river, Toucan is ecologically similar. However, lying outside the Gamba Complex, in a logging permit, and nearer to village sites along rivers, it has faced more hunting, village use, and recent logging. Increased oil development in Toucan means that the concession might come under similar management as is applied to Rabi. Some studies in this

volume lump Rabi and Toucan as one study site, since work often overlapped the adjacent zones.

### 4.4 Loango National Park

Loango National Park covers the coastal zone between the Ngové and Ndogo lagoon mouths, extending inland over sandy beach, coastal scrub, savanna, and forest habitat types. Studies were based near the Plaine de Simone, some 12 km from the southern mouth, and covering the broad southern range of the park to 10 km inland. This study area is characterized by extensive prairie-woodland mosaics, mangrove forests and coastal scrub along the beach, with lowland moist forest reaching inland. The forest understory is characteristically open. Most of the forest in the study had not been logged or heavily disturbed, although some evidence of logging and settlements exist. No contemporary villages are known, although evidence of some recent access by villagers was noted. Major river systems are absent in the study area, but a smaller stream network converges in a swamp in the south, and, depending on rain and tidal flux, numerous small lagoons and streams open to the ocean. Nearly all access was by foot, with beachside movement to sites quick and easy.

### 4.5 Moukalaba-Doudou National Park

Moukalaba-Doudou National Park encompasses the Doudou mountain range and adjacent savannas to the east, nearly touching the coast on its southern border. Studies were largely based in the southwest corner of the park (brief herpetological studies were carried out on the east side), accessed by the Ndogo Lagoon, and representative of the area's lower elevation reaches of primary forest. Swamp forest graded into upland forest in a series of steep rises with boulders, cliffs, and granitic rock. Rocky rivers and sandy streambeds bisected the terrain, flowing eventually into the lagoon. Human signs were noted only in a few machete cuts several years old. Lacking roads, trails, beach, or river access, this site was the least accessible.

## 5 Findings

Studies were conducted on vegetation, specifically trees; medium-to-large mammals; small mammals, with emphasis on terrestrial vs. volant; amphibians; reptiles; birds; fishes; and arthropods, with emphasis on 20 targeted taxa. A synopsis by group summarizes the work performed.

### 5.1 Trees

Seventy-five (75) 0.1-ha (50 x 20 m) biodiversity research plots were established throughout Rabi, Toucan, Loango and Moukalaba-Doudou. Plots were located to include a diversity of forest types. Researchers recorded all trees greater than five cm in diameter at breast height. These data are helping scientists describe the habitats by species composition and structure (Campbell *et al*. this volume).

A preliminary analysis from all sites describes dynamic, mature forests where tree-fall gaps are common, allowing for a mix of both early and late successional species. Lianas are abundant throughout the region. Our study plots, even ones located within the active rim of oil concessions, show disturbances mostly from natural causes; however there is evidence of localized selective logging throughout. Vegetation exhibits a gradient in both species composition and structure from the coast inland, with low species diversity and high habitat diversity along the coast changing to high species diversity and lower habitat diversity inland. While the inland forests from Toucan to Moukalaba-Doudou appear structurally similar, there are distinct differences in composition related mostly to soil moisture and disturbance history.

We recorded 6,626 trees of at least 351 different species. The forests at Rabi-Toucan are the richest in species composition, with 203 species recorded at Rabi and 180 at Toucan. Common species include *Dichostemma glaucescens*, *Diogoa zenkeri*, *Klaineanthus gaboniae* and *Coula edulis*. The families Leguminosae and Euphorbiaceae dominate. While there is considerable habitat diversity at Loango, species richness is relatively low at 95 documented species and monotypic habitats are common. Common species at Loango include *Anthostema aubryanum*, *Diospyros boala*, *Garcinia smeathmannii*, *Syzygium guineense* and a yet-to-be-identified *Diospyros* species. The families Ebenaceae, Euphorbiaceae and Myrtaceae dominate. Low-elevation forests in Moukalaba-Doudou are similar to those at Rabi-Toucan and are also very species rich. Common species in that study site include *Dichostemma glaucescens*, *Diospyros*

*physocalycina*, *Englerophytum letestui* and *Thomandersia hensii*. Dominant families are Ebenaceae and Euphorbiaceae.

Orchid diversity in the Gamba Complex was summarized by Stévart and Droissart (this volume). Seventy-three (73) species are recorded, of which 20 are terrestrial and 53 epiphytic. The richest epiphytic genera were *Bulbophyllum* (12 taxa) and *Polystachya* (9 taxa); *Eulophia* (6) was the most diverse terrestrial genus. Two species collected are new for Gabon, and three lower-Guinean-endemics are new species. Orchids from Monts Doudou and those from the coastal regions fall into two different biogeographic groups. Further inventories are encouraged, as there is likely two to three times the diversity of orchids in the Gamba Complex than is currently known.

### 5.2 Fishes

We deployed a variety of non-destructive sampling techniques – gillnets, seines, hoop nets, fish traps, market surveys, electric fish detection – to investigate rivers, natural and man-made streams and marshes, an inland lake, a large lagoon, man-made pools, and flooded forest and grassy areas. Sampling occurred at 53 stations throughout the Industrial Corridor. Researchers recorded fish, aquatic reptiles, and aquatic mammals encountered to describe the vertebrate fauna in habitat types ranging from brackish to freshwater (Mamonekene *et al*. this volume).

Sixty-seven (67) fish species were found in a one-month dry-season survey of the three river systems (Mbari, Echira, and Rabi) between the Rabi concession and the Ndogo Lagoon. The most diverse families are Cichlidae (11 species), Citharinidae (8 species), Mormyridae (7 species), and Aplocheilidae (6 species). These results are high compared to similar studies in the region, demonstrating a rich fish fauna. Our species accumulation curve was still rising at the survey's end (7 species added the last day), indicating an incomplete inventory. In addition to high species richness, notable finds for this inland area include seven species of electric fishes (Mormyridae), of which two are undescribed, 1-2 potentially new species under determination, and the presence of three marine fishes (*Elops lacerta, Polydactylus quadrifilis* and *Liza falcipinnis*) that entered the lower rivers of the coastal basin some 40 km inland. The highest diversity was found in the Rabi River system, whose headwaters contain the oil field.

Eighty-five (85) fish species were found in a one-month wet-season survey of the Ndogo Lagoon and smaller coastal drainages near Gamba. The most diverse families are Aplocheilidae (10 species) and Cichlidae (9 species). Species distribution correlated with the salinity gradient, with families like Eleotridae near mangroves, salt-intolerant species of Schilbeidae and Alestiidae in interior waters, and the greatest diversity in the middle mesohaline transition zone. Streams flowing into the lagoon constitute refuges for running-water species or species sensitive to perturbation like the mormyrid *Stomatorhinus walkeri*, which was absent from streams within the Gamba oil concession. Steams and marshes with oil or organic pollution exhibited lower species richness than undisturbed courses, although some regular species (*Neolebias ansorgii*, *Clarias* spp., *Epiplatys* spp., *Hemichromis fasciatus, Ctenopoma nanum*) seem to tolerate some pollution.

### 5.3 Amphibian and reptiles

Herpetological assessments were conducted in Gamba (wet and dry season), Loango (transition), Rabi, Toucan, and Moukalaba-Doudou (all wet season). The team sampled passively with pitfall and funnel traps (min. 800 trap-nights/site), and active day and night searches, including road surveys when possible, over a range of habitat types. As Gabon's herpetofauna is poorly known, photographs were taken to document color and patterning of live specimens, and representative specimens were retained for further studies.

Researchers recorded 147 species of amphibians and reptiles in the Gamba Complex: 66 species of amphibians and 81 species of reptiles.

The amphibian fauna consists of 64 frogs and two caecilians. Another 12 frog species previously recorded in Monts Doudou (Burger *et al*. 2004) bring the total amphibian richness of the Gamba Complex to 78 species – a record for any site in Gabon (Burger *et al*. this volume). A year prior to these surveys, Gabon's total richness was 72 species (Fretey and Blanc 2000), and now stands at 96 – a 25% increase in three years – affirming the importance of intensive biodiversity surveys for understudied groups. It is also notable that nearly 80% of the country's known amphibian fauna is found in the Gamba Complex, justifying its conservation value.

The reptile fauna consists of 81 species from this survey and another 5 previously known (Maran 2002,

Burger *et al*. 2004), totalling 86 species for the Gamba Complex, the longest list of any geographic area of comparable size in Gabon (Pauwels *et al*. this volume). Among snakes, the best-represented family is Colubridae with 32 species. Ten snakes (two atractaspidids, one colubrid, three elapids, four viperids) are dangerously venomous species of medical importance. A small series of amphisbaenians (burrowing "worm lizards") collected along the Toucan-Calao road included five specimens of a species previously known only from a single specimen described a century ago. Another significant find was a large and healthy population of long-snouted crocodiles (*Crocodylus cataphractus*), a species severely endangered by overhunting and habitat destruction.

A sea turtle survey and tagging was also conducted on a 5.75-km stretch of beach near Gamba for four and a half months. Species recorded were *Dermochelys coriacea* and *Lepidochelys olivacea.* For leatherbacks, researchers observed 607 nesting tracks and 25 non-nesting tracks, peaking in January. For olive ridleys, 71 nesting and three non-nesting tracks were observed, peaking in late November and early December. This study serves as an important baseline on sea turtle frequencies and monitoring will continue in successive seasons (Billes *et al*. this volume).

### 5.4 Birds

Bird assessments employed a combination of auditory/visual surveys in all major habitats at each of the five sites, and mist-netting in the understory. Surveys were conducted on foot mostly diurnally, but also at night for owls, nightjars, and other nocturnal species. Mist-netting was conducted to obtain data on furtive and non-vocal species, breeding condition and molt, genetic and parasite condition, and for baseline information on capture rates for long-term monitoring.

A total of 317 species was recorded: 158 species at Gamba, 204 at Rabi-Toucan, 203 at Loango National Park, and 177 at Moukalaba-Doudou National Park. In combination with Sargeant (1993) and Christy (2001), this brings the Gamba Complex's bird list to 455 species, representing 67% of Gabon's known avifauna. Significant records include range extensions within Gabon for nine species, first published specimen records from Gabon for two species, and records of other rare or threatened species for the Gamba Complex (Angher *et al*. this volume).

Mist-nets recorded 72 species. The highest capture rates were in natural edge habitats in Loango, perhaps partly due to movement along the habitat interface. Wet areas generally had higher rates than dry. Sites with human disturbance were within the range of natural sites. Species composition correlated with habitat, with coastal sites different from other non-forested sites, and high repetition in captured species within forest sites (74% of individuals captured in the 17 forest sites were of the same eight species).

### 5.5 Mammals

Terrestrial mammal studies used several techniques including observational surveys during day and night for arboreal and terrestrial medium-to-large sized mammals; camera traps baited with scent lures targeting elusive mid-sized mammals; a battery of pitfall, Sherman live-, and snap-traps for terrestrial small mammals; and mist-netting at night for bats. All techniques were used in each study area except mist-netting, which was restricted to Rabi. The range of habitat types was inspected at each study area (O'Brien *et al*. this volume, Lahm and Tezi this volume, Boddicker this volume, and Rodriguez *et al*. this volume), while laboratory studies were carried out afterwards (Primus *et al*. this volume).

Seventy–six mammal species were recorded throughout the Gamba Complex, 21 small species, 13 bats, and 42 medium-to-large sized species.

Small terrestrial mammals included 12 rodents and nine insectivores. In general a similar suite of species was found at each survey location, yet there was a definite coastal-inland gradient, with coastal sites containing only 60% the species richness of the inland sites. All shrews found are terrestrial and nocturnal except the giant otter shrew (*Potamogale velox*), which is aquatic and was found in a forest stream, and the golden mole (*Chlorotalpa leucorhina*), which is adapted for subterranean burrowing; both species are rare and exceptional finds. Rodent species composition seemed to shift along a coast-inland gradient, with coastal sites dominated by a single species, and several species were found only at inland sites, although others were more evenly distributed.

Thirteen species of bats were located in a one-month survey of the Rabi field, six Megachiroptera and seven Microchiroptera. A larger number of fruit bats was found, perhaps influenced by the difficulty of mist-netting insect-eating bats due to their echolo-

cating ability. Karyotype analysis was conducted on 17 selected species of bats, rodents and shrews to compare genetic variation with other collections of species in the region (Rodriguez *et al*. this volume).

Large mammal surveys used a variety of observation techniques paired with camera trapping. One team employed transect observations, including some nocturnal surveys; the other employed transect observations with camera trapping for photographic capture. Among the species of medium-to-large mammals are the chimpanzee, western gorilla, seven species of monkey, four species of bushbaby, six species of squirrel, swamp otter, seven species of mongoose, African civet, African palm civet, African golden cat, leopard, tree pangolin, aardvark, western tree hyrax, African forest elephant, hippopotamus, red river hog, water chevrotain, African forest buffalo, sitatunga, and eight species of duiker (Lahm and Tezi, this volume; Boddicker, this volume).

Marine mammals migrate to the equatorial waters of Gabon from the Antarctic region between July and September. Whale surveys were conducted by boat from various points on the coast of Gabon between 2000-2003. In those four seasons, the team worked with 857 whale groups, using transect surveys and genetic markers, leading to the identification of 800 individual whales. Thirty-seven (37) percent of groups were pairs, and 34% were competitive groups, typically indicating significant breeding activity. Genetic samples currently in analysis will determine sex, maternal lineage and relatedness, and help researchers understand how social organization and group formation effects breeding behavior (Rosenbaum and Collins, this volume).

### 5.6 Arthropods

Arthropod diversity was evaluated in a one-year study of four habitat types in the Greater Gamba Area to improve taxonomic and ecological knowledge of arthropods in the region. The study addressed 20 target taxa, with other specimens examined in biological reference collections. One objective was to compare and contrast insect communities found in four habitats – old secondary forest, young secondary forest, grassland around oil wells and cultivated gardens. These habitats were chosen to represent the broad ecological conditions and levels of human disturbance encountered around Gamba. A second objective was to assemble an arthropod reference collection for the country with a trained local parataxonomist staff. The reference collection, unique to the region, is intended to support the training of Gabonese and international researchers in the collection, identification and understanding of arthropods, and to bring value to their important ecological role in nature and the community – from pollination to decomposition to disease transmission.

Sampling was conducted with an array of passive-capture traps targeting different groups that move about in nature in different ways: malaise and canopy malaise traps for flying insects; yellow pan traps for low-flying insects; and pitfall traps for terrestrial insects. Traps were activated three days per week, and specimens were sorted, identified to morpho-species, mounted and entered into the data base each week for a year, concluding in July 2002.

Identifications are still being determined. The team examined 440,000 individuals, including 20,000 professionally prepared specimens, accumulated representatives of nearly 200 different families in its reference collections and published two manuscripts to date (Basset *et al*. 2004a,b).

## 6 Conclusions

The present study helps fill a knowledge gap on the biodiversity in Gabon. These studies represent the first baseline inventories for the Gamba Complex for fishes, bats, whales, orchids, amphibians, reptiles and arthropods, and an increase in knowledge and collections for sea turtles, vegetation, terrestrial small mammals, large mammals and birds. Although it is the most taxonomically-inclusive study we know of in a short time in Gabon, it is not exhaustive but rather illustrative of the diversity of organisms found in coastal and lowland forest ecosystems in the region.

Baseline data using standard assessment protocols provide a solid scientific foundation for biodiversity monitoring. Monitoring ecological trends is important for land managers who seek to understand and handle changes in resource condition over time. Certain data on species distribution in different habitat types and human-impact zones allow application to ecological monitoring. In 2004-5, SI/MAB is conducting applied research in the Industrial Corridor on ecological connectivity, forest fragmentation, and ecological monitoring. Combined results from these studies, with the results of the inventories and biodi-

versity distributions in the Complex, are being applied towards an ecological monitoring plan to assist conservation management (Dallmeier *et al.* this volume).

Building experience and capacity among institutions and individuals is important to the sustainability and success of conservation science practitioners. We were pleased to include six national institutions, 10 international institutions, 34 national collaborators and 33 international collaborators in the course of study, and thank them for their contributions. We are also working towards training for scientists, eco-guides, and research managers at the biodiversity laboratory base, so that collaboration in conservation, research and training can grow in the region.

## References


Alonso, A., F. Dallmeier and P. Campbell. 2001. *Urubamba: The Biodiversity of a Peruvian Rain Forest*. SI/MAB Series # 7, Smithsonian Institution, Washington, D.C., 204 p.

Angehr, G., B. Schmidt, F. Njie, P. Christy, C. Gebhard, L. Tchignoumba and M. Ombenotori. 2006. Bird surveys in the Gamba Complex of Protected Areas, Gabon. *In*: Alonso, A., M.E. Lee, P. Campbell, O.S.G. Pauwels and F. Dallmeier, eds., *Gamba, Gabon: Biodiversity of an Equatorial African Rainforest*. Bulletin of the Biological Society of Washington, No. 12.

Anonymous. 2002. *Les Parcs Nationaux du Gabon: Stratégie pour le Troisième Millénaire*. Multipress, Libreville, Gabon.

Basset, Y., J. Mavoungou, J.B. Mikissa, O. Missa, S. Miller and A. Alonso-M. 2004a. Discriminatory power of different arthropod data sets for the biological monitoring of anthropogenic disturbance in tropical forests. *Biodiversity and Conservation* 13:709-732.

Basset, Y., V. Novotny, S. Miller, G.D. Weiblen, O. Missa and A.A. Stewart. 2004b. Conservation and biological monitoring of tropical forests: the role of parataxonomists. *Journal of Applied Ecology* 41:163–174.

Basquin, P., G. van Beek, P. Christy, B. Clist, R. Guicherit, S. Lahm, A. Moungazi, J. Reitsma, H. Waardenburg, L. White and C. Wilks, eds., 1991. *Maguelou: An Environmental Study of the Ofoubou Area for Dupont*, E & P No. 8 BV.

Billes, A., B. Huijbregts, J. Marmet, A. Mounguengui, J.C. Mamfoumbi and C. Odzeano. 2006. Nesting of sea turtles in the Gamba Complex of Protected Areas: first monitoring of a nesting beach. *In*: Alonso, A., M.E. Lee, P. Campbell, O.S.G. Pauwels and F. Dallmeier, eds., *Gamba, Gabon: Biodiversity of an Equatorial African Rainforest*. Bulletin of the Biological Society of Washington, No. 12.

Boddicker, M.L. 2006. Large mammals encountered in the Gamba Complex of Protected Areas, Gabon. *In*: Alonso, A., M.E. Lee, P. Campbell, O.S.G. Pauwels and F. Dallmeier, eds., *Gamba, Gabon: Biodiversity of an Equatorial African Rainforest*. Bulletin of the Biological Society of Washington, No. 12.

Breteler, F.J. 1996. Tropical Africa, especially Gabon. Pp. 39-49 *in*: Breteler, F.J. and M.S.M. Sosef, eds., *Herbarium Vadense 1896-1996*. Wageningen Agricultural University Papers 96-2.

Burger, M., W.R. Branch and A. Channing. 2004. Amphibians and Reptiles of Monts Doudou, Gabon: Species Turnover along an Elevational Gradient. Pp. 145-186 *in* Fisher, B.L., ed., *Monts Doudou, Gabon: A Floral and Faunal Inventory with Reference to Elevational Variation*. Number 28, Memoirs of the California Academy of Sciences, San Francisco, CA.

Burger, M., O.S.G. Pauwels, W.R. Branch, E. Tobi, J. Yoga and E. Mikolo. 2006. An assessment of the amphibian fauna of the Gamba Complex of Protected Areas, Gabon. *In*: Alonso, A., M.E. Lee, P. Campbell, O.S.G. Pauwels and F. Dallmeier, eds., *Gamba, Gabon: Biodiversity of an Equatorial African Rainforest*. Bulletin of the Biological Society of Washington, No. 12.

Campbell, P., P. Rivera, D. Thomas, H. Bourobou-Bourobou, T. Nzabi, A. Alonso and F. Dallmeier. 2006. Floristic structure, composition and diversity of an equatorial forest in Gabon. *In*: Alonso, A., M.E. Lee, P. Campbell, O.S.G. Pauwels and F. Dallmeier, eds., *Gamba, Gabon: Biodiversity of an Equatorial African Rainforest*. Bulletin of the Biological Society of Washington, No. 12.

Christy, P. 2001. Gabon. *In*: Fishpool, L.D.C. and M.I. Evans, eds., *Important Bird Areas in Africa and Its Associated Islands: Priority Sites for Conservation*. Pisces Publications and BirdLife International, Newbury and Cambridge, UK.

Christy, P., R. Jaffré, O. Ntougou and C. Wilks. 2003. La forêt et la filière bois au Gabon. Libreville, Gabon, 389 p.

Christy, P. and S.M. Goodman. 2004. The birds of Monts Doudou, southwestern Gabon. Pp. 129-144 *in*: Fisher, B.L., ed., *Monts Doudou, Gabon: A Floral and Faunal Inventory with Reference to Elevational Variation*. Number 28, Memoirs of the California Academy of Sciences, San Francisco, CA.

Collomb, J.G., J.B. Mikissa, S. Minnemeyer-Mudunga, H. Nzao Nzao, J. Madouma, J.D. Mapaga, C. Mikolo, N. Rabenkogo, S. Akagah, E. Bayani-Ngoye, A. Mofouma. 2000. *A first look at logging in Gabon*. Global Forest Watch, World Resources Institute, Washington, D.C.

Comiskey, J., T.C.H. Sunderland and J.L. Sunderland-Groves. 2003. *Takamanda: the Biodiversity of an African Rainforest*. SI/MAB Series # 8, Smithsonian Institution, Washington, D.C., 182 p.

Dallmeier, F., A. Alonso and P. Campbell. 2002. Biodiversity monitoring and assessment for adaptive management: linking conservation and development. *Environmental Monitoring and Assessment* (Special Issue) 76:1-156.

Dallmeier, F., A. Alonso, P. Campbell, M.E. Lee, R. Buij and O.S.G. Pauwels. 2006. Ecological indicators for the Industrial Corridor in the Gamba Complex of Protected Areas: A zone of high biodiversity value and oil exploitation in southwest Gabon. *In*: Alonso, A., M.E. Lee, P. Campbell, O.S.G. Pauwels and F. Dallmeier, eds., *Gamba, Gabon: Biodiversity of an Equatorial African Rainforest*. Bulletin of the Biological Society of Washington, No. 12.

de Bie, S. and C. Geerling. 1989. *Ecological Baseline Study for Oilfield Development*. Nature Conservation Department, Agriculture University Wageningen, the Netherlands.

Emmons, L.H., A. Gautier-Hion and G. Dubost. 1983. Community structure of the frugivorous-folivorous forest animals of Gabon. *Journal of Zoology, London*: 199:209-222.

Environmental Resources Management. 1999. Impact assessment of the Bilinga concession seismic programme: Gabon. Shell Gabon, 183 p.

Fay, J.M. and M. Nichols. 2004. Land of the Surfing Hippos. *National Geographic Magazine*, August.

Fisher, B.L., ed. 2004a. *Monts Doudou, Gabon: A Floral and Faunal Inventory with Reference to Elevational Variation*. Number 28, Memoirs of the California Academy of Sciences, San Francisco, CA.

Fisher, B.L. 2004b. Diversity pattern of ants (Hymenoptera: Formicidae) along an elevational gradient on Monts Doudou in southwestern Gabon. Pp. 269-286 *in*: Fisher, B.L., ed., *Monts Doudou, Gabon: A Floral and Faunal Inventory with Reference to Elevational Variation.* Number 28, Memoirs of the California Academy of Sciences, San Francisco, CA.

Frétey, T. and C.P. Blanc. 2000. *Les Amphibiens d'Afrique Centrale, Liste faunistique, ADIE*, Libreville, Gabon, 40 p.

Gabon Vert. 2002. *An Environmental Impact Assessment for the Toucan Oil Site*. Unpublished report, Gabon Vert, Libreville, Gabon.

Goodman, S.M. and R. Hutterer. 2004. A report on the shrews (Mammalia: Soricidae) of Monts Doudou, Gabon: elevational distribution and preliminary insights into their ecology. Pp. 93-105 *in*: Fisher, B.L., ed., *Monts Doudou, Gabon: A Floral and Faunal Inventory with Reference to Elevational Variation*. Number 28, Memoirs of the California Academy of Sciences, San Francisco, CA.

Kamdem-Toham A, A.W. Adeleke, N.D. Burgess, R. Carroll, J. D'Amico, E. Dinerstein, D.M. Olson and L. Some. 2003. Forest conservation in the Congo Basin. *Science* 299:346.

Lahm, S.A. 2000. *A Zoological Study at the Elf Atora Drilling Site, Southwestern Gabon.* Unpublished report, Gabon Vert, Libreville, Gabon.

Lahm, S.A. and J.P. Tezi. 2006. Assessment of the communities of medium-sized and large arboreal and terrestrial mammals in the Rabi/Toucan region of the Ngové-Ndogo hunting domain and southwestern Loango National Park. *In*: Alonso, A., M.E. Lee, P. Campbell, O.S.G. Pauwels and F. Dallmeier, eds., *Gamba, Gabon: Biodiversity of an Equatorial African Rainforest*. Bulletin of the Biological Society of Washington, No. 12.

Laurance, W., A. Alonso, M. Lee, and P. Campbell. In press. Challenges to forest conservation in Gabon, Central Africa. *Futures.*

Lemoalle, J. and J.J. Albaret. 1995. *Vevy lagoon and Ndogo lagoon: an environmental appraisal*. ORSTOM and Shell Gabon, 18 p.

Letouzey, R. 1968. Etude phytogéographique du Cameroun. Encyclopédie biologique 69, Paul Lechevalier, France.

Mamonekene, V., S. Lavoué, O.S.G. Pauwels, J.H. Mve Beh, J.E. Mackayah and L. Tchignoumba. 2006. Fish diversity at Rabi and Gamba, Ogooué-Maritime, Gabon. *In*: Alonso, A., M.E. Lee, P. Campbell, O.S.G. Pauwels and F. Dallmeier, eds., *Gamba, Gabon: Biodiversity of an Equatorial African Rainforest*. Bulletin of the Biological Society of Washington, No. 12.

Maran, J. 2002. Les tortues continentales du Gabon. *La Tortue* 58-59: 46-67.

Morgan, B.J. 2000. *Ecology of Mammalian Frugivores in the Réserve de Faune de Petit Loango, Gabon*. PhD dissertation, University of Cambridge, 253 p.

Nicolas, V., P. Barrière, S. Guimondou and M. Colyn. 2004. Variabilité structurale des peuplements forestièrs de rongeurs (Muridae) et musaraignes (Soricidae) dans les Monts Doudou. Pp. 107-127 *in*: Fisher, B.L., ed., *Monts Doudou, Gabon: A Floral and Faunal Inventory with Reference to Elevational Variation*. Number 28, Memoirs of the California Academy of Sciences, San Francisco, CA.

O'Brien, C., W. McShea, S. Guimondou, P. Barrière and M. Carleton. 2006. Terrestrial small mammals (Soricidae and Muridae) from the Gamba Complex in Gabon: species composition and comparison of sampling techniques. *In*: Alonso, A., M.E. Lee, P. Campbell, O.S.G. Pauwels and F. Dallmeier, eds., *Gamba, Gabon: Biodiversity of an Equatorial African Rainforest*. Bulletin of the Biological Society of Washington, No. 12.

Oslisly, R. 2001. The History of Human Settlement in the Middle Ogooué Valley (Gabon): Implications for the Environment. Pp. 101-118 *in*: Weber, W., L.J.T. White, A. Vedder and L. Naughton-Treves, eds., *African Rain Forest Ecology and Conservation: An Interdisciplinary Perspective*. Yale University Press, New Haven and London.

Pauwels, O.S.G., M. Burger, W.R. Branch, E. Tobi, J. Yoga and E. Mikolo. 2006. Reptiles of the Gamba Complex of Protected Areas, southwestern Gabon. *In*: Alonso, A., M.E. Lee, P. Campbell, O.S.G. Pauwels and F. Dallmeier, eds., *Gamba, Gabon: Biodiversity of an Equatorial African Rainforest*. Bulletin of the Biological Society of Washington, No. 12.

Prendini, L. 2004. On the scorpions of Gabon and neighboring countries, with a reassessment of the synonyms attributed to *Babycurus buettneri* Karsch and a redescription of *Babycurus melanicus* Kovařik. Pp. 235 – 267 *in*: Fisher, B.L., ed., *Monts Doudou, Gabon: A Floral and Faunal Inventory with Reference to Elevational Variation*. Number 28, Memoirs of the California Academy of Sciences, San Francisco, CA.

Primus, A., J. Harvey, S. Guimondou, S. Mboumba, R. Ngangui, F. Hoffman, R. Baker, and C. Porter. 2006. Karyology and chromosomal evolution of some small mammals inhabiting the rainforest of the Rabi oilfield, Gabon. *In*: Alonso, A., M.E. Lee, P. Campbell, O.S.G. Pauwels and F. Dallmeier, eds., *Gamba, Gabon: Biodiversity of an Equatorial African Rainforest*. Bulletin of the Biological Society of Washington, No. 12.

Quammen, D. and M. Nichols. 2002. Megatransect 3: End of the line. *National Geographic Magazine*, August.

Quammen, D. and M. Nichols. 2003. Saving Africa's Eden. *National Geographic Magazine*, September.

Reitsma, J.M. 1988. Végétation Forestière du Gabon: Forest Vegetation of Gabon. *Tropenbos* Technical Series 1, The Tropenbos Foundation, Ede, The Netherlands.

Reitsma, J. 1991. Vegetation: transect plots. *In*: Basquin, P., G. van Beek, P. Christy, B. Clist, R. Guicherit, S. Lahm, A. Moungazi, J. Reitsma, H. Waardenburg, L. White and C. Wilks, eds., Maguelou: An Environmental Study of the Ofoubou Area for Dupont E & P No. 8 BV.

Rodriguez, R.M., F.G. Hoffmann, C.A. Porter and R.J. Baker. 2006. The bat community of the Rabi Oilfield in the Gamba Complex of Protected Areas, Gabon. *In*: Alonso, A., M.E. Lee, P. Campbell, O.S.G. Pauwels and F. Dallmeier, eds., *Gamba, Gabon: Biodiversity of an Equatorial African Rainforest*. Bulletin of the Biological Society of Washington, No. 12.

Rosenbaum, H. and T. Collins. 2006. The ecology, population characteristics and conservation efforts for Humpback Whales (*Megaptera novaeangliae*) on their wintering grounds in the coastal waters of Gabon. *In*: Alonso, A., M.E. Lee, P. Campbell, O.S.G. Pauwels and F. Dallmeier, eds., *Gamba, Gabon: Biodiversity of an Equatorial African Rainforest*. Bulletin of the Biological Society of Washington, No. 12.

Ross, R.J. 2004. Under the Canopy: Advancing Conservation in Gabon. *Africa Geographic*, August.

Sargeant, D. 1993. A birders guide to Gabon, West Africa. Self-published.

Shell Gabon. 1993. *Rabi Phase II Environmental Statement*. Unpublished report, Gamba, Gabon.

Sosef, M.S.M, Y. Issembe, H.P. Bourobou Bourobou and W.J.M. Koopman. 2004. Botanical Diversity of the Pleistocene Forest Refuge Monts Doudou. Pp. 17-91 *in*: Fisher, B.L., ed., *Monts Doudou, Gabon: A Floral and Faunal Inventory with Reference to Elevational Variation*. Number 28, Memoirs of the California Academy of Sciences, San Francisco, CA.

Stévart, T. and V. Droissart. 2006. Diversity of orchids in the Gamba Complex, Gabon. *In*: Alonso, A., M.E. Lee, P. Campbell, O.S.G. Pauwels and F. Dallmeier, eds., *Gamba, Gabon: Biodiversity of an Equatorial African Rainforest*. Bulletin of the Biological Society of Washington, No. 12.

Thibault, M., B.L. Fisher and S.M. Goodman. 2004. Description of Monts Doudou, Gabon, and the 2000 Biological Inventory of the Reserve. Pp. 3-15 *in*: Fisher, B.L., ed., *Monts Doudou, Gabon: A Floral and Faunal Inventory with Reference to Elevational Variation*. Number 28, Memoirs of the California Academy of Sciences, San Francisco, CA.

van Noort, S. 2004a. Ichneumonid (Hymenoptera) diversity. Pp. 187-216 *in*: Fisher, B.L. (ed). *Monts Doudou, Gabon: A Floral and Faunal Inventory with Reference to Elevational Variation*. Number 28, Memoirs of the California Academy of Sciences, San Francisco, CA.

van Noort, S. 2004b. Agaonid (Hymenoptera) diversity. Pp. 217-233 *in*: Fisher, B.L., ed., *Monts Doudou, Gabon: A Floral and Faunal Inventory with Reference to Elevational Variation*. Number 28, Memoirs of the California Academy of Sciences, San Francisco, CA.

Walsh, P.D. and L.J.T. White. 1999. What it will take to monitor forest elephant populations. *Conservation Biology* 13:1194-1203.

Walsh, P.D., K.A. Abernethy, M. Bermejo, R. Beyers, P. De Wachter, M.E. Akou, B. Huijbregts, D. Idiata Mambounga, A. Kamdem Toham, A.M. Kilbourn, S.A. Lahm, S. Latour, F. Maisels, C. Mbina, Y. Mihindou, S. Ndong Obiang, E. Ntsame Effa, M.P. Starkey, P. Telfer, M. Thibault, C.E.G. Tutin, L.J.T. White and D.S. Wilkie. 2003. Catastrophic ape decline in western equatorial Africa. *Nature* 422:611-614.

Ward, C., M. Lee, F. Dallmeier and A. Alonso. 2003. *The Edge of Africa / Gabon: Paradis de la Biodiversité.* Hylas Publishing, N.Y.

Ward, C. and M.Lee. 2004. Secrets of the Forest. *Africa Geographic*, August.

White, F. 1983. *The Vegetation of Africa, a descriptive memoir to accompany the UNESCO/ AETFAT/ UNSO vegetation map of Africa.* Natural Resources Research. UNESCO, Paris, France.

White, L.J.T. 2001 The African Rain Forest: Climate and Vegetation. Pp. 3–29 *in*: Weber, W., L.J.T. White, A. Vedder and L. Naughton-Treves, eds., *African Rain Forest Ecology and Conservation: An Interdisciplinary Perspective*. Yale University Press, New Haven and London.

Wieringa, J. 1999. *Monopetalanthus* exit. A systematic study of *Aphanocalyx*, *Bikinia*, *Icuria*, *Michelsonia* and *Tetraberlinia* (Leguminosae, Caesalpinioideae). PhD Thesis, dissertation number 2686, Wageningen Agricultural University, The Netherlands.

Wilkie, D.S. and N. Laporte. 2001. Forest Area and Deforestation in Central Africa. Pp. 119-139 *in*: Weber, W., L.J.T. White, A. Vedder and L. Naughton-Treves, eds., *African Rain Forest Ecology and Conservation: An Interdisciplinary Perspective.* Yale University Press, New Haven and London.

WIWO. 1993. Coastal waterbirds in Gabon – Winter 1992. WIWO, The Netherlands.

WWF. 2003. *Strategy for the Management of the Gamba Complex of Protected Areas, Gabon*, 2003-2008. Unpublished draft.