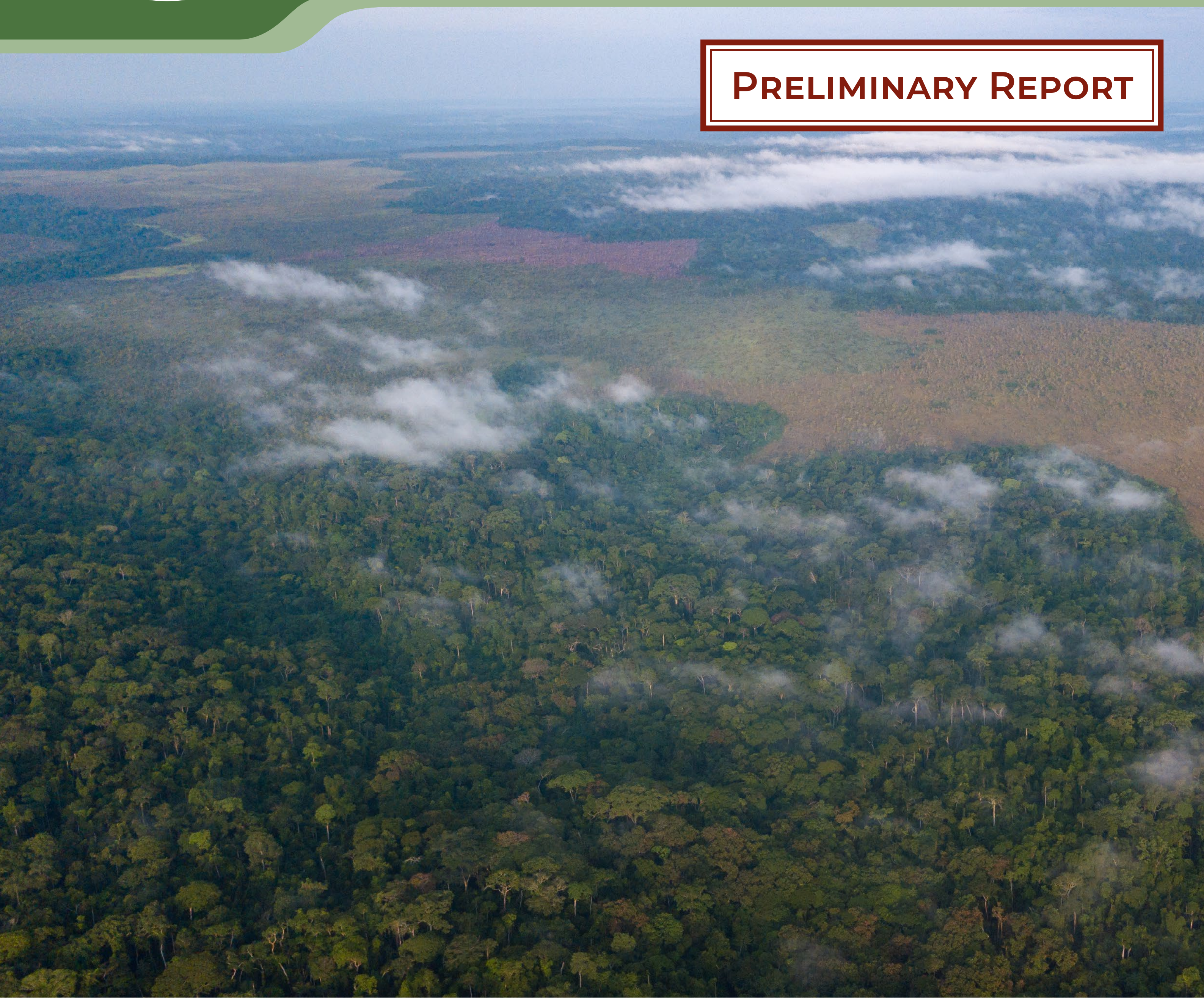
Biodiversity Express Survey

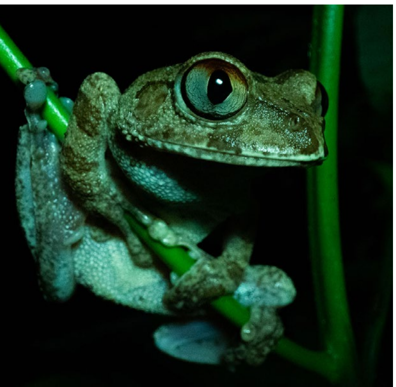
Malebo expedition,

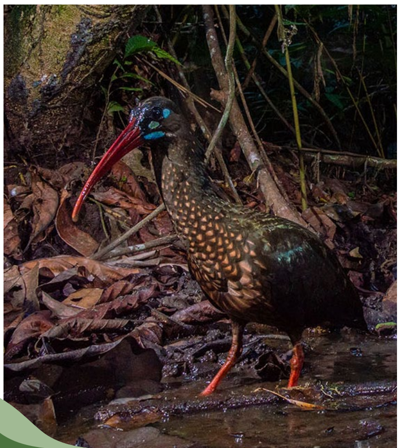
Mai-Ndombe, DRC

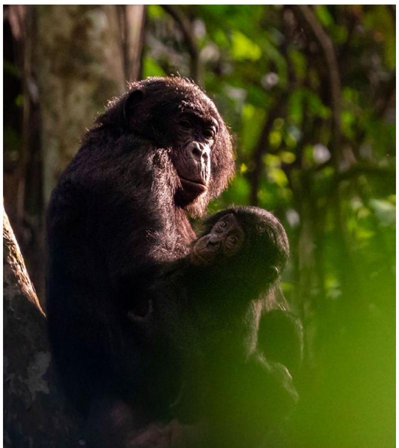
OCTOBER 2021

PRELIMINARY REPORT









BINCO
Biodiversity Inventory for Conservation

BES 10.0

Biodiversity Express Survey (BES) 10.0
The Malebo Expedition, Mai-Ndombe, DRC, October 2021
Biodiversity Inventory for Conservation (BINCO)
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Cover pictures
1. Aerial image of the forest and savannah matrix (Photo by Niklas Weber)
2. Leptopelis ocellatus (Photo by Niklas Weber)
3. Spot-breasted Ibis (*Bostrychia rara*) (Photo by Niklas Weber)
4. Bonobo (*Pan paniscus*) (Photo by Niklas Weber)
5. Mud-puddling butterflies (Photo by Niklas Weber)

Biodiversity Express Surveys (BES) are snapshot biodiversity studies of carefully selected regions. Expeditions typically target understudied and/or threatened areas with an urgent need for more information on the occurring fauna and flora. The results are presented in an Express Report that is made publicly available online for anybody to use and can be found at www.binco.eu. Teams consist of a small number of international specialists and local scientists. Results presented in express reports are dynamic and will be updated as new information on identifications from the survey becomes available.

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EXPEDITION FACT SHEET

Location

Four sites in the target project area (Malebo, Mai-Ndombe, DRC) were visited (WGS84):

1. WWF Station Malebo, 455 masl (S -2.457076, E 16.483474).
2. Camp 1: Bopambu Forest, part of Nkombo forest, 356 masl (S -2.43763, E 16.63943).
3. Camp 2: Lekuma Forest, part of Nkombo forest, 314 masl (S -2.53089, E 16.81898).
4. Camp 3: Mongama forest, 347 masl (S -2.65178, E 16.59856).

Time in the field

6 October - 28 october (22 days)

Expedition Members

Booto, Junior	Camp & logistics manager (DRC)
Ekani, Justin	Camp & logistics manager (DRC)
Erens, Jesse	Herpetologist (Netherlands)
Jamie, Gabriel, Dr.	Ornithologist (UK)
Jocque, Merlijn, Dr.	Expedition leader (Entomologist/Herpetologist) (Belgium)
Jones, Samuel, Dr.	Ornithologist (UK)
Mbende, Menard	Co-expedition leader (DRC)
Mertens, Jan	Entomologist (Belgium)
van Berkel, Tim	Mammalogist (Netherlands)
Weber, Niklas	Wildlife Photographer (Germany)

Permits

Export permit for biological samples issued to BINCO by the Ministère de l'environnement et développement durable, secrétariat général à l'environnement et développement durable, le secrétaire général, Kinshasa, 15 september 2021, N° 007/ANCCB-RDC/SG-EDD/BTB/09/2020.

Financial and logistical support:

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ACKNOWLEDGEMENTS

We would like to thank Pauwel de Wachter, Guy Kayembe, Martin Kabaluapa, Jennifer Hacking, Nima Raghunathan, Kouane Paul Ngoran, Isabelle Vertriest, Nicolas Tubbs for the opportunity to collaborate to the ongoing WWF projects in DRC and help conserve some of the truly unique ecosystems and its wildlife on this planet. The current expedition was made possible by the help of a long list of people, to which we owe our most sincere thanks especially for preparing the fieldwork. These include; Laurence Hanon, Inoussa Njomboket, Jerome Laycock and Samy Matungila in the early stages of preparation, Wouter Dekoninck from the RBINS for pre-expedition advice, Daniel Malalu, Fifi Mukanda, Jean Mutamba and the whole WWF team in Kinshasa, DRC for their tireless 24/7 help to accommodate the expedition plans, Amy Porter for advice and information on the site, Lore Geeraert for help with the maps in the report. We extend our thanks to the many local people that guided us through their forests as guides and porters. Especially to Willy Mbemba, Junior Batangeli and Vedas Ngwanza for their superb support in the field and the wonderful meals. We thank the commune chiefs of Mbanzi, Louvua, and Mongama, for allowing us to conduct research in their respective regions.

SUMMARY

The Congo Basin is the huge green heart of the African continent characterised by exceptional biological richness and a number of flagship species of conservation importance such as the bonobo. Increasing demographic and economic development has placed increasing pressure on these biological resources, accelerating mining and logging activities as well as the burgeoning bushmeat trade. For effective protection of these biological resources, it is fundamental to obtain an understanding of species presence and distributions across the Congo Basin. As in many parts of tropical Africa, the biodiversity of the Democratic Republic of Congo remains poorly studied.

In support of ongoing WWF DRC and WWF Belgium conservation action in the country, we sought to better understand and update the biological knowledge of the Malebo region (Mai-Ndombe province) by undertaking a rapid multi-disciplinary biological inventory. Our main aims included trialling drone-based thermal imaging to detect bonobos (*Pan paniscus*), and landscape scale biodiversity surveys with attention to both forest and savannah habitats. We undertook fieldwork at four study sites between 6 - 28 October 2021 with the specific intention of crossing the dry/wet seasonal divide. We collected data on birds, mammals, amphibians, reptiles, and selected invertebrate groups (butterflies, hawkmoths and emperor moths, dragonflies, spiders and ground beetles).

During the survey we detected bonobos sleeping in their nests with drone-based thermal imaging for the very first time. Additional research and capacity building is needed to further develop this survey method. However, this proof of concept opens new avenues of data collection with significant application for the monitoring and conservation of this endangered species.

We recorded 158 species of birds, 40 species of herpetofauna, 27 mammal species and a to-be-confirmed number of invertebrate species in the Malebo region. Our findings include several species with conservation concern such as grey parrot (IUCN listed as Endangered) and dwarf crocodile (IUCN listed as Vulnerable). Species accumulation curves for all of the studied groups showed no sign of plateauing. We also identified several range extensions of varying significance including Grey-throated Rail (*Canirallus oculeus*), Zenker's Honeyguide (*Melignomon zenkeri*), Lemon-bellied Crombec (*Sylvietta denti*), Bates's Sunbird (*Cinnyris batesi*), Woodhouse's Antpecker (*Parmoptila woodhousei*), and *Hyperolius* cf. *veithi*. Pending confirmation, we also potentially recorded Forest Swallow (*Hirundo fuliginosa*) for the first time in DRC. In addition, we also obtained ecological information and documented sounds and images for several species for the first time in the field. Preliminary analysis of the collected samples indicates the potential presence of several species new for science, but these require confirmation.

In our survey, forest and savannah habitats both contributed to the landscape diversity, with species unique to both habitats observed. A larger proportion of the observed large mammals, herpetofauna and invertebrates was unique to forested habitats.

The Malebo region and its community forests are, at the moment of writing, largely intact in terms of its biological components and key species (still) present. We collected evidence, however, to suggest that the situation is changing. The region is at a critical stage from which to refine and extend the conservation priorities to include more species-specific conservation initiatives and sustainably manage its forest and savannah ecosystems.

RÉSUMÉ

Le bassin du Congo est l'immense cœur vert du continent africain caractérisé par une richesse biologique exceptionnelle. Le développement démographique et économique croissant a exercé une pression croissante sur ces ressources biologiques, accélérant les activités minières et forestières ainsi que la pression de chasse. Pour une protection efficace de ces ressources biologiques, il est fondamental de comprendre la présence et la répartition des espèces dans le bassin du Congo. Comme dans de nombreuses régions d'Afrique tropicale, la biodiversité de la République Démocratique du Congo reste peu étudiée.

En appui aux actions de conservation en cours du WWF RDC et du WWF Belgique dans le pays, nous avons cherché à mieux comprendre et actualiser les connaissances biologiques de la région de Malebo (province du Mai-Ndombe) en entreprenant un inventaire biologique multidisciplinaire rapide. Nos principaux objectifs comprenaient la mise à l'essai de l'imagerie thermique par drone pour détecter les bonobos (*Pan paniscus*) et des études de biodiversité à l'échelle du paysage en portant une attention particulière aux habitats forestiers et de savane. Nous avons entrepris des suivis sur quatre sites d'étude entre le 6 et le 28 octobre 2021 avec l'intention spécifique de franchir le fossé saisonnier sec/humide. Nous avons collecté des données sur les oiseaux, les mammifères, les amphibiens, les reptiles et certains groupes d'invertébrés (papillons, sphinx et papillons empereurs, libellules, araignées et carabes).

Au cours de l'enquête, nous avons détecté pour la toute première fois des bonobos dormant dans leurs nids grâce à l'imagerie thermique par drone. Des recherches supplémentaires et un renforcement des capacités sont nécessaires pour développer davantage cette méthode d'enquête. Cependant, cette preuve de concept ouvre de nouvelles voies de collecte de données avec une application significative pour le suivi et la conservation de cette espèce en voie de disparition.

Nous avons enregistré 158 espèces d'oiseaux, 40 espèces d'herpétofaune, 27 espèces de mammifères et un nombre à confirmer d'espèces d'invertébrés dans la région de Malebo. Nos découvertes incluent plusieurs espèces dont la conservation est préoccupante, telles que le perroquet gris (UICN répertorié comme En danger) et le crocodile nain (UICN répertorié comme Vulnérable). Les courbes d'accumulation d'espèces pour tous les groupes étudiés n'ont montré aucun signe de plafonnement. Nous avons également identifié plusieurs extensions d'aire de répartition d'importance variable, notamment le Râle à gorge grise (*Canirallus oculeus*), l'Indicateur de Zenker (*Melignomon zenkeri*), le Crombec à ventre citronné (*Sylvietta denti*), le Souimanga de Bates (*Cinnyris batesi*), le Pic de Woodhouse (*Parmoptila woodhousei*) et *Hyperolius* cf. *veithi*. En attendant la confirmation, nous avons également potentiellement enregistré l'Hirondelle des forêts (*Hirundo fuliginosa*) pour la première fois en RDC. De plus, nous avons également obtenu des informations écologiques et documenté des sons et des images pour plusieurs espèces pour la première fois sur le terrain. L'analyse préliminaire des échantillons collectés indique la présence potentielle de plusieurs espèces nouvelles pour la science, mais celles-ci nécessitent une confirmation.

Dans notre récherche, les habitats de forêt et de savane ont tous deux contribué à la diversité du paysage, avec des espèces uniques aux deux habitats observées. Une plus grande proportion des grands mammifères, de l'herpétofaune et des invertébrés observés étaient uniques aux habitats forestiers. La région de Malebo et ses forêts communautaires sont, au moment de la rédaction, en grande partie intactes en termes de ses composantes biologiques et espèces clés (encore) présentes. Nous avons recueilli des preuves, cependant, pour suggérer que la situation est en train de changer. La région est à un stade critique à partir duquel affiner et étendre les priorités de conservation pour inclure des initiatives de conservation plus spécifiques aux espèces et gérer de manière durable ses écosystèmes de forêt et de savane.

1 Introduction

The Congo Basin is the green heart of the African continent. It is the world's second-largest tropical forest and ranges from the gulf of Guinea in West Central Africa to the Albertine RIft on the eastern border of the Democratic Republic of Congo.

The Congo Basin forests are associated with high precipitation, the centre of the basin receiving up to 3000 mm/year. This region, however, was not always as wet, and the Congo Basin not always as forested. Climatic conditions over the past million years have shifted substantially, and ice age cycles (Fredoux 1994) have triggered sharp oscillations in forest and savannah coverage (Jolly et al. 1998). During the driest periods, the forest may even have shrunk to small refuges in areas of highest rainfall. These former refuges are now thought to contain particularly high levels of endemism and species richness (Diamond and Hamilton 1980). Beginning about 5,000 years ago, the climate became drier and forests contracted. Loss of tropical forest and concurrent invasion by savannah woodland habitats culminated around 2,500 years ago when the central part of the Congo may have been savannah woodland (Maley and Brenac 1998). From around 2,000 years ago a wetter climatic period allowed forest to re-expand into many savannah areas, and there is evidence from parts of West and Central Africa that forest expansion might still continue to this day (Maley and Brenac 1998).

Continuous flux between forest and non-forest habitats has been a major agency in evolution all over Africa, but the form this has taken differs from one region to another (Kingdon 1990). This waxing and waning of forest and savannah habitat in the Congo Basin has resulted in an "evolutionary whirlpool" (Kingdon 1990) and a complex biodiversity landscape caused by local extinctions, recolonisations and radiations of adapted species across a hierarchical structure of increasingly larger river basins. Based on dominant or major vegetation types and climate, it is possible to identify nine biomes in Africa (Burgess 2014). Within these biomes, ecoregions can be distinguished as regions that contain geographically distinct assemblages that share a majority of their species and ecological dynamics, share similar environmental conditions, and interact ecologically in ways that are critical for their long-term persistence (114 such ecoregions have been identified for Africa, Burgess 2004).

Despite the overwhelming biological value of the DRC and its fascinating biogeographical positioning, surprisingly little biodiversity data are available. Species distribution data are fundamental to our understanding of biodiversity patterns and processes, and a necessary first step for conservation initiatives. Our knowledge of the distribution of organisms on Earth varies hugely with many temporal, spatial, and taxonomic biases (Meyer et al. 2016) and large gaps remain globally (Lomolino 2004). Overall, tropical Africa remains poorly sampled (Sosef et al. 2017). Biodiversity data in the DRC are available from a number of studies scattered across the country. Some of the most substantial contributions to the biological knowledge of the region include historic expeditions such as the American Museum Congo Expedition (1909–1915), and a range of scientific missions organised by The Royal Belgian Institute of Natural Sciences (RBINS) during the period 1925–1960 (see the archives online http://www.apncb.be/missions). During this period the RBINS was responsible for the management of the national parks of Congo through its sister institute "Institute of the National Parks of Belgian Congo'' until the independence of Congo from Belgium in 1960. Scientific missions were organised to survey the biodiversity in the national parks. The study region in Malebo currently has no protected areas or national parks.

Conservation threats

The conservation threats in the Malebo area, and in the DRC more generally, are in line with many other locations in the tropics. While forest degradation has been minimal in the Congo Basin, deforestation has been accelerating (de Wasseige et al. 2012, Megevand 2013). The Congo Basin is abundant in natural resources such as high value timber and possesses many geologic resources. Additionally, palm oil plantations and other commercial agriculture operations are a growing threat, putting greater pressure on the Congo's forests and rivers. At the time of writing, access to much of the Congo Basin remains difficult because of a lack of infrastructure, a factor that has been beneficial for the preservation of forest ecosystems across the region. However, a large and growing percentage of the Congo Basin is under concession to logging and mining companies. While such activities often include related infrastructure projects such as roads and dams to facilitate extraction of the targeted resources with benefits for local people, it often comes with a high environmental impact. Logging and mining activities open up the forests for large groups of people and make these ecosystems accessible for the bushmeat and fuelwood markets (Sonter et al. 2018). Unsustainable hunting of wildlife for the commercial bushmeat market is one of the more urgent conservation challenges in the region and threatens to wipe out many species (**Figure 1**). The total bushmeat harvest in the Congo Basin alone is estimated at 4.5–4.9 million tonnes per year (Fa et al. 2002). The demand for fuelwood and charcoal also rapidly grows and in most parts of Africa intensive tree cutting and conversion of forest to agriculture counteracts any forest expansion caused by increased rainfall and forest cover (FAO 2001).

Figure 1. "Rien passe" - A commonly used snaring set-up in Malebo, centered around a small enclosed area fenced off with sticks in the ground that contains some kind of bait. The fenced area is only reachable through the noose. It targets all kinds of small animals including small mammals, birds and even snakes and is called "nothing passes". (Photo by Niklas Weber)

Study region

Our study region is situated in the Mai-Ndombe province, close to Malebo. The region is characterised by semi-deciduous forests, swamp/waterlogged forests, and open-canopy forests dominated by Marantaceae understorey. These patches transition to a mosaic of savannahs and gallery forests. Forests mostly represent terra firma soil conditions and encompass various habitat types, i.e., re-colonizing *Uapaca* sp., old secondary, mixed mature, old growth monodominant, riverine gallery and Marantaceae forests (Inogwabini et al. 2008), with large variations in vegetation structure occurring over small spaces. Dominant tree species also vary substantially between forests (Serckx 2014). The local climate is characterised by a small dry season in February or March (Inogwabini et al. 2008) and a large dry season from May to August (Pennec 2016). The major rainy season is in November and December, with annual variations.

The Malebo region is situated at an interesting transition zone between biomes and ecoregions (Burgess et al. 2004). More specifically for biomes between "Tropical and subtropical moist broadleaf forests" and the "Tropical and subtropical grasslands, savannahs, shrubland and woodlands" (Fig. 2.4 Burgess et al. 2004). In terms of terrestrial ecoregions, Malebo is roughly situated in the western Congolian forest-savannah mosaic at the intersection with the southern Congolian savannah-mosaic and the central Congolian lowland forests and close to the eastern Congolian swamp forests (at the other side of the Congo river) (Fig. 2.2 Burgess et al. 2004).

The Malebo region was identified in the USAID funded central Africa regional program for the environment (CARPE) as a priority community conservation zone at the end of 2006. WWF has been active in Malebo since 2006. Incoming funds helped manage natural resources in the region and WWF actions are geared towards generating alternative livelihoods for communities. Research in the region has focussed on bonobos and large mammals (see, e.g., Inogwabini 2011, Serckx 2016, Onishi et al. 2020). However, little is known about much of the rest of the biodiversity in the region. We thus aim to help better understand the biodiversity and conservation value of the Malebo area in this rapid biodiversity assessment, aiding and accelerating ongoing conservation initiatives.

Access and logistics

Biodiversity surveys were focused on or close to areas of the Directorate-general Development Cooperation and Humanitarian Aid of the Belgian government (DGD) PHASE II (2022–2026) in Mai-Ndombe province, Malebo, DRC.

Our expedition operated from a 'basecamp' at the WWF station in Malebo. From here we visited three discrete satellite camps in the region that were selected prior to our visit. Site selection criteria included the presence of "good" and extensive forest as well as savannah closeby in order to document the biodiversity in both habitats. In each of the camps we made sure to survey some time in marsh forests close to the water, terra firma forests and (more open) savannah (**Figure 3**). A further essential characteristic of these sites was availability of (and proximity to) fresh water. The selected study sites were validated in-country by recommendations of WWF DRC staff, our local partner. After confirmation, permissions from local villages to work here were sought and a scouting trip led by Junior Booto together with representation of local villagers inspected the selected locations in situ.

Basecamps were accessed from the WWF station through a combination of 4x4 access to the closest village and hiking in (8–18 km). Help from local people was obtained to carry in scientific and logistic material (up to 600 kg).

Figure 2. Transport between villages was by 4x4 over non hardened roads. As rains progressed during the fieldwork movements got slower and more unpredictable. (Photo by Niklas Weber)

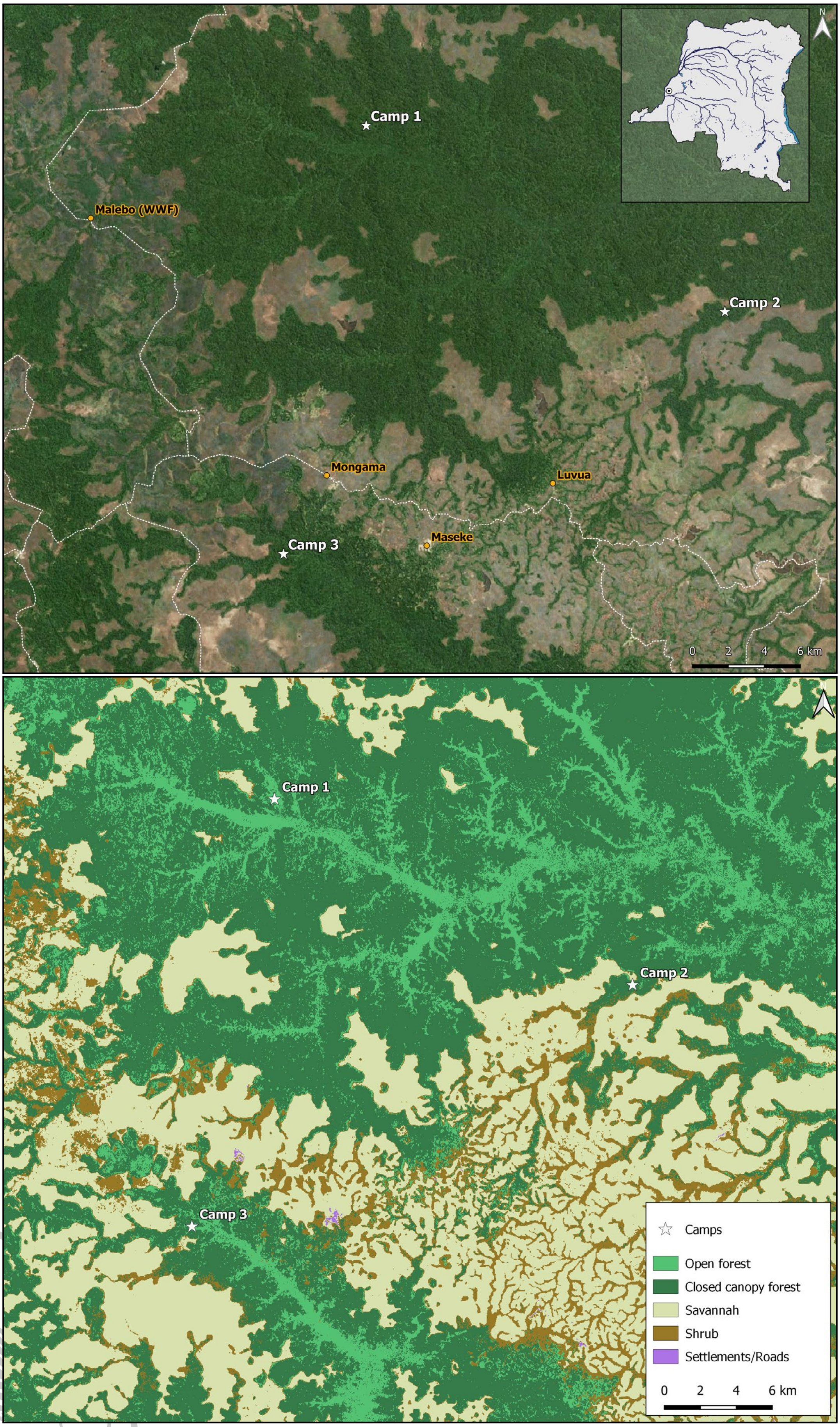

Figure 3. Study region of the Malebo expedition 2021, with indication of the WWF station in Malebo, major villages and camp locations. Dot in the DRC map indicates the location of the study site. (above). Classification of forest and savannah habitats based on elevation and distance to water (below).

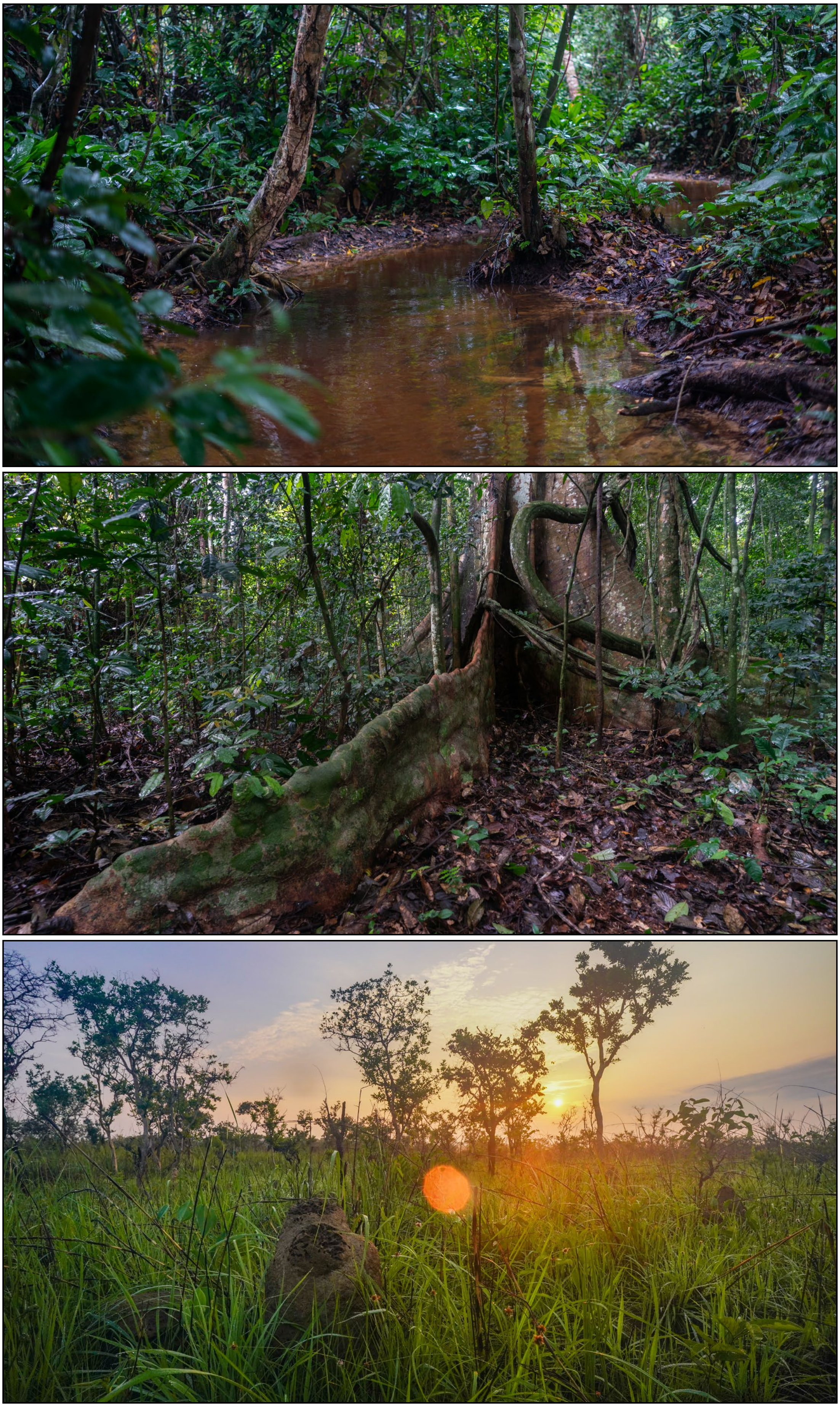

Figure 4. In each of the camps we made sure to spend some time in swamp forests (upper), terra firma forests (center) and (open) savannah habitats (lower). (Photos by Niklas Weber)

Malebo, WWF station 6–8, 15, 26–28 October 2021

The WWF station at Malebo served as our headquarters for the expedition from which visits to other study sites were undertaken. We only collected data ad-hoc at WWF Malebo, while modifying and testing specific aspects of our survey design. The site is based at the Bopambu river fringed by gallery forest with low canopy dry forest surrounding the field station. Open patches of savannah surround the broader site, with a savannah wetland upstream. The site connects a forest corridor leading to a larger forest patch to the south.

Bopambu Forest, part of Nkombo forest - Camp 1 8–15 October 2021

This camp was within the territory of Maseke village, but we entered the site via Mbanzi village. Situated in a forested valley, the camp was in dense Marantaceae undergrowth close to the Bopambu river (and smaller tributaries) before it flows together with the Bambou river. Adjacent to the camp, the Bopambu river braided into a swamp forest split by numerous small streams. Away from this wetter swamp forest, the drier forest (particularly on the incline leading down to the camp) was characterised by large *Millettia laurentii* De Wild (IUCN listed as Endangered) trees with a canopy of ~50 m and emergents up to ~70 m. To the north-east of the camp was a small enclosed savannah patch (2 km long and 600 m wide) dominated by grassland and woody vegetation. The savannah transition to forest was abrupt, occurring within ~20 m with virtually no cline between the two. Recently (according to our local guides) a family has moved to this savannah, and a small hut is now present here. At the time of our visit there were no cows present here, but we were told of plans to introduce cattle to graze here in due course.

Temperature (in °C): Mean ± sd: 24.6 ± 2.7, Range: 20.5–31.5
Relative humidity (%): Mean ± sd: 94.1 ± 7.0, Range: 64–100.0

Nkombo forest (locally known as Lekuma Forest)**, entry through Luvua village - Camp 2** 16–22 October 2021

The second camp was situated in a forested valley adjacent to the Lekuma river (~20 m width) with numerous small streams leading into it. The camp is situated in a smaller riverine strip of forest adjacent/connected to a much larger and more extensive forest block. Rocks of igneous origin were present on the forest floor and in the river (where in the first camp we found no rocks on the forest floor). A large area of wooded savannah was again adjacent to the entry point to the forest. This transition between forest and savannah was characterised by a short section of dense bushy vegetation. On the opposite side of the river to the camp (to the north - river crossing by a log) was a very small savannah patch and then the large block of forest, connected to that of the first camp (see **Figure 5**). A few scattered small wetlands and forested depressions were present along the river. Of note, numerous large (~40 m+) trees had naturally fallen in the forest at this site relatively recently, creating several large tree fall gaps.

Temperature (in °C): Mean ± sd: 23.6 ± 1.7, Range: 20.5–28.0
Relative humidity (%): Mean ± sd: 99.1 ± 0.9, Range: 88–100.0

Mongama forest - Camp 3

23–26 October 2021

The third camp was on the territory of Mongama village and situated in a flat-bottomed valley, adjacent to the Nzalimbali river (~10 m wide). Across the river (by wading) was a small enclosed savannah patch characterised by grassland and woody shrubs. Little to no wetlands/swamp forest was apparent at this site. Much of the forest in the immediate region was in poor condition, with characteristic signs of slash-and-burn agriculture. Adjacent to the camp, a very dense open patch of Marantaceae (no trees) was present. Nonetheless, on the gradual slope above the campsite there was some good quality forest characterised by high canopy and open understorey. The forest on the other side of the river, beyond the Savannah patches, was remarkably more intact and diverse.

Temperature (in C): Mean ± sd: 23.7 ± 2.5, Range: 20.5–31.5
Relative humidity (%): Mean ± sd: 97.1 ± 2.9, Range: 81–100.0

Figure 5. A savannah pocket close to BC1, Malebo, Mai-Ndombe, DRC. (Photo by Niklas Weber)

At each study site, a temperature/humidity logger (LASCAR ELB 2 Temperature and humidity data logger) was deployed to provide descriptive information on local variation in microclimate during our survey time. Loggers were deployed in forest patches close to camp in the shade to avoid direct sunlight and typically attached at ~1.5 m above the ground. Temperature and humidity was recorded at 15 minute intervals.

Aims

1. **Bonobo detection with drone-based thermal imaging: a viability study.** First trial of an innovative approach to surveying the cryptic bonobo, with the aim to accelerate population density surveys.

2. **Multiple taxa biodiversity assessment.** Rapid assessment of specific biological communities in the region to evaluate its conservation importance (including potential discovery of new species to science in specific focal groups).

3. **Identify the relative contribution of savannah and forest patches to the biological diversity in the landscape.** Linked to Aim 2, to understand the habitat contributions to the overall species diversity of the broader region and their respective conservation value.

4. **Ecotourism potential.** Look into the potential of ecotourism in the region as a viable alternative income for communities.

Figure 6. The Malebo 2021 Expedition team. Last row from left to right: Niklas Weber, Jesse Erens; middle row from left to right: Junior Batangeli, Jeancy Elenga, Tim van Berkel, Olivier Batangeli, Sam Jones, Justin Ekani, Gabriel Jamie; front row from left to right: Jan Mertens, Junior Booto, Merlijn Jocque & Willy Mbemba. (Photo by Niklas Weber)

2 Biodiversity surveys

2.1 Using thermal infrared drones to detect bonobos: a viability study

Tim van Berkel, Tobias Dahms, Tom Martin, Merlijn Jocque, Niklas Weber

2.1.1 Overview

The bonobo (*Pan paniscus*) is an endangered great ape species endemic to the Democratic Republic of Congo (Fruth et al., 2016) with poaching, the commercial bushmeat trade and disease transmission representing their major threats (IUCN & ICCN, 2012; Fruth et al., 2016). Bonobo occurrence (based on nest presence) is best predicted in terms of distance from agriculture and forest edge density, suggesting that bonobos either avoid areas of higher human activity or fragmented forests (Hickey et al., 2013), although this can vary with season (Pennec et al., 2020). Estimates of their original distribution range from 343,000 km^2 (Butynski, 2001) to 840,400 km^2 (Thompson-Handler, Malenky, & Reinartz, 1995), but its population status remains uncertain. An analysis of all existing bonobo survey data up to 2010 identified four strongholds for the species; the 'northern block' (Maringa-Lopori-Wamba), the 'eastern bloc' (Tshuapa-Lomami-Lualaba), the 'southern block' (Salonga) and the 'western block' (Lac Tumba Lac Mai Ndombe) (Hickey et al. 2013). These authors, however, also indicated that despite the substantial investment of resources and survey effort, data collected between 2003 and 2010 covered less than 30% of the total bonobo geographic range (IUCN & ICCN, 2012). Based on the information available, a minimum of 15,000–20,000 individuals have been estimated, although this estimate remains uncertain.

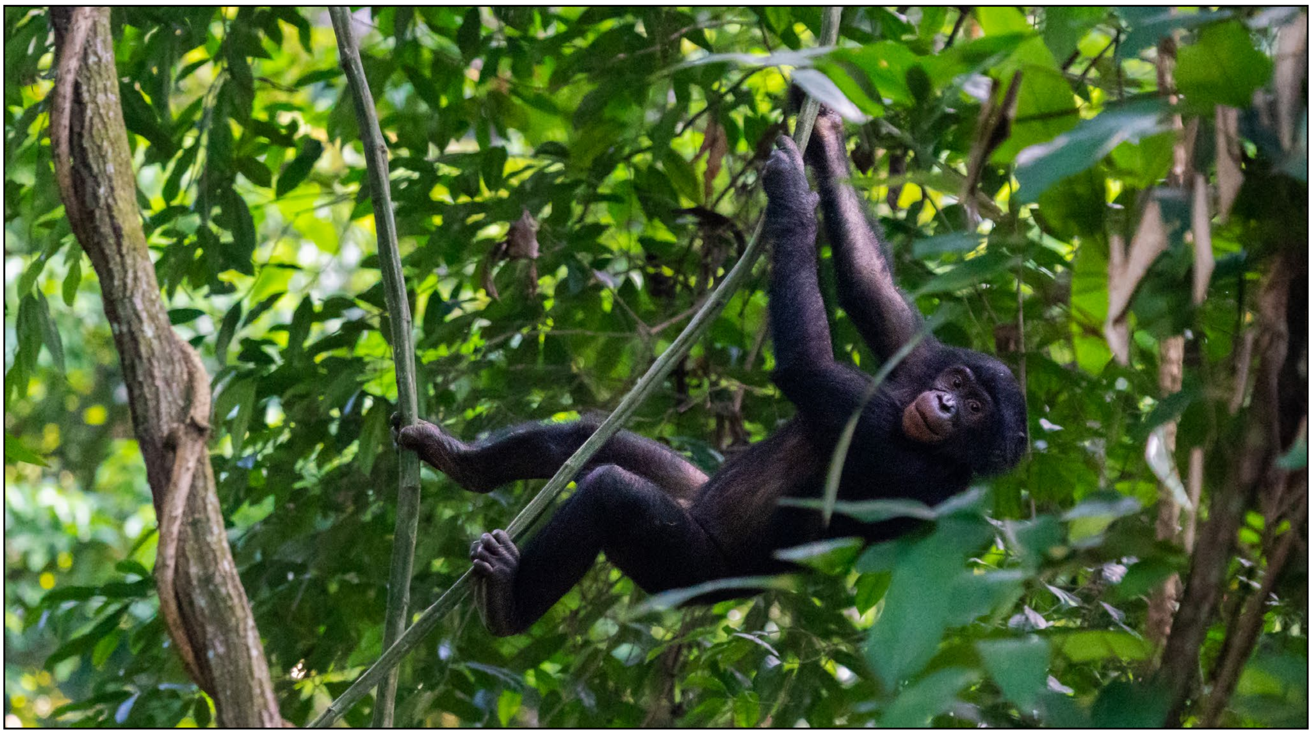

Figure 7. Bonobo (*Pan paniscus*) of the Nkala group. (Photo by Niklas Weber)

Figure 8. A recent bonobo nest. (Photo by Niklas Weber)

Bonobos are a shy, cryptic species that live in low densities in one of the largest and most inaccessible forests in the world. It is therefore unsurprising that bonobo populations across a large proportion of their range remain unsurveyed, explaining some of the variability in their population estimates (Kühl, 2008; Fruth et al., 2016). Bonobos live in large social groups called communities, which occupy a large home range (22–60 km^2) and can overlap extensively with other communities (Hashimoto et al., 1998). Community size is variable, with between 10–120 individuals having been reported from different communities (Kano & Mulavwa, 1984). While the community is a unit that is relatively stable over time and only changes with permanent changes between communities, on a daily basis it is usually split into smaller parties, membership of which changes more regularly (Furuichi, Thompson, & Fruth, 2008).

Due to their elusive nature and low density, the standard method to assess bonobo density and abundance focuses on indirect signs - specifically nest counts. Amongst primates, nest building is a characteristic unique to great apes, and numbers of nests can serve as a proxy indicator of bonobo density (Kühl, 2008). Bonobos construct a new nest each night (Fruth, 2016), at extremely variable heights (5–50 m) (Fruth 1995), but usually in the mid-canopy, with males generally building their nests lower than females (Fruth & Hohmann, 1993). Nests take a long time to decay (several months) making them more numerous and easier to observe than the species itself. While methods relying on nest counts have some advantages, they depend on several assumptions and associated uncertainties. Specifically, this method relies on the nest decay rate (the time it takes for nests to disappear). As such, an understanding of the estimated daily nest construction rate and the proportion of nest builders in the community is needed to provide accurate density estimates. These variables are time-consuming to gather, can only be collected from habituated groups and/or may vary geographically and over time. Many bonobo density studies (e.g. Waller & White, 2016) have therefore used estimations presented in the literature from secondary sources (e.g. Fruth, 1995; Mohneke & Fruth, 2008) rather than assessing these specifically for their study location. Such assumptions potentially introduce a substantial margin of error in reporting density estimates. Nest decay, for instance, is known to vary greatly geographically and temporally, as it depends on several factors which remain poorly understood (Bessone et al., 2021) and can take several years to calculate accurately (Kühl, 2008; Serckx, 2014). Plumptre & Reynolds, (1997) developed the marked nest counts method, which does not require nest decay rates to be calculated. However, this method does require repeated visits to the same site to record new nests made since the last visit, increasing survey effort.

Considerable effort is thus required to obtain accurate bonobo population estimates, and actively hinders conservation efforts, where a given conservation strategy relies on accurate and repeated density/abundance estimates. At this moment there remains no reliable estimation of the global bonobo population and most population data comes from a small number of established and calibrated sites, with population sizes in unsurveyed sites remaining entirely unknown. New technological developments might provide an answer to help collect the necessary data.

Drone-based surveys have been used to survey rainforest primate species using RGB imagery (e.g. Wich,et al., 2015; Bonnin et al., 2018) and thermal infrared (Burke et al., 2019; Kays et al., 2019; Spaan et al., 2019; Wich et al., 2015; Zhang et al., 2020). Such methods remain untested for surveying bonobos, although the principals remain the same as in these previous studies. Bonobos are relatively large-bodied and sleep in close-knit groups (within 30 m radius) in individual nests, which they build relatively high in trees (Fruth, 1995; Mulavwa et al., 2010). These factors should thus make detection of their thermal signatures from the air possible, and are comparable to methods proven for other primates species.

To investigate the viability of detecting bonobos with thermal drones we visited the Malebo (or Mbali) region, part of the bonobos 'western stronghold' (Lac Tumba-Lac Mai Ndombe) (Hicks et al. 2013). The bonobos here inhabit a forest-savannah mosaic, which makes this a unique research location, as the forest dynamics differ from large stretches of rainforest, and bonobos are known to utilise the savannah in several ways (Onishi et al., 2020), especially since most previous research has been carried out on bonobos living in tropical rainforests (Badrian & Malenky, 1984; Furuichi et al., 2008; Mohneke & Fruth, 2008; Mulavwa et al., 2010). WWF-DRC in Malebo has been actively engaged in bonobo research and conservation since 2007. Major research in the region focused on bonobo ecology living in the forest-savannah mosaic, and their conservation (Inogwabini, 2011; Onishi et al., 2020; Pennec et al., 2020; Serckx et al., 2014, 2015; Serckx, 2014; Trolliet et al., 2016). Three bonobo groups, which have been continuously undergone habituation efforts since 2001 by WWF-DRC and the local NGO Mbou-Mon-Tour (MMT), inhabit the local community forests of Nkala, Mpelu and Manzano (Onishi et al., 2001).

Here, we aimed to test a 'proof of concept' using drone-based thermography methodologies to obtain data on bonobo populations. We aimed to establish whether a thermal camera mounted below a drone (dubbed a thermal drone) can reliably detect bonobos. The key challenge with this approach is to find the right environmental and technical conditions that allow reliable detection of bonobos and confirm that these are bonobos and not other primates (e.g. the much smaller *Cercopithecus* sp.). As part of this exercise, we used software and hardware for flight planning and image analysation provided by thermal DRONES GmbH, Germany. For flight planning we used the open source software QGroundControl which enables satellite image and terrain data based automated flight planning without an internet connection (using) and has the capability of programming a range of parameters including camera specifications, image intervals, image overlap, flight height and flight speed. We also used a custom program to generate drone survey missions around known coordinates (to survey the nests identified by the trackers).

Should this approach prove successful, there are many advantages associated with this method that could revolutionize population research for this species. One of the most obvious advantages with remote sensing methodologies is that drones can cover a large area in a short time and do not require researchers to physically cross difficult terrain to survey the animals themselves. Instead, large quantities of data could be captured remotely and analysed automatically at a fraction of the effort and cost. With drone and thermal camera technology advancing rapidly, their use could prove a viable alternative to nest count surveys, on the proviso that it can be proved such methods can detect nests in the field. We postulate that a drone-mounted thermal camera can reliably record bonobo thermal signatures (the heat pattern a bonobo produces) from the air when the bonobos are on their nests at night and when the ambient temperature has cooled down enough to differentiate between environment and bonobo. Our fieldwork in Malebo thus aimed to test this hypothesis.

2.1.2 Methods

Study area

The study region is a dynamic savannah-forest mosaic landscape, with forests centred along the lower-lying draining channels and savannah occupying the higher grounds. Burning of savannah by a large cattle ranching organisation and local villagers are the main factors inhibiting natural forest regeneration (Serckx, 2014). A variety of forest types, sizes and shapes, each connected to each other by various corridors, are present in the survey area (Pennec et al., 2016; Serckx et al., 2016). Forest structure and species composition is highly homogenous and can vary substantially over distances of only several meters (Serckx, 2014). Principal vegetation types include old secondary, mixed mature, Uapaca, riverine gallery and Marantaceae forests (Serckx, 2014). Both the Nkala and Mpelu forests (named after the adjacent communities that own and protect them) are used for hunting and fishing. The communities belong to the Bateke people who have a taboo against eating bonobos, and as such the species is not hunted here (Inogwabini, Nzala, & Bokika, 2013). Since 2013, WWF and MMT have been working with the local communities to create a community natural reserve status for the forests where the bonobos occur (Serckx, 2014).

The presence of savannah provides access through roads and trails to the forest, allowing drone take-off and landing points to be located close to the bonobo sleeping sites even if they move large distances, maximising flight time.

Bonobo group characteristics

Two habituated bonobo groups inhabit the forests of Nkala and Mpelu. The groups are followed daily when possible, from leaving the nest in the morning to nest construction in the evening. The Nkala group recently suffered a sharp and sudden decline in members, from around 14 in 2017 to 10 in 2019 when four male adult and subadults disappeared, without showing any signs of disease (Onishi et al., 2020). This may indicate poaching. MMT has observed several other bonobo groups around the Nkala forest, although the relationship and connectivity with the Nkala group is not yet understood (Onishi et al., 2020).

Surveys

The drone study took place at the end of the dry and beginning of the wet season from 8–13 October 2021.

We expected that the best time to detect bonobos is at night when communities are roosting. Bonobo thermal signatures are expected to stand out most at night when the animals are stationary and the difference between their thermal signature and that of the environment is highest, this being the case with other studies using drones to detect large primates (e.g. Wich et al., 2015).

We aimed to conduct repeated flights over these sleeping locations to obtain as many data points as possible during a six-night survey period. This would a) determine whether bonobo thermal signatures can be recorded from the air, b) allow for an estimation of bonobo detection probability and c) provide data for the development of a machine learning protocol to automate image analysis.

We flew the thermal drone following North-South transects (**Figure 9**) at 100–120 m above ground level, over a 400 m x 400 m area with the bonobo sleeping site at its centre. Flight speed was 8 and 12 ms-1. These were chosen based on our previous experience using thermal drones to detect roe deer (*Capreolus capreolus*) fawn (Wildretter.de, 2021). A 400 m x 400 m area was chosen as a conservative size, since these dimensions would be wide enough as not to miss any group members. Overlapping georeferenced thermal images were taken at set time intervals during each flight to record bonobo heat signatures.

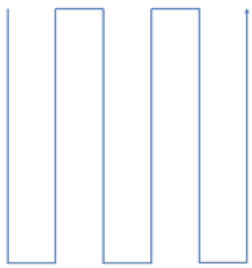

Figure 9. Drone survey pattern

Flights were conducted using a commercially available drone, the DJI Mavic 2 Enterprise Advanced, equipped with a 640 x 512 px, 30 Hz radiometric thermal camera with a 9.2 mm focal length lens and 45 x 37° (V x H) field of view. The stabilized camera was pitched to take nadir images (angled directly downward at 90° from the ground). Maximum flight time per battery is about 28 minutes and flights of approximately 22 minutes have been accomplished. The thermal camera was programmed to take thermal images with a 65–85% overlap to maximise bonobo detection probability and learn how distance and angle from the camera affects detection probability.

Sleeping locations were visited the morning after the flight to allow ground-truthing of recorded heat signatures, after the bonobos had left their nests. GPS coordinates of all observed nests were taken, together with their location in the canopy and whether the nests were covered by the canopy or open to the sky.

Software

Drone images were analysed manually using the software Poitagger developed by Israel (2017). The software is still in development but is specifically being built to analyse wildlife detections and geo-localisation based on thermal imagery from drones.

The software calculates the geo-coordinates of each pixel within the image based on the camera position and orientation when the image was captured. It provides the possibility to export the defined points of interests (POIs) within the images to a handheld GPS device and as a flight path for the drone. This can be used for ground truthing or protection of the animal. A neural network based autodetection of different species (currently roe deer fawns) is in development.

2.1.3 Results

Three drone surveys were conducted during two nights during our six-night survey period. For our first survey night (8–9 October) we received two different GPS coordinates of the Nkala group from the tracker team. We drove as close to these coordinates as possible (the Mbou-Mon-Tour field station), from which the drone was launched. We conducted nine flyovers with a speed of 12 m/s at 100 and 120 m altitude between 23:00 and 00:03 h over the nearest provided GPS coordinates. Each flyover took about three minutes to complete.

Post-flight analysis of the thermal images taken during the survey showed no thermal signatures, indicating the coordinates did not match the bonobo sleeping site. Small, single pixel heat signatures were detected at several locations but not at the location of the GPS coordinates.

We conducted three more flyovers (at 12 ms^{-1}, 120 m altitude) over the coordinates that were further away from the launch site, from 04:16 to 04:29 h in the morning, October 9th. In-flight inspection of images was only possible when there was a direct connection between the flight controller and the drone, but this was lost frequently due to the drone surveying out of the controller’s range. Heat signatures were not visible on the flight controller screen during flights. Only post-flight analysis of the images using our software allowed us to see if any heat signatures were recorded. This analysis showed we recorded seven thermal signatures, located around the received GPS coordinates, on four thermal images. Thermal signatures ranged between two and seven pixels. We were, however, unable to ground-truth the data by visiting these locations in the field due to absence of the trackers that same morning.

Trackers were not able to follow the bonobos until the period of nest building in the evening for the following two nights. On October 11th they found the Nkala group and provided their GPS coordinates for the night. Although we left WWF HQ at 03:00 h on the 12th, heavy rain prevented flying until 05:40 h when we were able to conduct a single flyover until 05:58 h before the rains restarted. Based on the previous survey we decided to fly at 8 m/s, which resulted in greater overlap and slightly more clarity of thermal images, at an altitude of 120 m. During the flyover we recorded eight thermal images with 19 heat signatures located around the coordinates provided by the trackers. After the flight we visited the nest site and took GPS fixes of all the observed nests (N = 8) at the sleeping site to match these against the thermal signatures obtained from the drone. Locations of thermal signatures were near (< 50 m) the nest locations but did not match those exactly (**Figure 10**).

We were not able to conduct flights during the last two survey nights (12 and 13 October). This was due to rain on the 12th and a tracker falling ill on the 13th.

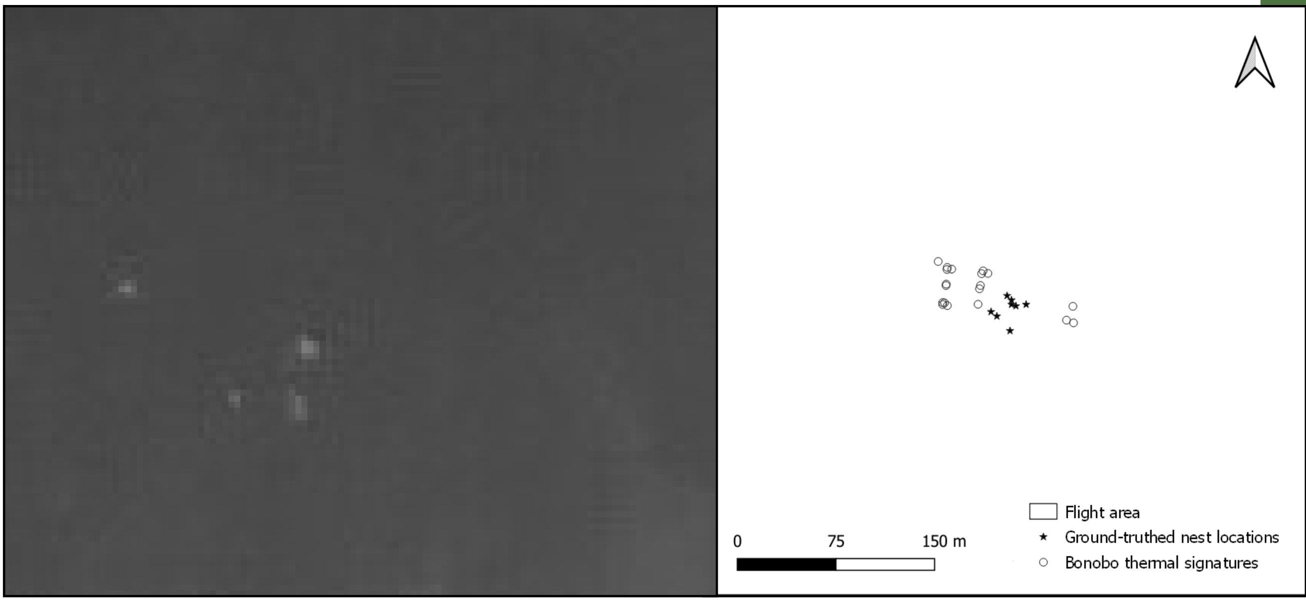

Figure 10. Cropped thermal image (left) showing four bonobo heat signatures obtained during Survey 3. Overview of the flight area (right) detailing the locations of thermal signatures and bonobo nest locations in the field.

Table 1. Thermal drone survey characteristics compared with the number of ground-truthed nests.

Survey ID	Date	Flight speed (ms^{-1})	Flight height (m)	Flight time	Flyovers	Images containing bonobo heat signatures	Bonobo thermal signatures*	Nests recorded in the field**
1	09-10-2021	12	120	04:16 – 04:24	2	1	1	-
2	09-10-2021	12	100	04:27 – 04:29	1	3	6	-
3	11-10-2021	8	120	05:40 – 05:58	1	8	19	8

* The number of signatures does not necessarily represent the number of individuals as images overlap spatially, leading to potentially multiple detections of the same individual

** It was not possible to conduct a ground-truthing survey due to logistical issues

2.1.4 Discussion

We successfully detected bonobos with a thermal drone for the first time. This is an important first step towards their use as a tool to survey bonobo populations. We discuss some challenges and insights below.

Spatial discrepancies

We recorded consistent spatial discrepancies (up to 50 m) between thermal signatures and ground-truthed nest locations, for which we propose three causes: 1) Bonobos sleep at a priori unknown heights in the trees, while the georeferencing software we used is programmed so that the object viewed is assumed to be situated at ground level. This causes a discrepancy between the perceived and actual location, as demonstrated by **Figure 11**. The further away from the drone a bonobo thermal signature is recorded (and thus the further away from the centre of the image), the larger the discrepancy between it and the estimated location. Only objects directly underneath the camera will have zero discrepancy. 2) The software used requires calibration for the specific thermal camera used, and 3) the locations of the GPS points from the drone and or from the ground-truthed points are not accurate. This was certainly the case for ground-truthed locations, as the handheld GPS devices gave an accuracy of between 7 and 12 m. While 12 m would not pose a practical problem, differences of 50 m would increase the time it takes to find the actual nests in the field.

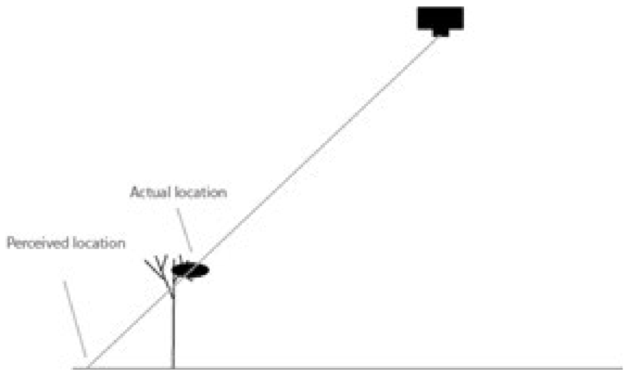

Figure 11. Example of how a bonobo heat signature could be recorded to be in a different location by the drone software

Detection probability and ground-truthing

Not all bonobos present in the community were likely detected during our surveys due to a variety of factors including canopy density above the nest, nest height, nest distance from tree trunk, size of individual, whether a nest is situated close to or underneath another nest and location of the drone compared to the nest. We need to better understand these factors to understand what proportion of a community is likely to be missed.

If individuals have a chance of not being detected by the thermal camera during a survey, ground truthing would remain a necessary feature for this method. Ground-truthing requires visiting the detected nest sites as soon as possible after the survey (ideally the next morning) to record the locations of all fresh nests in the area. With repeated measures, the difference between the number of thermal signatures and nest records from the field will provide a measure of the detection probability of detecting a bonobo. This is an important aspect of density surveys.

Due to the reduced front and missing side overlap the chance to detect nests from other viewpoints was reduced compared to the flight paths normally used for wildlife detection within meadows. For future tests the impact of the overlap on the detection probability needs to be assessed by repeated flights with different overlap settings.

Analysis of thermal signatures

Manually analysing potentially thousands of thermal images for bonobo thermal signatures is time-consuming. However, this process can be automated (Corcoran et al., 2019; Santangeli et al., 2020), but requires several thousand images taken in the field as points to train a machine learning algorithm. The Malebo site is an ideal location to collect this data, given that it contains three habituated bonobo communities which are easy to access in terms of both vehicle access for the research team and take-off and landing sites for the drone.

Furthermore, we need to understand how bonobo thermal signatures differ from other species to avoid false positives. Even so, we believe that confounding bonobo heat signatures with those of other species (other arboreal mammals such as sympatric monkeys or genets) is unlikely due to their large size (thermal signature) and gregariousness (multiple large thermal signatures in one location). This combination should allow for accurate differentiation and identification of bonobos.

The software Poitagger already has a (not exposed) interface for a convolutional neural network based wildlife detection algorithm which could be adapted for bonobos and thermal DRONES is testing the use of its detection algorithm on board of custom made drones. These are based on the open source autopilot software Arducopter which can also be used to fly fixed wing drones.

Autonomy

The biggest limitation in drone-based surveys remains in their autonomy (survey time) per flight (~22 minutes in this survey). Bonobos live at low densities, which requires surveys to cover large areas. For a more in-depth survey, drones with a longer flight time and/or a higher resolution of thermal imaging camera would be needed. Custom-made drones or fixed wing drones with a longer flight time are available and would represent a step to overcoming this limitation. Another approach would be the use of a swarm of rotary wing drones as the one used in this study. The advantages and disadvantages of these approaches are to be assessed in future.

Additionally, the resolution of thermal cameras determines the area that can be surveyed, as thermal image resolution limits flight height. Doubling flight height would allow doubling of the area surveyed per unit time. In our case, flying higher than 120 m would progressively reduce the number of pixels to such an extent that these cannot be accurately measured. However, with a higher resolution thermal camera, higher flying heights could be obtained, and thus drones could cover a larger area. The technology around drones and thermal is progressing rapidly and this more advanced technology is expected to become affordable for conservation research projects. But currently there are no commercially available cameras with a higher resolution than the one used in this study. Therefore, the only solution would be to use an array of thermal cameras with adapted lenses to achieve a wider area to be captured per overflight. This would require a custom-made drone and camera.

Our location provided open space to launch our drone and easy access to the forest patches inhabited by the bonobos. Finding open launch spaces and adequate access will be more challenging in contiguous closed canopy rainforest. Even so, gaps in the canopy caused by tree falls, or from a boat via rivers or streams, could provide an adequate alternative. This would require rotary wing drones or fixed wing drones with vertical take-off and landing capabilities. Ground-truthing the obtained thermal signatures by visiting these locations would still require significantly less time than conducting (repeated) ground nest surveys.

Weather and tracker challenges

There were two main reasons why we were not able to conduct surveys for four out of the six survey nights: Bad weather and lack of GPS coordinates. Rain during one survey night stopped us from surveying for one night and restricted survey time a second night, as the drone is not capable of operating in the rain, and thermal signatures of animals will likely be reduced when the animal is wet and they cool down. Rain also limited the trackers from following the bonobos to their nest site for one night. An accidental provision of two separate GPS coordinates one night (one correct, and one false) also led to flights being conducted over the wrong area.

The quality of thermal images is significantly impacted by the humidity. For future studies seasons with lower humidity should be selected to improve the image quality and the detectability of the bonobos.

Software challenges & needs for further development

The software we used was essential for survey planning. However, we noted that the time interval and overlap between images did not seem to match those inputted in the software. The cause of this will be investigated. For further studies flight paths with higher overlap (85% frontal and at least 20% side overlap) and lower flight speeds should be used or at least compared to the current settings.

The possibility to revisit the detected hotspots with the drone and capture images with higher resolution should be used in future studies to a) improve georeferencing and b) to collect additional images for the artificial intelligent algorithm.

Conclusions & further research

This study has provided a vital proof of concept that thermal drone methodologies are capable of surveying bonobos in their natural habitat. We recommend expanding on this initial result with a more in-depth survey over a longer period in the dry season (important, given high rainfall has been shown to be a strong impediment to the methodology) to refine the method and software. We would recommend reducing the survey area to a maximum of 200 x 200 m, at least for the Nkala group, to increase meaningful survey time as bonobo thermal signatures were all within a 100 m radius and fitted well within our 400 x 400 m survey area.

One important aspect of conducting repeat drone surveys over groups of known composition would be to build a verified database (consisting of at least 1000 images, and preferentially more) of bonobo (and probably other primate species) images under as many different environmental conditions as possible to train an artificial intelligent algorithm that is capable of automatically identifying bonobo thermal signatures. This will save researchers from having to manually analyse potentially tens of thousands of images. Such a database would ideally be sourced from multiple sources, and could be completed in collaboration with other research groups interested in drone-based primatology survey methods (i.e. Liverpool John Moores University, Queensland University of Technology).

Once the methodology, software and database have been fine-tuned and tested more extensively in the field, the method can be rolled out to new and unexplored areas to help determine bonobo distributions throughout their habitats and generate more accurate density and, ultimately, population size estimates of bonobos.

2.2 Large mammals

Tim van Berkel

2.2.1 Introduction

Africa is known for its remarkable mammalian megafauna. Many large mammal species (generally > 1 kg) play a crucial role in their respective ecosystems as top predators (e.g. most of the large felids and canids) or ecosystem engineers (e.g. elephants), for example. Large mammal populations across Africa are in decline however, with multiple threats including habitat loss, hunting, poaching and human encroachment onto previously undisturbed habitats (Ripple et al., 2015; Ripple et al., 2016). Although mammals are generally among the more well-studied faunal groups worldwide, the distributional patterns of many species remain poorly understood and little up to date information is available. This is particularly the case for many rainforest-dwelling species, which are often nocturnal and elusive, and can range over large areas. Small (generally <1 kg) mammals are much less studied still (Leader-Williams and Dublin, 2000), and also receive less conservation attention (Amori and Gippoliti 2001; Amori et al. 2011; Verde Arregoita 2016). They nonetheless comprise the majority of mammalian species (Kennerley et al., 2021).

Most of the WWF research in the Malebo region is associated with large mammals. As a result, large mammal fauna is fairly well known from the region (Inogwabini, 2020a, N'Goran et al., 2020). Research efforts have focussed specifically on bonobo (*Pan paniscus*, see also **Chapter 2.1**), and forest elephant (Inogwabini 2007). Seven species of primates are recorded from the region, as well as buffalo (Inogwabini 2011). Many large African mammals have never been recorded here, however, although lions were formerly present (Inogwabini 2007, 2011, 2020b).

During this survey we undertook a short camera traps survey to record terrestrial medium and large mammals. Here, we present the preliminary results from this camera trap survey in addition to opportunistic mammal observations recorded throughout fieldwork.

2.2.2 Methods

Camera traps

We deployed 18 camera traps (Bushnell Trophy Cam models 119875 (7x), 119776 (5x), 119477 (2x), 119676 (1x), 119577 (1x), Moultrie M-50i 13270 (2x) at our three field sites and across habitat types. Cameras were active 24 hours a day for a total survey effort of 152 camera trap nights (109 in forest, 43 in savannah) (**Table 2**).

Table 2. Camera trap nights for each camp (Bopambu Forest Camp 1, Nkombo Forest Camp 2, Mongama Forest Camp 3). The number of camera traps deployed is indicated in brackets.

Camp	Forest	Savannah	Total
1	46 (11)	30 (7)	76
2	33 (13)	7 (5)	40
3	30 (12)	6 (3)	36
Total	**109**	**43**	**152**

Cameras were set to take as many images per detection trigger as possible (1–3), followed by a video (25 seconds) after, (although the latter setting was only possible for the Bushnell Trophy Cam model 119875). Cameras were placed around 30–40 cm above and perpendicular to the ground in a variety of microhabitats in places likely to be frequented by a variety of mammals (including trails, ponds, bushes and fruiting trees), and places with signs of recent mammal activity.

Opportunistic surveys

Opportunistic surveys consisted of spotlighting at night to survey nocturnal mammals and day surveys to record primarily primates and squirrels. In addition, indirect mammal records were collated from signs such as tracks and dung, as well as opportunistic records from other team members. Only reliable records with photo vouchers or multiple observers were included.

Species identification was undertaken with the aid of The Kingdon field guide to African mammals, 2nd edition (Kingdon, 2015).

2.2.3 Results

Combining all survey types, at least 27 terrestrial mammal species, belonging to eight orders, were recorded across our survey sites in forest (N = 24) and savannah habitats (N = 3) (**Table 3**). Of these, five species (in the forest) could not be identified to species level. The camera trap survey recorded the majority of species (N = 14). In addition, two bat species were also recorded from two separate locations roosting in hollow trees, the identification of which is still ongoing. In addition, some mammal tracks recorded are still being analysed and may add further species to the inventory.

Threatened and other notable species records as well as some notes on hunting are discussed below.

Table 3. List of all mammals recorded during the expedition. Camp '1', '2', '3', and 'WWF' refer to the sites as indicated in "Expedition fact sheet" on page 4. Types of records: S = Sound, V = Visual, C = Camera trap, S = Spoor, D=Drone. Species in brackets should be treated as unverified.

Order	Common name	Scientific name	Camp	Habitat	Record type	IUCN status
CARNIVORES	African civet	*Civettictis civetta*	123	F	C	LC
	Blotched genet	*Genetta maculata*	2WWF	F	VC	LC
	Tree civet	*Nandinia binotata*	2	F	V	LC
	Mongoose sp.	-	13	F	C	-
	Mongoose sp.	-	3	S	S	-
EVEN-TOED UNGULATES	Bay duiker	*Cephalophus dorsalis*	123	F	C	NT
	Blue duiker	*Philantomba monticola*	123	F	VCS	LC
	Red river hog	*Potamochoerus porcus*	123	F	CS	LC
	Sitatunga	*Tragelaphus spekii*	2	F	S	LC
	African buffalo	*Syncerus caffer*	2WWF	S	S	NT
	Bushbuck	*Tragelaphus scriptus*	123	S	CS	LC
HYRAXES	Western tree hyrax	*Dendrohyrax dorsalis*	123	F	S	LC
PRIMATES	Bonobo	*Pan paniscus*	123	F	SVCS	EN
	De Brazza's monkey	*Cercopithecus neglectus*	1	F	V	LC
	Red-tailed monkey	*Cercopithecus ascanius*	13	F	V	LC
PROBOSCIDS	Forest elephant	*Loxodonta cyclotis*	1	F	S	CR
PROSIMIANS	Common potto	*Perodicticus potto*	3	F	V	NT
	Dwarf galago	*Galagoides* sp.	123	F	V	-
RODENTS	African dormouse	*Graphiurus* sp.	13	F	VC	-
	African giant squirrel	*Protoxerus stangeri*	123	F	VC	LC
	Brush-tailed porcupine	*Atherurus africanus*	123	F	CS	LC
	Congo rope squirrel	*Funisciurus congicus*	123	F	VC	LC
	Emin's pouched rat	*Cricetomys emini*	23	F	C	LC
	Lord Derby's anomalure	*Anomalurus derbianus*	23	F	V	LC
	Squirrel sp.	-	1	F	V	
	Zebra mouse	*Lemniscomys striatus*		S	V	LC
SENGIS	Four-toed sengi	*Petrodromus tetradactylus*	23	F	C	LC

Notable records

Bonobo

A single record of bonobo was detected on the camera traps. Multiple nests as well as a single camera trap image of the species were recorded at the Nkombo forest (Camp 2). Bonobo nests and vocalisations were also recorded at the Mongama forest (Camp 3).

Bay Duiker

Bay duiker was recorded on three camera traps at Camp 1 and one camera at Camp 2 (**Figure 12**). Duiker trails were regularly observed at all three sites.

Figure 12. Camera trap image of Bay duiker (left) and blue duiker (right).

Mongooses

Several mongooses and signs of mongooses were observed. Prints of a mongoose species were observed across a road through the savannah at Camp 3. Three independent mongoose events from three camera trap locations in the forest were also recorded (**Figure 13**). No certainty about species has been reached yet.

Figure 13. Three independent mongoose records from three different camera locations in Camp 1.

Dwarf galago

Dwarf galago (*Galagoides* sp.) were seen during each night survey (N = 4) at all three sites. The species could only be identified to genus level as the two species that are known to occur in the region (*G. demidoff* and *G. thomasi*) can only reliably be distinguished in the field by their vocalisations.

Squirrel

A squirrel (**Figure 14**) was observed 13 October 2021 at 11:59 h in Camp 1. The individual was about 15 m high up on the main trunk of a large tree, being quite vocal. Identification is still in progress.

Figure 14. Record of an as yet unidentified squirrel.

Sitatunga

One individual was recorded on camera trap near a large pond in Camp 2. Tracks of the species were also observed nearby.

Hunting

Evidence of hunting was present in the forests at all three sites. Signs included active hunters, rat traps, shotgun cartridges and spring snares. Species targeted included brush-tailed porcupine, red river hog, Emin's pouched rat, duiker and squirrels.

2.2.4 Discussion

We recorded 27 mammal species during our survey at the three sites, including bonobo. Despite the local communities not hunting bonobos, people from outside have reportedly started to hunt bonobos in the forests of Luvua. Some notable species that were not recorded but that could be expected in the forests (based on IUCN distribution data) include African golden cat (*Profelis aurata*), otter shrew (Potamogale velox), giant pangolin (*Smutsia gigantea*), long-tailed pangolin (*Uromanis tetrodactyla*), tree pangolin (*Phataginus tricuspis*) water chevrotain (*Hymoschus aquaticus*). Most of these species occur either naturally (top predators such as the large cats) or due to overhunting (pangolin) in low densities and our camera trap effort was too low to confirm the presence (or absence) of these species. Pangolins most probably are still present in the area. One of our local guides reported he killed a giant pangolin in a patch of savannah near Camp 3 in 2016. Since then he knew of one more person to have killed one in 2017, but has not seen one, or knew of one seen, since. Hunting pressure could have led to the species only surviving in the more remote areas of the forests, or the species is very difficult to observe in the first place..

We only recorded three large and medium mammals from the savannah habitat (buffalo, bushbuck and a mongoose species) of which only bushbuck was recorded by camera trap. Our camera trap survey effort here was lower than in the forest. Most species recorded in the savannah were detected through indirect observations of dung, trails and footprints.

The temporal limitations of this rapid biodiversity assessment and associated brief deployment of camera traps provides some first insights in some of the mammal species present. To better understand the mammalian community in the area a grid structured long term camera trap survey covering different seasons would be needed. Also a better geographic coverage including some sites located further away from the nearby communities would be needed to record some of the low density species.

Our survey still provided valuable records, despite the relatively low survey effort, and can be used as a baseline for future studies.

2.3 Avifauna

Gabriel Jamie*, Sam Jones* *both authors contributed equally to this work

2.3.1 Introduction

The Democratic Republic of Congo (DRC) is the country with the highest avian species richness in Africa (1,117 species as of Demey et al. 2000). Its avian diversity stems from the wide range of biomes occurring within its borders. At its center lies the vast and species rich expanse of the lowland Congo Basin rainforest (Guineo-Congolian biome). On its southern border, the Congo Basin transitions into the deciduous Zambezian woodlands and, to the north, into the Sudan-Guinea savannahs, each of which contain distinct and speciose assemblages. Its eastern edge is bordered by the endemism-rich mountains of the Albertine Rift which rise to over 5,000 m elevation and traverse a range of habitats from humid rainforest to alpine grassland. The Congo river itself supports a suite of species either restricted solely to it or extending to adjacent river systems and mangroves, while the country's small but significant stretch of coastline gives access to diverse marine communities and mangroves. Additionally, species endemic to the more geographically restricted biomes of the Lake Victoria basin, the Upemba plains, and the Lake Lufira area are all represented in DRC (Fishpool & Evans 2001).

Despite (and in part because of) its ornithological richness, the avifauna of DRC remains extremely poorly understood. The key work on the region's avifauna remains James Chapin's four volume "Birds of the Belgian Congo" the first volume of which (Chapin 1932) was published almost 90 years ago and before the country gained independence. The book's lasting relevance is a testament to the depth and breadth of Chapin's work but also to the relative paucity of ornithological fieldwork conducted in the country since. For this reason, the ecology and evolutionary history of many species within DRC are hardly known. Indeed, the only comprehensive coverage of the DRC avifauna in contemporary literature is in Sinclair & Ryan (2010), a work covering the entirety of sub-Saharan Africa. Thus, the extent to which the apparent range limits of many species reflect true boundaries versus artefacts of inadequate sampling ('Wallacean shortfall') remains to be established. As such, the boundaries or transitions between the biogeographical regions outlined above are often poorly defined. By extension, the fine-scale variation among communities within these biomes, and the importance of barriers such as the Congo river in creating and/or maintaining this exceptional avian diversity remain to be unraveled.

It is in this context that the Malebo region of DRC provides particular ornithological interest. Biogeographically, it is situated close to the intersection of the Guinea-Congolian and Zambezian biomes, while also lying within 30 km of the Congo river. The ranges of species associated with forests of northern Angola are known to extend into south-western DRC though it is not known whether ranges extend as far north-east as Malebo (>350 km from the Angola border at its closest point). On a local scale, the habitats at Malebo form a mosaic of lowland tropical rainforest and savannah. In some situations (such as our first study site, Bopambu Forest) the savannah was completely enclosed by forest. In others (such as at our two other study sites of Lekumah and Mongama Forests) it exists as a large stretch of land adjacent to the forest whose projections extend into the savannah. Additionally, the forests themselves are characterized by heterogeneity, comprising both mature dry forests and waterlogged swamp forests.

2.3.2 Methods

Preparatory work

In preparation for our fieldwork we reviewed species ranges and records from relevant literature (Sinclair & Ryan 2010, Chapin 1932, Fishpool & Evans 2001), in addition to online resources (e.g. eBird). We adopted as non-assumptive an approach to our preparatory work as possible, creating a list of plausible species that covered effectively the entire avifauna of the DRC and adjacent regions in central Africa. While collating these data, we also compiled an extensive sound recording archive from pre-existing recording sets, augmented with recordings of particular species from the online sound repositories Xeno-canto and the Macauley Library (www.xeno-canto.org / https://www.acaulaylibrary.org/).

Survey methodologies

We surveyed birds using four main techniques (see below) which were supplemented with records/observations from other more occasional methods. Because a principal aim of our fieldwork was to characterise avifaunal communities of both forest and savannah habitats, we replicated these methods across both habitat types at the three research camps. Where clear differences (obvious ecotone boundaries) existed within forest, we also replicated our survey efforts in these habitats to most effectively capture within site avifaunal variation. Typically differences within forests were dry 'terra firma' forest characterised by high canopies (40–60 m high) and waterlogged swamp forests with much lower canopies and extensive liana tangles. The principal survey methods were as follows:

1) Dawn chorus records/point counts

In both forest and savannah habitats at each camp we conducted standardised dawn chorus recordings and point counts. Dawn chorus recordings followed methods described by Herzog et al. (2016), using directional shotgun microphones (Sennheiser ME66, paired with a recording device). A given survey site was visited within the first hour of the dawn chorus (corresponding with first light at ~0515), where a 15 minute, uninterrupted, dawn chorus recording was made. During the first 8 minutes of the recording, the recordist initially pointed the microphone in the direction of greatest vocal activity and then rotated 90 degrees clockwise every minute until two rotations were completed. For the remaining 7 minutes recordings were made opportunistically/irrespective of direction to document the vocalisations of species not recorded in the previous 8 minutes or to get better recordings of species already recorded. Each dawn recording site was separated by at least 250 m following recommendations in Herzog et al. (2016) and were typically situated along access trails through the forest for ease of silent movement at dawn. Dawn chorus recordings were usually conducted by two observers: one observer recording and the other noting down species during the recording period. This approach allowed us to archive the dawn chorus and identify unknown species post-hoc.

We augmented these dawn chorus recordings with point counts undertaken across the same habitat gradient. Each point count was 10 minutes in length and we bounded all species recorded in this period to an estimated 50 m radius around the point ensuring species recorded during these surveys were explicitly in the target habitat. Across each habitat type we conducted between 3–5 point counts per research camp.

2) Mist-netting

We erected teams of 6, 9 and 12 m mist-nets across the same habitat types as those targeted for other methods. Nets were not opened on a specifically standardised protocol, but we aimed to cover the habitat types in our survey area with broadly equal coverage. Nets were opened at times of peak activity (typically following dawn chorus recordings) and kept open until capture rates discernibly reduced. Captured birds were ringed with a small coloured and uniquely numbered ring, checked for moult (body and flight-feather) and breeding condition. We also measured the following biometrics– maximum tarsus, maximum (straightened/flattened) wing chord, tail length, bill tip to anterior nares, bill tip to skull, bill width at anterior nares, bill depth at anterior nares, Kipp's distance, mass and wing formulae (emarginated primaries, longest primaries forming the wing tip and the length of the penultimate outermost primary to other primaries). Finally, we also collected blood (2 x samples: on FTA cards and another in 90% ethanol) and feather samples and took standardised sets of photographs (head and eye, spread wing, spread tail and the bird in the photographic grip) for the majority of captured birds. Untargeted mist-netting was undertaken on 5 separate days for >120 net hours.

3) Passive acoustic monitoring (Audiomoths)

Because nocturnal Afrotropical forest birds are some of the poorest known species in the region, we made particular effort to attempt to document their presence and behavioural song patterns. We deployed 'Audiomoths' (passive acoustic monitoring devices – see openacousticdevices.info/audiomoth) in the same habitat types as those covered by other surveys. We deployed 2 units in each habitat type at each camp, set to record continuously from dawn to dusk (1800–0500). At the time of writing these data are not yet processed.

4) Opportunistic surveying

We birdwatched extensively throughout the survey period in addition to the described methods. Particular effort was made to document species for which our standardised methods were least likely to capture such as non-vocal raptors, aerial insectivores and non-vocal species typically only encountered occasionally in roving mixed species flocks, fruiting trees or on forest edges. Because the phenology of many tropical species is poorly known, we also noted relevant information on breeding behaviour and will report these together with our data on breeding condition of birds caught in mist nets in the final report.

Finally, we also augmented our records with those seen and documented by other members of our expedition team either in the field or in camera traps.

Digital vouchers and the daily log

We made extensive efforts to unambiguously document species digitally with sound recordings and still images in the form of verifiable digital 'vouchers' to be archived on online recording platforms. Specifically, at the time of writing we are in the process of uploading and digitally archiving this media on the online avian recording archive the Macauley Library (via eBird) and xeno-canto. This approach to inventorying in the absence of collecting physical specimens by archiving digital voucher specimens follows that suggested by Lees et al. (2014).

At the end of each day, we compiled our collective sightings into the form of a 'daily log'. This comprised all species detected throughout the day with estimated numbers of individuals within each habitat type. Inherently the daily number of species recorded varied dependent on which habitat types we focussed on in that given day, but it nonetheless serves as an accurate representation of species relative abundance via 'bird days' (number of days /23) within which a species was recorded.

Species inventory, accumulation curve and annotated checklist

An initial species inventory from our survey comprising 158 confirmed species, in addition to several other species to be resolved is presented in **Table 4**. Included in this table are the habitat types these species were recorded in, daily mean count (± sd) and 'bird days' a species was recorded on. Accompanying this, **Figure 15A** displays a species accumulation of new species added throughout the survey period alongside against a baseline number of species recorded on a daily basis. **Figure 15B** displays the same accumulation curves but between forest and savannah habitats. We considered species recorded 'within' these habitat distinctions when we adjudged a given species to be 'using' the specific habitat type. For example, we regularly recorded species such as Hornbills flying over Savannahs, but this did not qualify it to be using this habitat. In contrast, for species such as Bee-eaters of swifts for which we recorded hawking over both habitat distinctions their addition to the habitat specific species accumulation curves were often on different dates and as such the total species for each habitat do not sum to the overall species inventory. Inevitably there is a degree of uncertainty over the distinction of habitat usage for some species. For cases where a species was discernibly using both habitats, we adopted the most encompassing approach and ascribed the species to both habitats (e.g. Bates's Nightjar – a forest nightjar, but for which we recorded utilising the forest/wooded savannah transition for its song posts).

Below the summary table, we also provide an annotated checklist of species of conservation concern, notable records (e.g. range extensions or particularly rare species) and then shorter individual accounts for all species recorded during the survey. Finally, owing to the limited data available on breeding phenology and morphometrics of much of the avifauna of the region, we will follow these summaries with accounts of breeding records and morphometric data collected during the expedition in the final report.

2.3.3 Species inventory

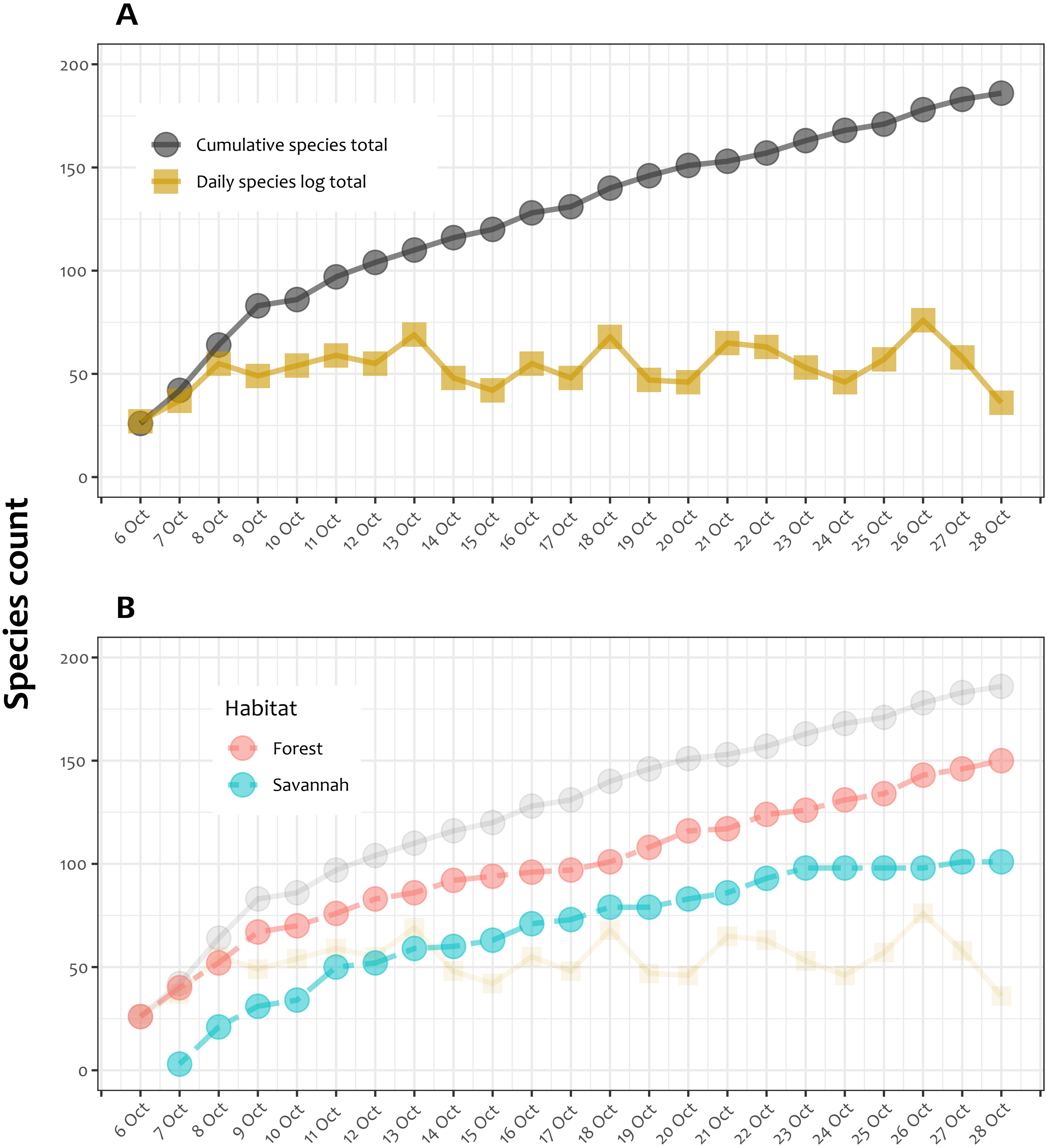

Figure 15. A. Species accumulation (i.e. daily new species detected during our survey) in comparison to daily species log totals, and **B.** species accumulation within respective habitat types against background rates displayed in **A.** Note, species can be represented in both Forest and Savannah accumulation curves owing to some species being detected in both habitat types – see description in methods.

Table 4. Preliminary inventory of species recorded during the expedition across the three camps. 'Bird days' represents the number of individual survey days on which a given species was recorded on, and acts as a proxy for overall abundance of species within the survey period. 'dc' = daily count. Habitat breakdowns correspond to those in Figure 15B. with a more thorough breakdown to be presented in the final report (F = forest, S = Savannah). All species detected fall under either IUCN status are LC ('Least Concern'), or EN ('Endangered').

English name	Latin name	IUCN Status	Habitat	Bird days/23	Min - max dc	Mean dc (sd)	Mode dc
Spot-breasted Ibis	*Bostrychia rara*	LC	F	7	2-4	2 (0.79)	2
Yellow-billed Kite	*Milvus aegyptius*	LC	F/S	6	1-6	3 (1.41)	2
Palm-nut Vulture	*Gypohierax angolensis*	LC	F/S	4	1-1	1 (0)	1
Bat Hawk	*Macheiramphus alcinus*	LC	F	1	2	2	2
African Harrier-hawk	*Polyboroides typus*	LC	F/S	8	1-3	2 (0.92)	1
Black Sparrowhawk	*Accipiter melanoleucus*	LC	F	1	1	1	1
Red-chested Goshawk	*Accipiter toussenelii*	LC	F	6	1-1	1 (0)	1
Eurasian Hobby	*Falco subbuteo*	LC	S	1	1	1	1
Red-necked Francolin	*Pternistis afer*	LC	S	13	1-5	3 (1.65)	5
Grey-throated Rail	*Canirallus oculeus*	LC	F	1	1	1	1
Afep Pigeon	*Columba unicincta*	LC	F	12	1-4	2 (0.94)	1
Western Bronze-naped Pigeon	*Columba iriditorques*	LC	F	8	1-2	1 (0.46)	1
Red-eyed Dove	*Streptopelia semitorquata*	LC	F/S	13	1-4	2 (0.89)	2
Cape Turtle Dove	*Streptopelia capicola*	LC	S	3	1-2	2 (0.58)	2
African Green Pigeon	*Treron calvus*	LC	F	11	1-5	2 (1.69)	1
Blue-spotted Wood-dove	*Turtur afer*	LC	F/S	13	1-5	2 (1.22)	1
Turtur sp.	*Turtur* sp.		F	3	1-2	1 (0.58)	1
Grey Parrot	*Psittacus erithacus*	EN	F	16	1-6	2 (1.53)	1
Black-collared Lovebird	*Agapornis swindernianus*	LC	F	1	5	5	5
Great Blue Turaco	*Corythaeola cristata*	LC	F	21	1-15	7 (3.95)	10
Black-billed Turaco	*Tauraco schuettii*	LC	F	18	1-2	1 (0.49)	1
Klaas's Cuckoo	*Chrysococcyx klaas*	LC	F/S	9	1-1	1 (0)	1
African Emerald Cuckoo	*Chrysococcyx cupreus*	LC	F	17	1-4	2 (0.81)	2
Olive Long-tailed Cuckoo	*Cercococcyx olivinus*	LC	F	6	1-2	1 (0.41)	1
Red-chested Cuckoo	*Cuculus solitarius*	LC	F	17	1-3	2 (0.9)	1
Black Cuckoo	*Cuculus clamosus*	LC	F	12	1-3	2 (0.67)	1
Blue Malkoha (Chattering Yellowbill)	*Ceuthmochares aereus*	LC	F	6	1-2	2 (0.55)	1
Senegal Coucal	*Centropus senegalensis*	LC	F/S	17	1-5	3 (1.18)	2
Vermiculated Fishing-owl	*Scotopelia bouvieri*	LC	F	6	1-3	2 (0.82)	1
Bates's Nightjar	*Caprimulgus batesi*	LC	F/S	1	1	1 (0)	1
Nightjar sp.	*Caprimulgus* sp.		F	1	1	1	1
Swift sp.	*Apus* sp.		F/S	6	1-200	47 (62.98)	1
African Palm-swift	*Cypsiurus parvus*	LC	F/S	4	1-25	8 (11.53)	1
Sabine's Spinetail	*Rhaphidura sabini*	LC	F/S	3	2-5	2 (1.22)	2

English name	Latin name	IUCN Status	Habitat	Bird days/23	Min - max dc	Mean dc (sd)	Mode dc
Cassin's Spinetail	*Neafrapus cassini*	LC	F/S	5	1-6	2 (2.24)	1
Common Swift	*Apus apus*	LC	F/S	13	4-300	75 (76.04)	40
Speckled Mousebird	*Colius striatus*	LC	S	2	1-2	2 (0.71)	1
Black Scimitarbill	*Rhinopomastus aterrimus*	LC	F	1	2	2	2
White-bellied Kingfisher	*Corythornis leucogaster*	LC	F	5	1-2	1 (0.45)	1
African Pygmy-kingfisher	*Ispidina picta*	LC	F/S	7	1-3	2 (0.76)	1
African Dwarf-kingfisher	*Ispidina lecontei*	LC	F	6	1-2	1 (0.41)	1
Blue-breasted Kingfisher	*Halcyon malimbica*	LC	F	14	1-3	2 (0.85)	1
Woodland Kingfisher	*Halcyon senegalensis*	LC	F	1	1	1	1
Chocolate-backed Kingfisher	*Halcyon badia*	LC	F	13	1-3	2 (0.85)	1
Striped Kingfisher	*Halcyon chelicuti*	LC	F	1	1	1	1
Broad-billed Roller	*Eurystomus glaucurus*	LC	F/S	1	2	2 (0)	2
Blue-throated Roller	*Eurystomus gularis*	LC	F/S	2	1-1	1 (0)	1
Black Bee-eater	*Merops gularis*	LC	F	1	2	2	2
Rosy Bee-eater	*Merops malimbicus*	LC	F/S	6	1-30	14 (12.62)	10
Little Bee-eater	*Merops pusillus*	LC	S	2	1-1	1 (0)	1
White-throated Bee-eater	*Merops albicollis*	LC	F/S	11	1-50	26 (19.78)	50
European Bee-eater	*Merops apiaster*	LC	F/S	9	1-15	4 (4.57)	1
Red-billed Dwarf Hornbill	*Lophoceros camurus*	LC	F	1	1	1	1
African Pied Hornbill	*Lophoceros fasciatus*	LC	F	16	1-10	4 (2.72)	2
Black-casqued Wattled Hornbill	*Ceratogymna atrata*	LC	F	12	1-5	2 (1.38)	2
White-thighed Hornbill	*Bycanistes albotibialis*	LC	F	22	1-30	6 (6.79)	2
Sladen's Barbet	*Gymnobucco sladeni*	LC	F	2	5-5	5 (0)	5
Grey-throated Barbet	*Gymnobucco bonapartei*	LC	F/S	1	5	5 (0)	5
Gymnobucco sp.	*Gymnobucco* sp.		F	3	1-10	5 (4.51)	1
Yellow-billed Barbet	*Trachylaemus purpuratus*	LC	F	1	1	1	1
Hairy-breasted Barbet	*Tricholaema hirsuta*	LC	F	15	1-4	2 (1.28)	1
Speckled Tinkerbird	*Pogoniulus scolopaceus*	LC	F	20	1-5	2 (1.23)	2
Yellow-rumped Tinkerbird	*Pogoniulus bilineatus*	LC	F/S	20	1-8	3 (2.04)	1
Yellow-throated Tinkerbird	*Pogoniulus subsulphureus*	LC	F/S	22	1-15	5 (2.99)	5
Red-rumped Tinkerbird	*Pogoniulus atroflavus*	LC	F/S	16	1-3	1 (0.63)	1
Yellow-spotted Barbet	*Buccanodon duchaillui*	LC	F	2	1-2	2 (0.71)	1
Zenker's Honeyguide	*Melignomon zenkeri*	LC	F	3	1-1	1 (0)	1
Least Honeyguide	*Indicator exilis*	LC	F	11	1-2	1 (0.3)	1
Buff-spotted Woodpecker	*Campethera nivosa*	LC	F	1	1	1	1
Brown-eared Woodpecker	*Campethera caroli*	LC	F	1	1	1	1
Yellow-crested Woodpecker	*Dendropicos xantholophus*	LC	F	1	1	1	1
Rufous-sided Broadbill	*Smithornis rufolateralis*	LC	F	11	1-2	1 (0.47)	1
Flappet Lark	*Mirafra rufocinnamomea*	LC	S	13	1-4	2 (0.96)	1

English name	Latin name	IUCN Status	Habitat	Bird days/23	Min - max dc	Mean dc (sd)	Mode dc
Banded Martin	*Neophedina cincta*	LC	S	2	1-1	1 (0)	1
Forest Swallow* ID awaiting confirmation	*Atronanus (Petrochelidon) fuliginosus*	LC	F/S	2	1-1	1 (0)	1
Black Saw-wing	*Psalidoprocne pristoptera*	LC	F/S	3	2-4	2 (0.82)	2
Barn Swallow	*Hirundo rustica*	LC	F/S	18	2-100	19 (21.73)	10
Lesser Striped Swallow	*Cecropis abyssinica*	LC	S	2	1-1	1 (0)	1
Cecropis sp.	*Cecropis* sp.		S	1	1	1	1
South African Cliff-swallow	*Petrochelidon spilodera*	LC	F/S	4	1-2	1 (0.5)	1
Longclaw sp.	*Macronyx* sp.		S	1	2	2	2
Pipit sp.	*Anthus* sp.		S	1	1	1	1
Shining Drongo	*Dicrurus atripennis*	LC	F	2	2-2	2 (0)	2
Western Black-headed Oriole	*Oriolus brachyrynchus*	LC	F	1	1	1	1
Pied Crow	*Corvus albus*	LC	F/S	7	1-10	4 (3.41)	5
White-winged Black Tit	*Melaniparus leucomelas*	LC	S	1	3	3	3
Dark-capped Bulbul	*Pycnonotus barbatus*	LC	F/S	16	2-20	6 (5.13)	2
Icterine Greenbul	*Phyllastrephus icterinus*	LC	F	15	2-6	4 (1.41)	5
Yellow-whiskered Greenbul	*Eurillas latirostris*	LC	F	16	1-7	3 (2.22)	1
Little Greenbul	*Eurillas virens*	LC	F	7	1-5	3 (1.72)	1
Plain Greenbul	*Eurillas curvirostris*	LC	F	3	1-2	1 (0.58)	1
Little Grey Greenbul	*Eurillas gracilis*	LC	F	1	4	4	4
Ansorge's Greenbul	*Eurillas ansorgei*	LC	F	4	1-2	2 (0.5)	2
Slender-billed Greenbul	*Stelgidillas gracilirostris*	LC	F	7	1-3	1 (0.79)	1
Red-tailed Greenbul	*Criniger calurus*	LC	F	12	1-14	4 (3.7)	2
Red-tailed Bristlebill	*Bleda syndactylus*	LC	F	8	1-5	2 (1.41)	1
Honeyguide Greenbul	*Baeopogon indicator*	LC	F	3	1-2	1 (0.58)	1
Swamp Palm Bulbul	*Thescelocichla leucopleura*	LC	F	7	1-6	4 (1.77)	4
Spotted Greenbul	*Ixonotus guttatus*	LC	F	13	2-8	4 (1.83)	2
Western Nicator	*Nicator chloris*	LC	F/S	21	1-5	2 (1.14)	2
Rufous Flycatcher-thrush	*Stizorhina fraseri*	LC	F	21	1-5	3 (1.33)	1
Fire-crested Alethe	*Alethe castanea*	LC	F	8	1-4	2 (1.07)	1
Forest Robin	*Stiphrornis erythrothorax*	LC	F	4	1-4	2 (1.26)	2
Rufous-tailed Palm-thrush	*Cichladusa ruficauda*	LC	S	1	1	1	1
White-browed Scrub-robin	*Cercotrichas leucophrys*	LC	S	9	1-4	2 (1.05)	1
Sooty Chat	*Myrmecocichla nigra*	LC	S	1	2	2	2
Icterine Warbler	*Hippolais icterina*	LC	S	1	1	1	1
Garden Warbler	*Sylvia borin*	LC	F	1	1	1	1
Red-faced Cisticola	*Cisticola erythrops*	LC	S	1	1	1	1
Whistling Cisticola	*Cisticola lateralis*	LC	S	18	1-12	4 (2.73)	3
Short-winged Cisticola	*Cisticola brachypterus*	LC	S	15	1-10	4 (2.59)	2

English name	Latin name	IUCN Status	Habitat	Bird days/23	Min - max dc	Mean dc (sd)	Mode dc
Croaking Cisticola	*Cisticola natalensis*	LC	S	10	1-3	2 (0.7)	1
Buff-throated Apalis	*Apalis rufogularis*	LC	F	16	1-5	2 (1.25)	1
Tawny-flanked Prinia	*Prinia subflava*	LC	S	16	1-10	4 (2.54)	2
White-chinned Prinia	*Schistolais leucopogon*	LC	S	2	2-2	2 (0)	2
Rufous-crowned Eremomela	*Eremomela badiceps*	LC	F	2	2-5	4 (2.12)	2
Green-capped Eremomela	*Eremomela scotops*	LC	S	4	2-4	3 (0.82)	3
Red-capped Crombec	*Sylvietta ruficapilla*	LC	S	1	2	2	2
Lemon-bellied Crombec	*Sylvietta denti*	LC	F	2	1-1	1 (0)	1
Green Crombec	*Sylvietta virens*	LC	F/S	9	1-3	3 (0.73)	3
Green Hylia	*Hylia prasina*	LC	F	21	1-11	4 (2.72)	2
Grey-backed Camaroptera	*Camaroptera brachyura*	LC	F/S	17	1-5	3 (1.3)	2
Olive-green Camaroptera	*Camaroptera chloronota*	LC	F	1	1	1	1
Yellow-browed Camaroptera	*Camaroptera superciliaris*	LC	F	1	1	1	1
Grey Longbill	*Macrosphenus concolor*	LC	F	13	1-3	2 (0.78)	1
African Shrike-flycatcher	*Megabyas flammulatus*	LC	F	1	3	3	3
Black-and-white (Vanga) Flycatcher	*Bias musicus*	LC	F/S	6	1-2	2 (0.5)	2
Spotted Flycatcher	*Muscicapa striata*	LC	F/S	5	1-2	1 (0.45)	1
Sooty Flycatcher	*Bradornis fuliginosus*	LC	F	1	7	7	7
Grey (Lead-coloured) Tit-flycatcher	*Fraseria plumbea*	LC	S	6	1-3	2 (0.84)	1
Grey-throated Tit-flycatcher	*Fraseria griseigularis*	LC	F	1	1	1	1
African Paradise Flycatcher	*Terpsiphone viridis*	LC	F/S	3	1-3	2 (1.15)	1
Red-bellied Paradise Flycatcher	*Terpsiphone rufiventer*	LC	F	22	1-10	3 (2.34)	2
Blue-headed Crested Flycatcher	*Trochocercus nitens*	LC	F	5	1-1	1 (0)	1
Western Black-headed *Batis*	*Batis erlangeri*	LC	S	9	1-5	2 (1.32)	1
Chestnut Wattle-eye	*Dyaphorophyia castanea*	LC	F	2	1-3	2 (1.41)	1
Lowland Sooty Boubou	*Laniarius leucorhynchus*	LC	F	14	1-5	2 (1.33)	1
Black-crowned Tchagra	*Tchagra senegalus*	LC	S	4	1-3	2 (1)	1
Purple-headed Starling	*Hylopsar purpureiceps*	LC	F	3	1-4	3 (1.73)	4
Violet-backed Starling	*Cinnyricinclus leucogaster*	LC	F/S	5	1-5	3 (1.52)	2
Chestnut-winged Starling	*Onychognathus fulgidus*	LC	F	1	2	2	2
Copper Sunbird	*Cinnyris cupreus*	LC	S	11	1-15	4 (3.95)	2
Green-throated Sunbird	*Chalcomitra rubescens*	LC	S	2	2-2	2 (0)	2
Blue-throated Brown Sunbird	*Cyanomitra cyanolaema*	LC	F	15	2-7	3 (1.33)	2
Olive Sunbird	*Cyanomitra olivacea*	LC	F	22	3-14	6 (2.83)	5
Bates's Sunbird	*Cinnyris batesi*	LC	F/S	5	1-5	2 (1.67)	1
Grey-headed Sunbird	*Deleornis axillaris*	LC	F	1	3	3	3
Grey-chinned (Green) Sunbird	*Anthreptes tephrolaemus*	LC	F/S	10	1-7	2 (1.96)	2

English name	Latin name	IUCN Status	Habitat	Bird days/23	Min - max dc	Mean dc (sd)	Mode dc
Collared Sunbird	*Hedydipna collaris*	LC	F	6	1-3	2 (0.89)	1
Orange-tufted Sunbird	*Cinnyris bouvieri*	LC	S	3	2-4	3 (1.15)	2
Olive-bellied Sunbird	*Cinnyris chloropygius*	LC	F	8	1-5	2 (1.36)	1
Northern Grey-headed Sparrow	*Passer griseus*	LC	S	2	2-5	4 (2.12)	2
Village Weaver	*Ploceus cucullatus*	LC	S	4	4-10	6 (2.71)	5
Viellot's Black Weaver	*Ploceus nigerrimus*	LC	S	2	25-45	35 (14.14)	25
Red-headed Malimbe	*Malimbus rubricollis*	LC	F	2	1-2	2 (0.71)	1
Blue-billed (Gray's) Malimbe	*Malimbus nitens*	LC	F	1	1	1	1
Fan-tailed (Red-shouldered) Widow	*Euplectes axillaris*	LC	S	1	5	5	5
White-winged Widow	*Euplectes albonotatus*	LC	S	4	1-8	3 (3.3)	1
Chestnut-breasted Nigrita	*Nigrita bicolor*	LC	F	1	1	1	1
Grey-headed (crowned) Nigrita	*Nigrita canicapillus*	LC	F	2	1-2	2 (0.71)	1
Pale-fronted Nigirita	*Nigrita luteifrons*	LC	F	1	1	1	1
Red-billed Firefinch	*Lagonosticta senegala*	LC	S	2	2-2	2 (0)	2
African (Blue-billed) Firefinch	*Lagonosticta rubricata*	LC	S	1	2	2	2
Black-bellied Seedcracker	*Pyrenestes ostrinus*	LC	S	1	1	1	1
Woodhouse's Antpecker	*Parmoptila woodhousei*	LC	F	1	1	1	1
Bronze Mannikin	*Spermestes cucullata*	LC	F/S	4	2-25	9 (10.59)	5
Black-and-white Mannikin	*Spermestes bicolor*	LC	F/S	8	2-15	6 (4.6)	2
Orange-cheeked Waxbill	*Estrilda melpoda*	LC	S	2	2-5	4 (2.12)	2
Pin-tailed Whydah	*Vidua macroura*	LC	S	4	1-3	2 (0.82)	2
Yellow-fronted Canary	*Crithagra mozambica*	LC	S	7	1-5	3 (1.86)	1

Notable records

Eurasian Hobby *Falco subbuteo*

A single (adult) bird flew over the Savannah patch of the Bopambu Forest on mid-morning of the 11 October. Eurasian Hobby is a common Afro-Palearctic migrant to west, east and southern Africa with its non-breeding range forming a ring around central Africa. There are no known records in DRC away from the extreme east or south of the country: Chapin (1932) noting 'it is not yet known from the forested regions of the Congo'. We are aware of no other records in west-central Africa, with the closest mapped edges of their non-breeding distribution in central Cameroon/ Central African Republic, and northern Angola. Migrant birds arrive in Africa generally from late October (Sinclair & Ryan 2010) and we presume our sighting pertains to a bird on passage, rather than wintering at the site.

Grey-throated Rail *Canirallus oculeus*

A single bird was photographed on a camera-trap in damp/waterlogged area adjacent to small river in swamp forest in Bopambu Forest on 12 October at 1730 (the same camera trap detected two Spot-breasted Ibises). A notable record of this generally uncommon and secretive species representing a significant range extension to the south of its previously known distribution. In DRC it is known from the north of the Congo river, although Birds of Africa and Birds of the world suggests its distribution may extend to the southern bank of the Congo (Taylor 2020).

Bates's Nightjar *Caprimulgus batesi*

Male singing from forest edge and savannah at Lekuma Forest on night of 20 October. Well photographed and sound recorded - perhaps some of the better publicly available documentation of this species. While this species is within range and not necessarily unexpected, it is nonetheless relatively scarce and infrequently observed well presumably as a result of its restriction typically to forest interior habitats.

Zenker's Honeyguide *Melignomon zenkeri*

One bird singing from midstory/sub-canopy terra firma close to camp in Mongama Forest. First detected on 24 October and observed daily until the 26 October (singing in close proximity - <50 m - to a Least Honeyguide). Extensively sound recorded and photographed, likely representing the best digital documentation of this little known and rare species. Indeed, its vocalizations are known from possibly as little as one series of recordings obtained in Cameroon which have been suggested as being wrongly attributed to this species and instead the equally rare and little known Yellow-footed Honeyguide M.eisentrauti (Short & Horne 2020). Nonetheless, the vocalisations of our bird were identical to that of the presumed Zenker's Honeyguide, and it also responded strongly to playback of this previous (the song is more strident than the mournful song of eisentrauti). Our observations represent a significant southward range extension with maps suggesting it was previously known primarily from areas north of the Congo river with the range perhaps extending slightly onto its south bank (Sincair & Ryan 2010), and as far east as western Uganda. Indeed, Chapin (1939) described the species as 'Everywhere rare..' and at the time of his writing its presence in DRC known from only 2 specimens. Our individual consistently sang from a 'song post' (see annotated checklist) allowing us to collect basic ecological data on its song patterns/timing, the first of its kind for the species (see Short & Horne 2020).

Forest Swallow *Hirundo fuliginosa*

A single of what was likely this species seen and photographed over savannah at forest edge transition at Bopambu Forest in late afternoon on 11 October. Slight notch to tail and flight behaviour both point to Forest Swallow over Square-tailed Sawwing but we nonetheless consider this identification provisional as we circulate images for external opinion. This caveat aside, our record would represent a new national record for DRC with previous closest records coming from Gabon and north-west Republic of Congo. In the latter country it has been considered a vagrant (Turner 2020) and it is possible that our record also pertains to vagrancy, although it is overall more likely to comprise a genuine range extension into the south-western Congo Basin.

Lemon-bellied Crombec *Sylvietta denti*

Recorded on at least two days in the Mongama Forest (24 and 26 October), although further examination of dawn chorus and other recordings may allow this species to be retrospectively recorded for other days. Our records extend the distribution of this (already patchily distributed) species into the southern DRC with the closest records generally on the north of the Congo river, north-western Congo/eastern Gabon and northern Angola. However, it widespread in tropical Africa from upper Guinea, east to western Uganda (e.g. Semuliki National Park) and occupied secondary as well as primary forest throughout its range suggesting it is perhaps more widespread than currently known (see Sinclair & Ryan 2010; Pearson 2020).

Chestnut-winged Starling *Onychoganthus hartlaubi*

A pair seen in the canopy on 24th October in the Mongama Forest. Not an uncommon Afrotropical forest starling, but a minor range extension as per Craig et al. (2020). We note, however, that this is on extreme southerly tip of the mapped range of the species in Sinclair and Ryan (2010).

Bates's Sunbird *Cinnyris batesi*

Small numbers recorded infrequently (5 days) in the savannah patch (typically in the more woody areas at Bopambu Forest. Mostly detected by the distinctive "Red-throated Pipit"-type call, but also seen. While relatively widespread from upper Guinea (eastern Liberia) to the eastern DRC and south to the extreme north of Zambia, Bates Sunbird is generally rare and localized throughout its range (Cheke & Mann 2020). Our observations extend the species range into western DRC, with the closest edges of its known distribution in northern Republic of Congo and possibly in central DRC (Cheke & Mann 2020, Sinclair & Ryan 2010).

Orange-tufted Sunbird *Cinnyris bouvieri*

Recorded on three days from savannah close to forest edge at Lekuma Forest. Restricted to Central/West central Africa although patchily distributed throughout the region (from northern Nigeria as far east as western Kenya and Uganda). Our records represent a small range extension into western DRC with the closest known populations in northern Angola and southern DRC, possibly as far north as Kinshasa (Cheke & Mann 2020, Sinclair & Ryan 2010).

Red-billed Firefinch *Lagonosticta senegala*

Seen in Mongama Village on 23 & 26 October. Common and widespread across sub-saharan Africa (Sinclair & Ryan 2010), although apparently largely absent from the Congo Basin (absent from Gabon, Republic of Congo, central/western DRC and northern Angola). Our records thus extend the range significantly westward into western DRC although it is probably likely the species occurs elsewhere in disturbed habitats throughout at least the immediate region.

Woodhouse's Antpecker *Parmoptila woodhousei*

Female captured in a mist net over small stream at Lekuma Forest on 19 October. In general, an uncommon species that is infrequently observed across its range in central-west Africa (although apparently more numerous in Gabon). Occurs as far north as southern Nigeria and south to northern Angola with the core of its distribution centered on the western edge of the Congo Basin in Gabon and northern republic of Congo, although apparently has occurred in Ituri, eastern DRC (Payne 2020). Our record is within the range of that mapped in Sinclair & Ryan (2010), but significantly east of that in Payne (2020) to the eastern bank of the Congo River.

2.3.4 Annotated Checklist

1. **Spot-breasted Ibis**
   At least two birds passed over the first campsite at Bopambu Forest most early mornings and evenings and roosting sites. On 14 October up to four birds were heard (two groups of two) passing over camp in evening. Two birds caught on camera trap in marshy area by river to north-east of campsite (same location as Grey-throated Rail later photographed at).

2. **Yellow-billed Kite**
   Birds recorded on 6 days - primarily in areas surrounding villages during walks between campsites. One bird also seen over savannah on 21 October. On 23 October an active nest was located at the edge of Mungoma village in "farmbush" habitat. The nest contained one well-developed chick and was being attended by the adults.

3. **Palm-nut Vulture**
   Birds recorded on 4 days over terra firma forest at Bopambu Forest, over Savannah at Mongama Forest and in transitional habitat close to villages near to Lekuma and farmbush near Mongama. Two adults, one juvenile and a bird in transitional plumage seen.

4. **Bat Hawk**
   Two in flight over edge of Lekuma forest viewed from savannah in mid-morning of 18 October.

5. **African Harrier-hawk**
   Seen frequently (8 days) over forest, forest edge and savannah at all three camps. Juveniles, adults and birds in transitional plumage all seen. An adult was watched performing what seemed to be a display flight over forest near first camp on 9 October with shallow wing beats and slow flight.

6. **Black Sparrowhawk**
   One light morph photographed in subcanopy of terra firma forest at Mungoma forest early morning on 26 October. Probably a female based on large size.

7. **Red-chested Goshawk**
   Detected frequently (6 days) with all encounters involving flyovers of calling birds through terra firma forest mostly in early mornings.

8. **Eurasian Hobby**
   One adult flew over savannah in mid-morning of 11 October. Likely a bird on passage through the area as not seen on previous or subsequent days. Main non-breeding range of the species in Africa thought to be further south (particularly in miombo woodlands from southern DRC southwards) with birds mainly arriving in late October (Birds of Africa).

9. **Red-necked Spurfowl**
Detected frequently (13 days) in savannah at all three sites. The only spurfowl/francolin detected during the survey period.

10. **Grey-throated Rail**
One bird detected on a camera trap in muddy area adjacent to small river in swamp forest in Bopambu Forest on 12 October. The same camera trap picked up two Spot-breasted Ibises. A notable record representing a range extension to the south of its previous known distribution. In DRC mainly known from areas to north of Congo river but Birds of Africa suggests the range may extend marginally to southern bank of the Congo.

11. **Afep Pigeon**
Detected frequently (12 days) singing from canopy and sub-canopy of forest at all three campsites and at WWF Malebo. Always calling from upland "terra firma" forest and not heard to sing from swamp forest or savannah areas.

12. **Western Bronze-naped Pigeon**
Detected frequently (9 days) singing from canopy and sub-canopy of terra firma forest. Not detected at Bopambu Forest but found at WWF Malebo, Lekuma, Mongama and the Bonobo Forest.

13. **Red-eyed Dove**
Detected commonly (14 days) at all sites. Mostly detected in savannah habitats but also found at forest edge at WWF Malebo and in "farmbush" habitat at edge of Bonobo Forest. Many birds singing.

14. **Cape Turtle Dov**
Detected infrequently (3 days) in savannah habitats where also heard to sing. The Malebo region is close to the northern range boundary for this species.

15. **African Green Pigeon**
Detected frequently (11 days) flying over savannah habitats and perched in terra firma forest. Several birds heard to sing. Seen flying over savannah habitat especially in evenings presumably commuting between feeding and roosting sites. Small aggregations seen (up to three birds) at fruiting trees above tree fall gaps in terra firma forest.

16. **Blue-spotted Wood-dove**
Detected commonly (13 days) in both savannah and terra firma forest habitats. Frequently heard singing in savannah while *Turtur* type song coming from forest needs to be followed up on to rule out other species such as Tambourine and Blue-headed Wood-dove (see next account).

17. **African Grey Parrot**
Detected commonly (16 days) usually in small groups of 2–6 birds flying over forest (both terra firma and swamp) and savannah. Heard to sing at dusk and after dark on several occasions. Most flyovers in early morning and evening presumably birds commuting between roosting and feeding sites.

18. **Black-collared Lovebird**
Flock of five flew over farmbush at edge of Bonobo Forest before briefly landing in tall tree on 27 October.

19. Great Blue Turaco
Detected essentially daily (21 days) with groups calling from forest canopy at all sites. Early morning and evening chorus of this species provided an evocative soundscape to fieldwork in the area.

20. Black-billed Turaco
Detected commonly (18 days) calling from forest at all sites though in much smaller numbers than Great Blue Turaco.

21. Klaas's Cuckoo
Detected frequently (9 days) singing from savannah, terra firma and swamp forest. Parasitises mainly sunbirds (Necatarinidae) as well as some warbler species (Cisticolidae). Many possible host species from both families were detected during the survey period.

22. African Emerald Cuckoo
Detected commonly (17 days) singing primarily from forest but also forest edge/well-wooded savannah. Not heard to sing from the swamp forest at Bopambu Forest. Known to parasitise Grey-backed Camaropteras which occur commonly at the site.

23. Olive Long-tailed Cuckoo
Detected infrequently (6 days) from each of the three main campsites. Always singing from terra firma forest giving both long and short versions of call. Suspected to parasitise broadbills with Rufous-sided being the only species detected locally.

24. Red-chested Cuckoo
Detected commonly (17 days) though not from Mongama Forest (the third campsite visited). Singing from both forest (terra firma and swamp) and savannah. With robin-chats being apparently absent from the area it would be interesting to know what species this cuckoo is parasitizing. Perhaps alethes or Forest Robins?

25. Black Cuckoo
Detected frequently (12 days) singing from swamp and terra firma forests at all study sites. Some birds visually verified as being of race gabonensis. Hosts mainly boubous and bush-shrikes the most common of which detected during the study period was Lowland Sooty Boubou.

26. Blue Malkoha
Detected infrequently (6 days) from midstory of terra firma and swamp forest. Birds head to give long trilling song preceded by short high-pitched notes.

27. Senegal Coucal
Detected commonly (17 days) from forest edge and savannah habitats at all three main survey sites. One bird seen in flight in savannah with stronger orange/buff tones to underparts reminiscent of Gabon Coucal but perhaps just a plumage variant of Senegal.

28. Vermiculated Fishing-owl
One bird heard calling from riverine forest at WWF Malebo on night of 6 October. Then heard each night from swamp forest adjacent to first campsite at Bopambu Forest (10–14 October) where up to three birds detected. Birds giving low single hoot calls as well as longer rhythmic series of calls. On night of 13 October two birds by camp were calling together (duetting) with

one individual given higher pitched versions of single hoot and extended calls compared to the other. Presumed to be a male-female interaction.

A single distant hoot given from the edge of Lekuma Forest on the night of 20 October was possibly this species though habitat (forest edge) was unusual and given only a single faint call heard it may have been from another owl species.

29. Bates's Nightjar
One male singing from forest edge and savannah at Lekuma Forest on night of 20 October. Allowed very close approach to small tree in savannah edge where it was singing from. Very well photographed and sound recorded. Pale markings on tail clear making it a male (along with vocal behaviour). Was calling from an area of well-wooded savannah that formed continuous band of trees connecting up to the forest some 50 m away.

30. Sabine's Spinetail
Small numbers (2–5 birds) seen on three days (8, 11 & 14 October) over savannah patch and forest edge in Bopambu Forest. Range maps (Birds of Africa) suggest this is a somewhat isolated population that occurs close to this section of Congo river.

31. Cassin's Spinetail
Small numbers (1–6 birds) seen on six days over forest gaps and savannah adjacent to forest in Bopambu and Lekuma Forests.

32. Common Swift
Large numbers (up to several hundred individuals) seen commonly (at least 14 days) over savannah and forest edge.

33. Speckled Mousebird
Seen on two days in savannah habitats on way to and at Lekuma Forest.

34. Black Scimitarbill
Two birds in farmbush on 26 October while we were walking out of Mongama forest to village.

35. White-bellied Kingfisher
1–2 birds heard and seen briefly in around swamp forest at Bopambu Forest on four days. Another one heard calling along river at Mongama forest on 25 October.

36. African Pygmy-kingfisher
Birds detected infrequently (7 days) in forest edge at WWF Malebo (6 days) and one in savannah close to forest edge at Lekuma Forest (1 day). On 6 October, an adult and immature were seen close together at WWF Malebo in open area close to casava plantation near forest edge. Possible that this was a recently fledged young suggestive of local breeding.

37. African Dwarf-kingfisher
1–2 bird detected daily between 17–22 October in forest adjacent to river around campsite at Lekuma Forest. This or another individual caught in mist net close to camp at Lekuma Forest on 19 October. Showed interesting moult pattern with small number of retained primaries and secondaries from previous generation.

38. Blue-breasted Kingfisher
Recorded commonly (14 days) calling from forest (terra firma & swamp) at all sites. Not recorded from savannah.

39. Woodland Kingfisher
One heard on route to Mongama forest from scrubby edge vegetation in farmbush on 23 October.

40. Chocolate-backed Kingfisher
Recorded frequently (13 days) calling from terra firma and swamp forest at all three camp sites. Vocal activity particularly notable in very early morning and just pre-dawn.

41. Striped Kingfisher
One singing from thin strip of riverine vegetation adjacent to savannah on walk in to Lekuma Forest on 16 October.

42. Broad-billed Roller
Two over savannah area near village close to Lekuma Forest on 22 October. Sound recorded. Sound recording needs checking to make sure no overlap in call with Blue-throated Roller.

43. Blue-throated Roller
One perched high in dead tree adjacent to narrow strip of riverine vegetation during transition between Lekuma Forest and Mongama village on 22 October. Another perched up at forest edge on route in to Mongama Forest on 23 October. Both birds photographed well.

44. Black Bee-eater
One perched up in forest edge at WWF Malebo on 7 October. Photographed.

45. Rosy Bee-eater
Flocks of up to 30 birds in flight over savannah, forest and forest clearings on 6 days. Seen daily over Bopambu Forest from 8–11 October. Smaller numbers seen on 15 and 23 October. Not clear if reduction in sightings towards end of trip due to our shifting location or whether birds seen were mostly on passage and moved on. No individuals seen perched during the survey period.

46. Little Bee-eater
One in savannah outside Lekuma Forest on 18 October and another in open wet savannah outside Bonobo Forest on 27 October.

47. White-throated Bee-eater
Seen frequently (11 days) in flocks of up to 50 individuals over forest, forest edge and savannah. Birds seen to perch in savannah, forest edge and in tree fall gaps in forest. All sightings were between 14–27 October with none observed 6–13 October. This likely reflected an arrival of birds in the general area rather than due to our shifts in location. Birds were seen over Bopambu Forest for the first time on 14 October despite us having been in the area without detecting them since 8 October.

48. European Bee-eater
Recorded frequently (9 days) flying over savannah, forest and forest edge. All records between 6–18 October with none from 19–28 October. This may reflect birds on passage moving through the general area.

49. Red-billed Dwarf Hornbill
One heard calling from forest close to edge with savannah in late morning of 21 October at Lekuma Forest. Present in background while sound recording White-chinned Prinias.

50. African Pied Hornbill
Recorded commonly (16 days) in forest, forest edge and flying over savannah. Usually in small groups of around 3–4 birds.

51. Black-casqued Wattled Hornbill
Recorded frequently (12 days) in canopy and terra firma forest at each of the three main campsites. Usually in small groups of 2–4 birds. Very vocal with nasal trumpeting calls often heard across the forest. Very heavy sounds of wingbeats when birds flew overhead.

52. White-thighed Hornbill
Recorded daily (22 days) in canopy of forest (terra firma & savannah), forest edge and flying over savannah. Very vocal. Heavy sounds of wingbeats in flight but not as strong as sound produced by Black-casqued Wattled Hornbills.

53. Sladen's Barbet
At least 5 seen in farmbush on way out from Mongama Forest on 26 October. Entering holes in tall dead trees. Photographed and sound recorded. Other *Gymnobucco* individuals present not seen well enough to determine if also Sladen's or whether Grey-throated Barbet. Mixed colonies of the two are known. Also at least 5 seen in farmbush at edge of Bonobo Forest on 27 October.

54. Grey-throated Barbet
4–5 birds seen well and photographed during transition between Lekuma Forest and Mongama Village on 22 October. Observed visiting probable nesting holes in tall dead trees along narrow strips of riparian vegetation with adjacent savannah.

55. Yellow-billed Barbet
One bird sound recorded giving slow deliberate hoots (much slower than Hairy-breasted Barbet) from terra firma forest above camp at Mongama Forest on 24 October. Additionally, two probables of this species sound recorded singing from terra firma at Bopambu Forest on 10 and 12 October. Sound recordings need to be followed up to confirm ID of these two individuals as occasionally Hairy-breasted Barbets were heard to give slow song deliveries before accelerating to "normal" speed.

56. Hairy-breasted Barbet
Recorded commonly (15 days) calling from terra firma and swamp forest at all three of the main campsites. One photographed on 14 October showing streaked throat of subspecies flavipuncta (sometimes considered a separate species "Streaky-throated Barbet".

57. Yellow-spotted Barbet
Two sound recorded giving accelerating hoot calls from terra firma forest during dawn chorus recordings at Lekuma Forest on 19 October. One bird distantly giving purring trill call from terra firma forest at Mongama Forest on 25 October.

58. Speckled Tinkerbird
Recorded almost daily (20 days) singing from terra firma, swamp and forest edge at all sites. One active nest (hole in dead tree) found near dining area at WWF Malebo. Least Honeyguide watched prospecting this nest before getting chased off by Speckled Tinkerbird.

59. Yellow-rumped Tinkerbird
Recorded almost daily (20 days) singing from forest edge, terra firma, swamp and savannah. Birds singing from within forest often close to tree fall gaps or other areas where forest structure more open. Compare Yellow-throated and Speckled Tinkerbird which would often call from more closed interior forest.

60. Red-rumped Tinkerbird
Recorded commonly (16 days) singing at all main survey sites. Seemed to call mainly from forest edge particularly near border with savannah but also occasionally from within forest. One bird brought out to savannah to investigate playback having been calling from forest edge suggesting that the species will sometimes use savannah adjacent to forest.

61. Zenker's Honeyguide
One bird singing from midstory/sub-canopy terra firma close to camp in Mongama Forest. First detected on 24 October and still singing there on 25 & 26 October (we left the site on 27 October so not able to check if still present). Singing began in mid-morning (around 1030 hrs) and continued into afternoon. Bird would sing at intervals of about 30 seconds to over 1 minute. Sporadically bird would disappear for 5–10 minutes (perhaps to go feeding) before returning to same area to continue singing. Very responsive to playback and came down to several meters to investigate. Extensively sound recorded and photographed and these may represent some of the best documentation of this species. The record represents a significant range extension with maps suggesting it was previously known primarily from areas to north of Congo river with the range perhaps extending slightly onto the south bank. Hosts of this species (and its west African congener Yellow-footed Honeyguide) are still completely unknown.

62. Least Honeyguide
Recorded frequently (11 days) at WWF Malebo, Lekuma Forest and Mongama Forest (but not at Bopambu Forest). One photographed prospecting and entering Speckled Tinkerbird nest at WWF Malebo on 8 October before being chased off by Speckled Tinkerbird adult. At both Lekuma and Mongama Forest, 1–2 individuals were on territory singing almost constantly throughout day. Both sound recorded.

63. Buff-spotted Woodpecker
One moving through midstory of swamp forest with mixed species flock (also including Blue-billed Malimbe, Brown-eared Woodpecker, African Paradise Flycatcher, Icterine Greenbul and Red-tailed Greenbul) at Bopambu Forest on 14 October. Another possible seen briefly in terra firma on 9 October.

64. Brown-eared Woodpecker
One with mixed species flock (also including Blue-billed Malimbe, Buff-spotted Woodpecker, African Paradise Flycatcher, Icterine Greenbul and Red-tailed Greenbul) at edge of swamp forest at Bopambu Forest on 14 October.

65. Yellow-crested Woodpecker
One heard drumming and watched foraging on trunk during dawn chorus surveys in terra firma at Lekuma Forest on 19 October.

66. Rufous-sided Broadbill
Recorded frequently (11 days) displaying from terra firma forest at each of the three main campsites. One caught in mistnet at Lekuma Forest on 19 October.

67. Flappet Lark
Recorded commonly (13 days) displaying in savannah habitats at each of the three study sites.

68. Banded Martin
One feeding above savannah with mixed hirundine flock at Bopambu Forest in morning of 13 October. Two over Mongama village on 22 October.

69. Forest Swallow
One photographed feeding low over savannah at forest edge transition at Bopambu Forest in late afternoon. Slight notch to tail and flight behaviour both point to Forest Swallow over Square-tailed Sawwing but photos need to be sent to experts for confirmation. This would represent a new national record for DRC with previous closest records coming from Gabon.

70. Black Sawwing
Two in savannah/forest edge in late afternoon at Lekuma Forest on 20 October. Another four seen at forest edge during transition from Lekuma Forest to Mongama village. One-two in farmbush close to edge of Mongama village on walk out from Mongama forest on 26 October.

71. Barn Swallow
Recorded commonly (18 days) over open areas in savannah and over forest gaps at all sites. Flocks of up to 100 birds recorded.

72. Lesser Striped Swallow
One over savannah at Lekuma Forest in late afternoon of 18 October and another on 21 October.

73. South African Cliff Swallow
Small numbers seen infrequently (4 days) over savannah and forest edge. Two over savannah at edge of Bopambu Forest on 8 October and singles over same savannah on 10 & 11 October. One over Malebo airstrip at forest edge on 28 October. This species is thought to be an intra-African non-breeding migrant to the area. Interesting that there was still an individual seen as late as 28 October.

74. Shining Drongo
Two seen, heard and photographed in terra firma above camp (close to area Zenker's Honeyguide was calling from) on 25 October at Mongama Forest. Another two individuals seen in farmbush on way out from Bonobo Forest on 27 October.

75. Western Black-headed Oriole
One heard only and sound recorded from subcanopy of terra firma forest at Mongama Forest. Sound recordings need to be checked to absolutely confirm ID versus that of e.g. Black-winged Oriole.

76. Pied Crow
Recorded infrequently (7 days) over WWF Malebo and villages during transition days.

77. White-winged Black Tit
2–3 seen in savannah near Lekuma Forest on 18 October.

78. Dark-capped Bulbul
Recorded commonly (16 days) in forest edge and savannah at all sites.

79. Icterine Greenbul
Recorded commonly (15 days) mostly in understory to midstory of terra firma but also in swamp forest at WWF Malebo, Bopambu, Lekuma and Mongama forests. Usually in small groups of 4–5 birds and sometimes with mixed species flocks.

80. Yellow-whiskered Greenbul
Recorded commonly (16 days) in midstory of terra firma and swamp forest at all main campsites. Four individuals caught in mist nets at Lekuma Forest. Very vocal. Not seen to join mixed species flocks.

81. Little Greenbul
Recorded infrequently (7 days) singing in understory of forest edge, tree fall gaps and farmbush. Seemed essentially absent from interior of terra firma forest (where species like Yellow-whiskered and Icterine Greenbuls common). Instead restricted to disturbed areas and edge of forest.

82. Plain Greenbul
Two in swamp forest loosely associated with mixed species flock and calling at Bopambu Forest on 14 October. One sound recorded singing from terra firma at Lekuma Forest on 19 October. Another singing by camp in terra firma at Mongama Forest on 26 October.

83. Little Grey Greenbul
About four birds foraging in midstory at river edge at WWF Malebo in forest close to chalets on 7 October. Photographed. An unidentified Eurillas greenbul that was possibly this species also seen at Bopambu Forest on 13 October.

84. Ansorge's Greenbul
Recorded infrequently (7 days) singing in terra firma and forest edge at WWF Malebo, Lekuma Forest and Mongama Forest.

85. Slender-billed Greenbul
Recorded infrequently (7 days) usually in group of 2–4 birds moving through midstory and canopy of terra firma and forest edge at WWF Malebo, Bopambu Forest, Lekuma Forest and Mongama Forest. Distinctive 'tyuuh' call often first revealed presence as birds passed through area.

86. Red-tailed Greenbul
Recorded frequently (12 days) in terra firma and swamp forest at all main study sites. Usually in small groups of 4–5 birds sometimes with mixed species flocks moving through midstory. Two captured in mist nets at Lekuma Forest on 19 October.

87. Honeyguide Greenbul
Two in forest edge at WWF Malebo on 8 October, one calling during dawn chorus surveys in terra firma at Mongama Forest on 24 October and another close to camp on 26 October.

88. Swamp Palm Greenbul
Seen infrequently (7 days) at forest edge/riverine forest around WWF Malebo, in swamp forest at Bopambu Forest and in farmbush close to small stream at edge of Bonobo Forest. Usually seen in highly vocal groups of 4–6 individuals.

89. Western Nicator

Recorded almost daily (21 days) from forest edge, terra firma, well-wooded savannah and tree fall gaps at all main survey sites. Very vocal. One photographed at WWF Malebo on 7 October.

90. Rufous Flycatcher-thrush

Recorded almost daily (21 days) mostly from terra firma but also sometimes from swamp forest and forest edge habitat grading into savannah. Very vocal from midstory of forest.

91. Fire-crested Alethe

Recorded for definite on at least 8 days though questions remain about single-note whistles heard frequently from forest that may have been from this species or from an Illadopsis species. Recorded from edge of swamp and terra firma forest as well as in terra firma and swamp forests proper. Distinctive slow, mournful two-note whistle often heard. Tow birds that escaped from nets in terra firma forest at Bopambu Forest were likely this species. One individual seen well at close range after it approached in response to playback at Bopambu Forest.

92. Forest Robin

Detected almost daily from understory of terra firma at Lekuma Forest (4 days) but not at other sites. Very vocal at Lekuma Forest and several individuals sound recorded.

93. Rufous-tailed Palm Thrush

One singing from base of palms and scrubby undergrowth at edge of farmbush habitat in Mongama Village on 23 October.

94. White-browed Scrub-robin

Recorded frequently (9 days) in savannah habitats at Bopambu Forest, Lekumah Forest and possibly from Mongama Forest (unconfirmed at this site). Sound recorded and photographed at Bopambu Forest savannah to rule out possibility of Brown-backed Scrub-robin.

95. Sooty Chat

Two males in savannah on drive back from Bonobo Forest to WWF Malebo on 27 October.

96. Icterine Warbler

One in area of well-wooded savannah outside of Lekumah Forest on 18 October.

97. Garden Warbler

One seen well and photographed in understory of farmbush-savannah transition near edge of Mongama village on 26 October.

98. Red-faced Cisticola

One sound recorded singing by village at drop off point before starting hike in to Bopambu Forest on 8 October. Should be 'Lepe' Cisticola based on range – a taxon that is currently treated as a subspecies but has historically been split.

99. Whistling Cisticola

Recorded commonly (18 days) from savannah at all main study sites. Highly vocal. The dominant cisticola species in savannah in the region.

100. Short-winged Cisticola

Recorded commonly (15 days) from savannah at all main study sites. Highly vocal and several observed doing display flights high above savannah. Also, small groups watched chasing one another while giving short high pitched 'tseep' calls. Slightly less common than Whistling Cisticola in savannah in region.

101. Croaking Cisticola
Recorded frequently (10 days) in savannah habitats at each of the three main study sites. The least common of the three regularly occurring cisticolas in the savannah. Seemed to favour less well-wooded, more open areas of savannah than did Whistling and Short-winged Cisticolas.

102. Buff-throated Apalis
Recorded commonly (16 days) singing from canopy and sub-canopy of tall open crowned trees in terra firma at Bopambu, Lekuma and Mongama Forests. Not detected in swamp forest of Bopambu Forest nor in savannah at any site. Identity visually confirmed using playback and one bird at Bopambu Forest photographed.

103. Tawny-flanked Prinia
Recorded commonly (16 days) from savannah at each of the main field sites. Highly vocal. One nest found at savannah patch in Mongama forest (empty) was probably from this species.

104. White-chinned Prinia
Two photographed and sound recorded duetting from savannah at Lekuma Forest on 21 October and heard again on morning of 22 October from same area. Interesting to see this species in the middle of savannah here whereas in northern Zambia (Mwinilunga) it is a species of riverine forest and larger "mushitu" patches.

105. Rufous-crowned Eremomela
About five seen and heard (sound recorded) in canopy of farmbush on way out from Mongama Forest on 26 October. Two were also in farmbush at Bonobo Forest on 27 October.

106. Green-capped Eremomela
Small group of three birds in savannah patch at Bopambu Forest on 11 October. 2–4 birds seen in same area on 12 & 13 October with birds observed nest building on the latter date. Additionally, two seen in savannah at Lekuma Forest on 18 October.

107. Red-capped Crombec
2–3 in savannah at edge of Lekuma Forest on 18 October.

108. Lemon-bellied Crombec
Recorded on at least two days from terra firma (24 October) and farm bush (26 October) at Mongama Forest. Sound recorded on 24 October. Further examination of dawn chorus and other recordings may allow this species to be retrospectively recorded for other days.

109. Green Crombec
Detected frequently (9 days) from forest edge habitat. Recorded daily at WWF Malebo and also in small riverine forest patches during transition days. Highly vocal. Seemed absent from interior forest and from open savannah.

110. Green Hylia
Recorded almost daily (21 days) from midstory of both terra firma and swamp forest at all study sites.

111. Grey-backed Camaroptera
Recorded almost daily (19 days) primarily from savannah but also from forest edge habitats.

112. Olive-green Camaroptera
One captured in mist net in terra firma at Lekuma Forest on 19 October.

113. Yellow-browed Camaroptera
One singing and subsequently seen well from forest edge habitat at Malebo airstrip on 28 October.

114. Grey Longbill
Recorded frequently (13 days) from terra firma and swamp forest at Bopambu, Lekuma and Mongama Forest. Highly vocal.

115. African Shrike Flycatcher
Three (two males and a female) photographed in subcanopy above campsite in terra firma at Bopambu Forest on 13 October.

116. Vanga Flycatcher
Recorded infrequently (6 days) in savannah and forest edge. Always in a male-female pair and very vocal. Pair observed nest building in savannah at Bopambu Forest on 13 October.

117. Spotted Flycatcher
Recorded infrequently (5 days) mostly in savannah but also once in farmbush on way out from Bonobo Forest.

118. Sooty Flycatcher
7 individuals (two small groups of three and four birds) hunting from tops of trees in farmbush close to Bonobo Forest on 27 October.

119. Grey Tit-flycatcher
Recorded infrequently (6 days) singing from savannah and savannah-forest transition zone. Recorded each day from these habitats at Bopambu Forets from 9–13 October. Another bird heard singing from savannah-forest transition zone at Lekuma Forest on 21 October.

120. Grey-throated Tit-flycatcher
One bird heard singing from terra firma forest and subsequently caught in mist net at Bopambu Forest on 12 October.

121. African Paradise Flycatcher
Recorded infrequently (3 days). 3–4 birds in forest edge at WWF Malebo on 6 October, another seen in flight low over savannah at Bopambu Forest on 13 October, and a male seen with a mixed species flock (also including Blue-billed Malimbe, Buff-spotted Woodpecker, Brown-eared Woodpecker, Icterine Greenbul and Red-tailed Greenbul) at edge of swamp forest in Bopambu Forest on 14 October.

122. Red-bellied Paradise Flycatcher
Recorded daily (22 days) in forest edge, terra firma and swamp forest. One captured in mistnet in terra firma at Lekuma Forest on 19 October. An individual responded strongly to playback of Bates's Paradise Flycatcher in terra firma on 18 October.

123. Blue-headed Crested Flycatcher
Recorded infrequently (5 days) singing mostly in midstory of terra firma but also once in swamp forest. Sound recorded and one male seen well in terra firma of Bopambu Forest on 9 October.

124. Western Black-headed Batis
Recorded frequently (9 days) from savannah at Bopambu Forest, Lekuma Forest and Mongama Forest. Several birds heard singing, sound recorded and photographed. One individual caught in savannah by people from village close to Bopambu Forest photographed in hand.

125. Chestnut Wattle-eye
Only recorded with certainty in forest/forest edge at WWF Malebo (but see unidentified species). Two males and a female on 6 October and 1 male on 7 October. Photographed. Not heard to vocalise.

126. Lowland Sooty Boubou
Recorded commonly (14 days) primarily singing from swamp forest and forest edge habitats. Multiple birds sound recorded though birds not seen.

127. Black-crowned Tchagra
Recorded infrequently (4 days) from savannah. All records were from birds singing in savannah on approach to or adjacent to Lekuma Forest. Not detected in savannahs at other sites.

128. Purple-headed Starling
One in terra firma at Bopambu Forest on 10 October, 4 perched in canopy of tall tree by tree fall gap during dawn chorus surveys at Lekuma Forest on 19 October (many other species active in area presumably drawn in by fruiting tree near gap). Another 4 seen perched in canopy in farmbush/forest edge habitat at Bonobo Forest on 27 October.

129. Violet-backed Starling
Recorded infrequently (5 days) in savannah and forest edge habitats at WWF Malebo, Bopambu Forest and Lekuma Forest.

130. Chestnut-winged Starling
Two (probably a pair) very vocal from subcanopy of terra firma above camp area at Mongama forest on 24 October. Female of pair photographed.

131. Copper Sunbird
Recorded frequently (11 days) in savannah habitats at Bopambu, Lekuma and Mongama Forests. The most abundant savannah sunbird species in area. Particularly numerous in Bopambu Forest savannah patch. One male caught in mist nets in savannah at Lekuma forest.

132. Green-throated Sunbird
Two in savannah at Bopambu Forest on 8 October and again on 11 October.

133. Blue-throated Brown Sunbird
Recorded commonly (15 days) in canopy and subcanopy of terra firma, swamp forest and forest edge at WWF Malebo, Bopambu, Lekuma, Mongama and Bonobo Forests. Highly vocal making detection easier.

134. Olive Sunbird
Recorded daily (22 days) in terra firma, swamp forest and forest edge. Highly vocal. Two caught in mist nets in terra firma at Bopambu Forest on 12 October and three in mist nets in terra firma at Lekuma Forest on 19 October.

135. Bates's Sunbird
Small numbers recorded infrequently (5 days) from savannah patch (enclosed by forest) at Bopambu Forest. Mostly detected by "Red-throated Pipit"-type call but also seen. Additionally, either this or Little Green Sunbird seen in savannah patch and forest edge at Mongama Forest (see "Sunbird sp." in unidentified species for more detail).

136. Grey-headed Sunbird
Three seen and photographed in midstory of terra firma at Lekuma Forest on 18 October. In vine tangles close to river edge (though still terra firma as steep-sided banks) downstream of camp. Responded strongly to playback of Fraser's Sunbird (with which it is sometimes considered conspecific).

137. Green Sunbird
Recorded frequently (10 days) in savannah habitats at WWF Malebo, Bopambu Forest, Lekuma Forest (on walk to pick up point) and Mongama Forest. On 25 October, 5–10 observed in savannah at Mongama Forest including what appeared to be some family parties.

138. Collared Sunbird
Recorded infrequently (6 days) in forest edge and terra firma. Most sightings from forest edge at WWF Malebo (4 days). Also seen with mixed species flock in terra firma on 13 October at Bopambu Forest.

139. Orange-tufted Sunbird
Recorded on three days from savannah close to forest edge at Lekuma Forest. Male and female on 17 October & 18 October and then two males and two females on 21 October.

140. Olive-bellied Sunbird
Recorded frequently (8 days) from forest edge, savannah, swamp forest and farmbush. On 6 October an adult male, female and three recently fledged juveniles were seen at WWF Malebo.

141. Northern Grey-headed Sparrow
Five in Mongama village on 23 October and another heard in same village on 26 October.

142. Village Weaver
Four in palms above village on route out from Bopambu Forest on 15 October. Ten in mixed colony with 40–50 Viellot's Black Weaver in large palm tree in village close to Lekuma Forest on 16 October and again on 22 October. All individuals showed extensive chestnut on throat and nape indicative of one of central African subspecies (possibly *collaris*).

143. Viellot's Black Weaver
40–50 birds in mixed colony with Village Weaver actively nest building in large palm in village close to Lekuma Forest on 16 October.

144. Red-headed Malimbe
Female in fruiting trees in treefall gap in terra firma at Lekuma Forest on 20 October and two in farmbush on way out from Bonobo Forest on 27 October.

145. Blue-billed Malimbe
One in mixed species flock at boundary between swamp and terra firma forest on 14 October at Bopambu Forest.

146. Fan-tailed Widow
5+ in wet savannah grassland at edge of Bonobo Forest on 27 October.

147. White-winged Widow
Male in non-breeding plumage in savannah of Bopambu Forest on 15 October and in savannah of Lekuma Forest on 18 October. Also three in non-breeding in savannah outside Mongama Village on 23 October.

148. Chestnut-breasted Nigrita
1–2 birds watched gathering dead leaves and bringing them to nest in midstory at transition between swamp and terra firma at Bopambu Forest on 14 October.

149. Grey-headed Nigrita
Singing male sound recorded from canopy of forest edge at WWF Malebo on 8 October. Two seen in canopy of treefall gap in terra firma at Lekuma Forest on 20 October.

150. Pale-fronted Nigrita
One in canopy of terra firma at treefall gap on 20 October at Lekuma Forest.

151. Red-billed Firefinch
Male and female in Mongama Village on 23 & 26 October – representing an extension of the known range. Previous closest records are in southern DRC.

152. African Firefinch
Two in savannah at Bopambu Forest on 11 October.

153. Black-bellied Seedcracker
One male in savannah early morning on 13 October.

154. Woodhouse's Antpecker
Female captured in mist net over small trickling stream in terra firma at Lekuma Forest on 19 October.

155. Bronze Mannikin
Flocks of up to 25 individuals recorded infrequently (4 days) in savannah, villages and farmbush.

156. Black-and-white Mannikin
Flocks of up to 15 individuals recorded frequently (8 days) in savannah, villages and farmbush.

157. Orange-cheeked Waxbill
Two in Mongama village carrying food to active nest on 23 October and 5+ in same village on 26 October.

158. Pin-tailed Whydah
Recorded infrequently (4 days) from savannah and village edge. Males in full breeding plumage observed on 15, 16, 22 & 26 October.

159. Yellow-fronted Canary
Recorded infrequently (7 days) from savannah habitats.

Unconfirmed species

Raptor sp.

One flew high over farm bush at edge of Mongama forest on 26 October where we were viewing Rufous-crowned Eremomelas. Long-tailed appearance but relatively broad, eagle shaped wings.

Turtur sp.

Low accelerating hoots of a *Turtur* sp recorded coming from within terra firma at Mongama Forest. Follow up work required to rule out Blue-headed Wood-dove and Tambourine Doves.

Owl sp.

What was possibly Spotted Eagle Owl calling from forest edge at Mongama forest. Sound recorded.

Nightjar sp.

Jesse Erens flushed an unidentified nightjar from the forest floor near forest-savannah transition at Bopambu Forest on 12 October but not able to confirm species. Additionally, Jesse Erens and Tim van Berkel heard a nightjar singing around midnight from the savannah at Lekuma Forest. Description of call matches either Black-shouldered or Fiery-necked Nightjar. Black-shouldered perhaps more likely on range but Fiery-necked comes close to south so unable to confirm which species involved.

Swift sp.

Large numbers (up to 150) very slender Apus swifts with markedly forked tails seen flying over forest gaps and savannah adjacent to forest at WWF Malebo and Bopambu Forest. Appearance seemed to match description of Bates's Swift – birds well photographed. Identification to be followed up.

Roller sp.

Broad-billed/Blue-throated Roller types seen in flight over forest (24 October) and perched up in canopy (25 October) at Mongama Forest.

Gymnobucco sp.

5–6 birds in canopy of tree adjacent to tree fall gap in terra firma of Bopambu Forest on 19 October. Individuals watched feeding one another. Distant and poor lighting meant it wasn't possible to determine if Sladen's or Grey-throated Barbet. On 23 October a probable Grey-throated seen distantly and photographed during walk in to Mongama Forest.

Honeyguide sp.

One Indicator honeyguide briefly perched up in tree at edge of Malebo airstrip on 28 October. A Thick-billed/Least/Wilcock's Honeyguide type but only seen very briefly so not able to confirm identity.

Woodpecker sp.

One seen briefly on 9 October in Bopambu Forest with bars on belly and another briefly on 13 October. On 18 October one was heard drumming in savannah adjacent to Lekumah Forest. On 24 October a medium sized olive green woodpecker with a red cap was seen with small mixed species flock in early morning – possibly Gabon Woodpecker but views not sufficient to confirm ID.

Martin sp.

One possible Banded Martin over savannah at Lekuma Forest on 17 October. An all dark martin briefly flew over savannah at Lekuma Forest on 18 October.

Cercropis sp.

Either Mosque or Red-chested Swallow seen over open savannah adjacent to Mongama village but not seen well enough to confirm which species.

Longclaw sp.

Two birds seen by small pool on road through savannah on way back to WWF Malebo from Bonobo Forest on 27 October. Either Yellow-throated on Fulleborn's Longclaw but not seen well enough to confirm species. Yellow-throated perhaps more likely on range though Fulleborn's extends into the south of DRC.

Pipit sp.

Large *Anthus* pipit seen in savannah at Bopambu Forest. Initially on ground but flew up to tree. Photographed. Some streaking on back. Exact date not recorded on daily log but likely in the range of dates from 9–14 October.

Illadopsis sp.

Possibly Scaly-breasted Illadopsis giving two note whistle call from terra firma at WWF Malebo on 9 October. Need to check recordings to confirm ID. Single note whistle heard in terra firma at WWF Malebo on 8 October, Bopambu Forest on 10 & 13 October, Lekuma Forest on 17, 19 & 21 October may have been illadopsis (Brown or Pale-breasted) or could have been single note from Fire-crested Alethe. Need to follow up with recordings.

Eurillas sp.

1–2 seen in subcanopy of fruiting tree in treefall gap in terra firma at Lekuma Forest on 20 October. Probably Plain or Ansorge's Greenbul but seen too distantly to confirm.

Hyliota sp.

Two birds seen in canopy of tall tree at tree fall gap in Lekuma Forest on 19 October. Closest match to Violet-backed Hyliota but seen too distantly to confirm.

Flycatcher sp.

Three apparent Muscicapid flycatchers seen high in canopy above hunter's camp at Lekuma Forest in evening of 16 October. Too distant and light too poor to make specific identification.

Wattle-eye sp.

One seen briefly with mixed species flock in terra firma of Bopambu Forest on 13 October. Presumed to be Chestnut Wattle-eye but not confirmed.

Cinnyris sunbird sp.

Several (5–8) small green sunbirds with small bills akin to a Bates/Little Green type seen on forest edge adjacent to savannah after rain in Mongama Forest on 25 October. Very difficult to follow and observe well and may have been some juvenile green sunbirds (some with short, not full grown tails would be consistent with this). However, calls unlike the "Red-throated Pipit"-type heard given by Bates.

Chalcomitra sunbird sp.

All dark male *Chalcomitra* species flew over forest edge at WWF Malebo on 28 October. Not seen well enough to confirm species ID but likely a Green-throated/Amethyst Sunbird.

Bishop sp.

Two in savannah at Bopambu Forest on 11 & 13 October – male in transitional plumage but not seen well enough to determine species. White-winged Widow subsequently seen in this same area so may have been this species.

Nigrita sp.

One flew over Malebo airstrip on 28 October. Probably Grey-headed Nigrita but view not good enough to confirm.

Figure 16. Putative Forest Swallow in flight on the forest/savannah edge in the Bopambu Forest. Pending confirmation, the first record of this species in DRC. (Photo by Gabriel Jamie)

Figure 17. Zenker's Honeyguide in the Mongama Forest. One of few records of this poorly known species, representing a significant range extension. (Photo by Sam Jones)

Figure 18. Grey-throated Rail captured on a remotely trigured camera trap in waterlogged forest in the Bopambu Forest. Representing a southern range extension of this cryptic species. (Photo by Niklas Weber)

Figure 19. Female Woodhouses Antpecker captured in a mist net in the Lekuma Forest. An uncommon and secretive species, representing a minor range extension. (Photo by Sam Jones)

Figure 20. Male Bates's Nightjar on Savannah/Forest edge of the Lekuma Forest. (Photo by Gabriel Jamie)

2.4 Herpetofauna

Jesse Erens

2.4.1 Introduction

While the Congo Basin harbours some of the largest intact tropical forests in the world, much remains unknown about the distribution, phylogeography and natural history of the amphibians and reptiles inhabiting the region. Hence, on both sides of the Congo river and in between its many tributaries, distribution gaps exist for most of the described central African herpetofauna, and many species likely remain undiscovered. As habitat degradation continues to surge within the region (Tyukavina et al. 2018), this is a significant impediment to biodiversity conservation efforts. Indeed, the Congo Basin has been noted as being one of the most data-deficient areas in the world in conservation assessments of reptiles (Böhm et al. 2013) and being a 'blind spot' for herpetofauna in general (Kielgast & Lötters 2011).

Most of the present knowledge on reptiles and amphibians in the Congo Basin was established around the early 1900s (see e.g. Schmidt & Noble 1998). Herpetological studies subsequently remained sparse throughout the 20th century due to the onset of civil war and the general inaccessibility of the central African rainforest. During the past decades however, a new wave of Congolese and international biologists has continued research and conservation activities in the DRC. Within the broader Malebo region, one herpetofaunal inventory was conducted in June 2013 in the area around Nkala village (E. Greenbaum, pers. comm.). This relatively short survey highlighted both range extensions and new species such as *Cardioglossa congolia*, illustrating the vast herpetological diversity likely still residing across the region's forest-savannah mosaic.

In parallel with habitat loss however, numerous other factors threaten amphibian and reptile populations in the Congo Basin. The spread of infectious diseases is a prominent conservation concern to amphibians, and especially the chytrid fungus *Batrachochytrium dendrobatidis* (*Bd*) has been linked to worldwide declines in frog diversity (Scheele et al. 2019). In a recent review, Zimkus et al. (2020) updated the known *Bd* occurrence across African amphibians, predicting a high habitat suitability for the disease in the western DRC, and also showing its presence around Malebo. Another example concerns the larger reptile species, which are increasingly hunted for the bushmeat trade when forests are opened up for extraction (e.g. Poulsen et al. 2009). Hence, pressures on the amphibian and reptile fauna of Malebo are likely to strongly increase in the near term as its ecosystems become more accessible.

Our herpetological surveys were conducted to contribute to a better understanding of the extant herpetofauna in Malebo in support of regional conservation efforts.

2.4.2 Surveys

We searched for amphibians and reptiles using several different methods. In each of the three field camps, we performed visual encounter surveys during the night, amounting to 2.5 hours of effective searching per survey (not including photography, sounds recording or other data handling time). In this way, three nocturnal surveys were conducted per field site, respectively focused on savannah, forest streams and forest interior. As no repeated measures of standardized transects could be conducted within the expedition time, these surveys were aimed at providing baseline semi-quantitative data on species occurrences across the focal habitats.

Further visual and acoustic searches were carried out opportunistically during the day. These were mostly carried out in the morning and late afternoon to increase our chances of recording diurnal and crepuscular species. To detect species potentially overlooked by active search methods, we additionally set up pitfall trap arrays. These were each composed of three pitfalls spaced 5 m apart and connected by a 10 m drift fence. In line with the visual encounter surveys, the arrays were set up in savannahs, in proximity to forest streams and within the forest interior. These were checked several times a day for herpetofauna and to ensure quick release of possible bycatch. In this manner, the pitfall sampling encompassed a total of nine days in each of the three different habitats in Bopambu and Lekuma and, given the limited time available in Mongama, two days only in savannah habitat.

Identification of amphibians and reptiles was based on various sources, including Chippaux & Jackson (2018) for the snake fauna, Frétey et al. (2011) for the amphibian fauna and Channing & Rödel (2019) for general reference. These field guides were complemented with various other primary literature sources, including species descriptions and taxonomic reviews. Amphibians were handled using nitrile gloves, and sampling bags were not reused between individuals and localities to prevent the transmission of pathogens.

2.4.3 Preliminary results

We tentatively recorded 40 species of amphibians and reptiles belonging to 29 different genera and 19 families (**Table 5**). These comprise 23 species of frogs (13 genera; 9 families), 8 lizard species (7 genera; 5 families), 8 snake species (8 genera; 4 families) and one species of crocodile. Although species distribution patterns remain to be assessed in detail, our surveys showed distinct species occurrences in both forest and savannah habitats. Within our study period - at the early onset of the rainy season - the largest species richness during visual encounter surveys was recorded around riparian habitats within forests, followed by forest interior and savannah habitats.

Note however that due to the recent timeframe of the surveys, uncertainty remains in the identification of several taxa, most notably for amphibians. Hence, these species are pending confirmation based on gathered photographic evidence, morphological data and/or molecular analyses of collected samples. The current figure therefore presents a conservative estimate of the number of recorded species, and several more species and potential cryptic diversity might be uncovered following further examination. An updated overview will be presented as more information becomes available, including details on threatened taxa (**Figure 21**), potential range extensions (**Figure 22**) and candidate species.

Table 5. The amphibian and reptile species provisionally recorded in the Malebo region. Localities refer to Bopambu (BP), Lekuma (LK), Mongama (MG) and the area surrounding the Malebo WWF station (WF). Note that the latter was only surveyed opportunistically, and did not receive the same searching effort as the other field localities. The columns "F/S" provides a preliminary indication of species only observed in either forest (F) or savannah (S) habitats. *Not designated to one of our study sites (found dead on road several kilometres south of the Malebo WWF station).

Class | Family	Species	BP	LK	MG	WF	F/S
Amphibia						
Arthroleptidae	*Arthroleptis* cf. *poecilonotus*	x	x	x		
	Arthroleptis cf. *sylvaticus*	x	x	x		
	Cardioglossa congolia	x	x			F
	Leptopelis ocellatus (schiotzi)	x	x	x		F
	Leptopelis cf. *notatus*	x				F
Bufonidae	*Sclerophrys camerunensis*	x				F
	Sclerophrys pusilla	x	x			S
	Sclerophrys sp.		x			F
Hyperoliidae	*Afrixalus osorioi*	x	x	x	x	
	Hyperolius cf. *cinnamomeoventris*	x			x	
	Hyperolius cf. *platyceps*	x				F
	Hyperolius cf. *veithi*		x	x		F
	Hyperolius sp.	x				F
Phrynobatrachidae	*Phrynobatrachus* cf. *auritus*			x		F
	Phrynobatrachus sp.		x		x	S
Pipidae	*Hymenochirus* cf. *boetgerii*	x				F
	Xenopus cf. *epitropicalis*	x				F
	Xenopus sp.		x			F
Ptychadenidae	*Ptychadena* cf. *perreti*	x			x	
	Ptychadena sp.		x	x		F
Pyxicephalidae	*Aubria masako*	x				F
Ranidae	*Amnirana* cf. *albolabris*			x	x	F
Rhacophoridae	*Chiromantis rufescens*		x			F
Reptilia						
Agamidae	*Agama picticauda*		x			
Colubridae	*Natriciteres fuliginoides*		x			F
	Dipsadoboa weileri		x			F
	Toxicodryas pulverulenta		x			F
Crocodylidae	*Osteolaemus osborni*	x				F
Elapidae	*Dendroaspis jamesoni*			x		F
Gekkonidae	*Hemidactylus mabouia*				x	
	Hemidactylus sp.	x	x	x		F

Class	Family	Species	BP	LK	MG	WF	F/S
		Lygodactylus sp.	x				F
	Gerrhosauridae	*Gerrhosaurus nigrolineatus*	x				S
	Lacertidae	*Ichnotropis* cf. *capensis*	x				S
	Lamprophiidae	*Chamaelycus* cf. *faciatus*	x			x	F
		Lycophidion sp.		x			F
		Gonionotophis sp.*					
	Scincidae	*Trachylepis* cf. *maculilabris*	x			x	
		Feylinia cf. *currori*			x		F
	Typhlopidae	*Afrotyphlops* sp.			x		S

Figure 21. *Osteolaemus osborni*. Only a single dwarf crocodile was observed during a stream survey in Bopambu Forest. This species is intensely hunted (also see discussion) and populations are becoming increasingly fragmented due to habitat loss. *O. osborni* was formerly considered a subspecies of *Osteolaemus tetraspis*, a monotypic genus still listed as Vulnerable by the IUCN Red List and under Appendix I of CITES. However, populations in the Congo Basin were shown to be genetically distinct and to constitute a separate species, thus elevating conservation concerns. (Photo by Jesse Erens)

Figure 22. *Hyperolius* cf. *veithi*. This species was described a decade ago from the central Congo Basin, within primary rainforest habitat in Salonga National Park (Schick et al. 2010). During our survey, we encountered individuals most likely belonging to the species in Lekuma forest and possibly Mongama forest that, if confirmed, present a strong westward extension (app. 420 km) of the species' known distribution range. Similar to its type locality, the species occurs in sympatry with other species of the *H. cinnamomeoventris* complex. (Photo by Jesse Erens)

Figure 23. *Afrixalus osorioi* being preyed upon by a wandering spider of the genus *Macroctenus* (family Ctenidae) in the forest of Bopambu. Spiders are well-documented predators of frog species in tropical ecosystems, with most observations stemming from the neotropics. There are indications that amphibians are a substantial food source for several tropical spider families, although more research is needed on this topic (Nyfeller & Altig 2020). (Photo by Merlijn Jocque)

2.4.4 Discussion

Our expedition took place at the onset of the rainy season, and heavy and prolonged rains did not start until the latter part of the study period. This was reflected in increased observations of reproductive activity, e.g. in the number of deposited egg masses around forest streams and new calling activity around emerging ephemeral water bodies in savannahs, towards the last days of field work. Many additional species can therefore undoubtedly be recorded during surveys in different seasons and given a longer time period. In addition, because of the limited time availability across field sites and habitats, field efforts were more focused on nocturnal searches than on diurnal and early morning searches. It is therefore likely that several more diurnal species, and especially savannah specialists, are present in the area, yet remained undetected during our study.

During the course of our field study, we observed several instances of active persecution of reptiles in the area. Most notably, this includes hunting of dwarf crocodiles *Osteolaemus osborni* around suitable river habitats, including several of the more remote stream sections visited during our study. Based on further anecdotal reports, forest tortoises are being captured by means of dog-assisted hunting, most likely targeted at species of the genus *Kinixys* that include several endangered taxa. Other local reports also hinted at the hunting of larger monitors and snakes. Based on our own limited observations we can however not attest to the current scale or trend of the hunting pressure on herpetofauna in the region. Yet, our associates stated that, while these activities have long been part of local persistence hunting, hunting activities are increasingly taking place for intended export to bushmeat markets in Kinshasa. Whereas most of the provisionally identified amphibian and reptile species are listed as Least Concern on the IUCN red list, several of these might present distinct lineages within species complexes. For instance, the populations of *Amnirana* cf. *albolabris* that are found around Malebo are divergent from other African populations, and probably present a separate species (Jongsma et al. 2018). Consequently, the presently available conservation status of species might provide an underestimation of threat levels to the herpetofaunal diversity present throughout the region.

In summary, our study highlights a broad diversity of reptiles and amphibians in Malebo, despite the rapid timeframe of our biodiversity assessment and the absence of intermittent heavy rains. This includes many populations of widespread central African species as well as more range-restricted and potential novel species. These findings enforce the notion that the existing network of forest and savannahs in Malebo supports a rich herpetofaunal community, and is a prime example of a ‘blind spot’ in the distribution of central African biodiversity. Hence, ongoing conservation programs would strongly benefit from additional and periodic monitoring efforts to establish more detailed species distribution patterns, and the targeted preservation of riparian ecosystems and surrounding gallery forests to sustain much of the existing herpetofauna.

2.5 Invertebrates

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2.5.1 Introduction

Invertebrates are the largest part of biodiversity but nonetheless are often overlooked in rapid biodiversity assessments. Insects and many other arthropod taxa facilitate essential ecosystem processes (e.g. decomposition, pollination) upon which other organisms depend. Most arthropods are highly habitat specific and will respond strongly to changes in their surroundings. The fine grained ecological niche specificity of many invertebrate species together with the large diversity make this group ideal potential indicators of habitat quality (Brown, 1991). A good understanding of what species are present, their environmental preferences and geographical distribution is needed to assess the habitat quality based on the arthropod taxa. This information is often lacking, especially in tropical environments (Bonebrake et al., 2010).

The first step is to document what species are present. The geographic extent of DRC makes it highly challenging to synthesise information on invertebrates. For most invertebrate groups no good national overviews exist and mostly isolated studies or reports are available. More common to find taxonomic works reviewing a smaller taxonomic unit and including species from DRC. Difficult access, administrative constraints and civil unrest have without doubt affected and limited entomological research the last decades in the country. No published invertebrate inventories are available for the region and, in fact, most of our current knowledge on arthropod diversity for the DRC is based on biodiversity inventories and subsequent research dating back to the early- to mid-20th century. For example, the extensive Congo expedition by Herbert Lang and James Chapin from 1909 to 1914 yielded many new species and comprehensive inventories of the study area (Curran et al., 1928; Holland et al., 1920). The entomological collections from the colonial era, such as the ones present in the Royal Museum of Central Africa (RMCA), still harbour species previously unknown to science (e.g., a new species of Cossidae (Yakovlev, 2020)) and a large part of recent taxonomic publications on DRC biodiversity are based on material/samples collected a long time ago.

Butterflies – often the best studied invertebrate taxon (Thomas, 2005) – have a nationwide checklist and identification manual but it dates back to 1981 ("Les Papillons du Zaïre", Berger & Seko, 1981). Since then, scattered research on advancements in the field of afrotropical butterfly taxonomy such as taxonomic revisions (e.g. Aduse-Poku et al., 2016; Mitter et al., 2011) and newly discovered species (e.g. Sáfián et al., 2020) in DRC were published. Few larger studies are available such as a study of the biodiversity of the Albertine rift reports 43 endemic butterfly species from Eastern DRC (Davenport, 2003), but the total number of butterfly species of the area could not be reported due to a lack of surveys (Plumptre et al., 2007).

As part of the biodiversity survey we looked at selected invertebrate groups and collected butterflies, hawk moths (Sphingidae), emperor moths (Saturniidae), dragonflies and damselflies (Odonata), arachnids (Arachnida) and beetles (Coleoptera). For the latter, we focussed on tiger beetles (Cicindelidae), ground beetles (Carabidae) and longhorns (Cerambycidae). We used a combination of standardised survey methods and opportunistic methods. Results will be made available in the updated report after one year. Here we present an overview of methods used and some preliminary results.

2.5.2 Methods

The target taxa were collected through six main methods during our fieldwork (pitfall trapping, bait trapping, light trapping, winkler trapping, nocturnal surveys, and hand catching). We surveyed different (micro)habitats to cover as much diversity as possible. **Table 6** summarises the focal groups and methods. Apart from these focal groups, other taxa were collected on an opportunistic basis.

Table 6. Overview of targeted invertebrate groups and the collecting methods used for each group.

		Pitfall trap	Bait trap	Light trap	Winkler trap	Torching	Hand net
Araneae		x			x	x	
Coleoptera	Carabidae	x		x		x	
	Cicindelidae	x		x			x
	Cerambycidae			x			x
	Other		x	x			
Lepidoptera	Sphingidae			x			
	Saturnidae			x			
	Rhopalocera		x				x
Odonata				x			x

Invertebrate pitfalls

Pitfall series consisted of five transparent plastic cups (height: 13.7 cm, ø 11.5 cm). These were dug into the ground in a quincunx pattern (⁙) with the four outer cups at about 5 m from the central one. The rim of the cups was made level with the surrounding soil. The pitfalls were filled with a 50–70% ethanol solution as a preservative (see **Table 7**). Spiders, dung beetles, ground beetles, and tiger beetles were the target groups of this method. Other invertebrates that fell in the traps were also collected.

Table 7. Location and survey effort of Invertebrate pitfall trap series in each camp. A series consisted of five 1L pitfall traps, except for (*) indicating 4 pitfall traps. The latitude (South), longitude (East), setup time, take down time, full survey duration and habitat information is provided.

Camp	Latitude	Longitude	From	To	Duration	Habitat
1	S2° 26.214'	E16° 37.925'	09/10/2021 10:30	14/10/2021 14:45	5d 4h15	Forest
2	S2° 31.830'	E16° 49.107'	17/10/2021 16:30	21/10/2021 16:00	3d 23h30	Forest
3	S2° 39.117'	E16° 35.899'	23/10/2021 13:00	25/10/2021 12:00	1d 23h	Forest
1	S2° 26.223'	E16° 38.374'	09/10/2021 09:00	14/10/2021 12:00	5d 3h	Riverine
2	S2° 31.910'	E16° 49.346'	19/10/2021 10:00	21/10/2021 15:30	2d 5h30	Riverine
3*	S2° 39.163'	E16° 35.882'	23/10/2021 17:00	26/10/2021 09:00	2d 15h	Riverine
1	S2° 26.093'	E16° 37.701'	09/10/2021 10:00	14/10/2021 09:00	4d 23h	Savannah
2	S2° 32.195'	E16° 49.110'	18/10/2021 10:00	21/10/2021 09:00	2d 23h	Savannah
3	S2° 39.518'	E16° 35.791'	23/10/2021 14:30	26/10/2021 09:00	2d 18h30	Savannah

Herpetological pitfalls

The herpetological pitfall series was mainly geared towards herpetofauna (see "2.4 Herpetofauna" for survey effort and methodology). However, these large pitfall traps also capture invertebrates. These traps were checked daily in the morning and the spiders and beetles were collected.

Bait traps

Series of five bait traps were set up in each habitat, three at approximately 20 cm from the ground and the remaining two just below the tree canopy (varying from 5 m in the savannah up to 30 m in the forest habitats). Some canopy traps were installed on a rope which was first shot over a high branch with a weight and a catapult (Notch Big Shot). The traps were modified from hanging organisers (IKEA PS FÅNGST) so that a narrow opening at the bottom is the only access point to the bait. The bait consisted of fruits, mostly bananas, that had fermented for several days in a separate container after which it was placed on a plate in the trap. The bait was replaced every two days, or more frequently under adverse weather conditions. The traps were checked daily and the fruit feeding butterflies and beetles were collected.

Table 8. Locations and survey effort for baited butterfly traps at each camp, latitude (South) and longitude (East), setup and take down times, full survey duration and habitat information is provided.

Camp	Latitude	Longitude	From	To	Duration	Habitat
1	S2° 26.214'	E16° 37.925'	10/10/2021 10:30	14/10/2021 14:45	4d 4h15	Forest
2	S2° 31.830'	E16° 49.107'	18/10/2021 13:00	21/10/2021 16:00	3d 3h	Forest
3	S2° 39.117'	E16° 35.899'	23/10/2021 13:00	25/10/2021 16:00	2d 3h	Forest
1	S2° 26.301'	E16° 38.400'	09/10/2021 16:00	14/10/2021 16:30	5d 0h30	Riverine
2	S2° 31.910'	E16° 49.346'	19/10/2021 10:00	21/10/2021 15:30	2d 5h30	Riverine
3	S2° 39.116'	E16° 35.858'	24/10/2021 10:00	25/10/2021 16:00	1d 6h	Riverine
1	S2° 26.093'	E16° 37.701'	10/10/2021 09:30	14/10/2021 09:00	3d 23h30	Savannah
2	S2° 32.177'	E16° 49.126'	18/10/2021 10:00	21/10/2021 09:00	2d 23h	Savannah
3	S2° 39.518'	E16° 35.791'	23/10/2021 13:30	25/10/2021 09:00	1d 19h30	Savannah

Light trap

The light trap consisted of a 125W UV Mercury vapour bulb (Philips, HPL-N) strung centrally in a cross-shaped tent made of white reflective cloth. The bulb was powered by a small generator. The light trap was usually set up in a clearing in the forest to increase visibility and remained attended at all times. All beetles and target moths were collected. Light trapping was performed for at least three nights at each campsite, usually from around sunset till 22:00. Target groups were hawkmoths, emperor moths, ground beetles and scarabs but occasional dragonflies, spiders and other beetle groups were also collected.

Table 9. Light trap location at each camp in latitude latitude (South) and longitude (East), the start and end time, and a total of the trapping effort is provided.

Camp	Latitude	Longitude	Date	Start time	Stop time	Duration
Malebo	S2° 29.021'	E16° 30.147'	07/10/2021	18:00	21:30	3h30
1	S2° 26.266'	E16° 38.393'	09/10/2021	18:15	22:00	3h45
1	S2° 26.266'	E16° 38.393'	10/10/2021	18:15	22:30	4h15
1	S2° 26.266'	E16° 38.393'	11/10/2021	18:45	22:00	3h15
1	S2° 26.266'	E16° 38.393'	12/10/2021	19:15	21:45	2h30
2	S2° 31.827'	E16° 49.104'	17/10/2021	19:00	22:00	3h
2	S2° 31.816'	E16° 49.081'	18/10/2021	17:45	22:00	4h15
2	S2° 31.816'	E16° 49.081'	20/10/2021	17:45	22:30	4h45
2	S2° 31.827'	E16° 49.104'	21/10/2021	18:30	22:00	3h30
3	S2° 39.117'	E16° 35.899'	23/10/2021	18:00	22:00	4h
3	S2° 39.117'	E16° 35.899'	24/10/2021	17:30	21:30	4h
3	S2° 39.117'	E16° 35.899'	25/10/2021	18:00	22:00	4h
Malebo	S2° 29.021'	E16° 30.147'	27/10/2021	03:15	06:00	2h45
					Total	**23h30**

Figure 24. A. Invertebrate pitfall trap in Bopambu Forest, a leaf provides protection from the rain. B. Light trapping tent. C. Fruit bait trap set up in the savannah patch near Bopambu Forest. (Photos A & C by Jan Mertens, Photo B by Niklas Weber)

Winkler trap

Litter from the forest floor was collected and stuffed into four Winkler traps which were placed under a tarp so that the material could dry. The traps were left undisturbed for three days. The ground-dwelling invertebrates were collected in jars containing 70% ethanol at the bottom of the trap.

Nocturnal surveys

Invertebrate surveys at night mainly aimed at collecting ground-dwelling spiders from within soil litter and lower vegetation by reflection of head torch light. At least five families of spiders can be located by light reflection in their eyes (Lycosidae, Zodariidae, Sparassidae, Ctenidae and Pisauridae). These searches were conducted in the early night (before midnight). Ground beetles and longhorns encountered during this survey were also collected.

Diurnal catching

Surveys with handheld insect nets were performed at different times of the day to collect invertebrates through both opportunistic catching and targeted surveys in specific habitats such as savannah, forest clearings, riverine forest, and rivers. The target groups were butterflies, dragonflies and tiger beetles. Other invertebrate taxa were collected opportunistically.

Invertebrate samples were stored in 70% ethanol, with the exception of butterflies and moths which were stored in glassine envelopes within airtight containers with silica gel.

2.5.3 Results

In this preliminary report (one month after the fieldwork) we cannot offer much information on the invertebrates. In total, about 570 butterflies, 130 moths, and 250 invertebrate samples (multiple specimens) were collected. We were able to do a preliminary identification of Sphingidae which is summarised below (**Table 10**).

Figure 25. Left *Atemnora westermannii* hovering above a shotgun microphone. **Right** Some of the collected hawkmoth specimens in a display case. (Photo A by Gabriel Jamie, Photo B by Jan Mertens)

Table 10. Preliminary list of hawkmoth species and the method with which they were collected.

n°	subfamily	species	author	method
1	Macroglossinae	*Atemnora westermannii*	(Boisduval, 1875)	photograph
2	Macroglossinae	*Euchloron megaera megaera*	(Linnaeus, 1758)	light trap
3	Macroglossinae	*Nephele* cf. *bipartita*	Butler, 1878	light trap
4	Macroglossinae	*Nephele funebris*	(Fabricius, 1793)	light trap
5	Macroglossinae	*Nephele maculosa*	Rothschild & Jordan, 1903	light trap
6	Macroglossinae	*Nephele rosae rosae*	Butler, 1875	light trap
7	Macroglossinae	*Temnora* cf. *fumosa*	(Walker, 1856)	light trap
8	Macroglossinae	*Temnora* cf. *sardanus*	(Walker, 1856)	light trap
9	Macroglossinae	*Temnora radiata*	(Karsch, 1892)	light trap
10	Smerinthinae	*Polyptychus carteri*	(Butler, 1882)	light trap
11	Smerinthinae	*Polyptychus* cf. *herbuloti*	Darge, 1990	light trap
12	Smerinthinae	*Polyptychus lagnelae*	Pierre, 2014	light trap
13	Smerinthinae	*Polyptychus p. paupercula*	(Holland, 1889)	light trap
14	Smerinthinae	*Polyptychus retusus*	Rothschild & Jordan, 1908	light trap
15	Smerinthinae	*Polyptychus trisecta*	(Aurivillius, 1901)	light trap
16	Sphinginae	*Coelonia fulvinotata*	(Butler, 1875)	light trap

3 Concluding remarks

Within the temporal and spatial constraints of a rapid biodiversity assessment, our survey provides additional insights into the biodiversity of the Malebo region. We were able to document the presence of a large number of species across taxonomic groups including several species of conservation concern including Grey Parrot (*Psittacus erithacus*) (IUCN listed as Endangered) and Dwarf Crocodile (*Osteolaemus tetraspis*) (IUCN listed as Vulnerable). We also identified several range extensions, including Grey-throated Rail (*Canirallus oculeus*), Zenker's Honeyguide (*Melignomon zenkeri*), Lemon-bellied Crombec (*Sylvietta denti*), Chestnut-winged Starling (*Onychoganthus hartlaubi*), Bates's Sunbird (*Cinnyris batesi*), Orange-tufted Sunbird (*Cinnyris bouvieri*), Red-billed Firefinch (*Lagonosticta senegala*), Woodhouse's Antpecker (*Parmoptila woodhousei*) and *Hyperolius* cf. *veithi*. Pending confirmation it is likely that we provided the first record of Forest Swallow (*Hirundo fuliginosa*) in DRC. We further collected a wealth of ecological information on many species and documented, both in sounds and images, several species for the first time in the field. Species accumulation curves for none of the studied groups showed any plateauing. Preliminary analysis of the collected samples points towards the potential presence of several species new for science (spiders, beetles, a frog,…), but these need to be confirmed and information will be added to this report with future updates.

Forest versus savannah

Survey effort was divided between savannah and two types of forest (the latter defined by proximity to water (**Figure 3**)). Grouping habitats into these three categories is a convenient yet blunt generalisation, with elimination of a wide range of ecologically relevant variables that impact on the inhabiting fauna, and should be seen mostly as a thought exercise. Bird species richness was greater in forests than savannah in terms of overall species recorded in each habitat (Forest = 142 species, Savannah = 85 species) and in unique species recorded in each habitat (Forest = 100 species, Savannah = 44 species) , although this is to be expected considering the exceptional avian diversity of the Congo Basin forests and the variation of forested habitats sampled during our study. A larger proportion of the observed species for large mammals, herpetofauna (24 species versus 3 species) and most invertebrates was exclusively observed in the forest habitats. This lower species richness in savannah habitat should, however, be interpreted carefully, and is at least partly the result of seasonal and survey-related constraints. For instance, many amphibian and invertebrate savannah species have a well defined activity peak after substantial precipitation. For some invertebrate groups, such as tiger beetles (Cicindelidae), we expect more species in open habitats. Additionally, while most larger megafauna occur in savannah habitats, they are heavily hunted in this region and largely absent or occurring in low densities and difficult to detect in a short time frame. Previous studies showed that high-rainfall tropical grassy biomes have vertebrate species richness comparable with that of forests, despite having lower plant diversity (e.g. Murphy et al; 2016). A more in-depth long-term survey looking at biodiversity components in both savannah as well as forest habitat would be needed to determine its true biological diversity and conservation value.

Bonobo thermal imaging detection

The proof of concept for bonobo detection with drone-based thermal imaging provides a new means of data collection with significant applications for conservation and our understanding of this critically endangered species. This method would allow researchers, for the first time, to collect distribution and density data on the animals themselves instead of relying on proxies of their presence (nests and tracks). Additional research and capacity building is needed to further develop this survey method.

Ecotourism

Ecotourism potential is necessarily a combination of both the motivations of potential visitors, and ease of logistics. These factors considered, we believe Malebo has the potential to offer some unique wildlife tourism opportunities. Perhaps the most obvious draw to the region is that of the presence of reliable wild bonobo encounters. Because of the uniqueness of habituated bonobos to the region, reliable (almost guaranteeable) encounters offer a major draw to both serious wildlife watchers and the general public, especially in the small but growing wildlife tourism market of 'mammal watching. Currently, similar experiences specifically targeted at seeing wild bonobos exist in Salonga and Lomako, although these are expensive and generally logistically quite challenging (~ 1–3 thousand USD per person). Thus, assuming costs can be managed below this figure, there is the potential of using the excellent facilities at Malebo to operate similar trips. Malebo has the added advantage of the forest-savannah matrix, allowing easy access to the forests and bonobo groups.

International birdwatching tourism specifically, is a major ecotourism market, but largely (especially for a country such as DRC) dependent on the presence of specific desirable species. While we observed many bird species of high scientific interest during our survey work, the same species are not necessarily of interest to ecotourism. As such, perhaps the most desirable of the species observed during our survey work are that of Sladen's Barbet (endemic to DRC) and Zenker's Honeyguide (very difficult and infrequently observed across its range). However, because of the position of Malebo in proximity to the Congo river we believe that there is also distinct potential for a mixed birdwatching and bonobo tour itinerary focussing on both Bonobos and some of the broader regional speciality birdlife, ultimately ending at Malebo. Congo river endemics, including Congo sunbird, Congo martin, African river martin and to a lesser extent bob-tailed weaver, are all desirable regional speciality species for bird watching tourists that could be combined as part of a tour via river travel from Kinshasa, ultimately ending in Malebo where numerous other species are available, in addition to the major draw of bonobos. Indeed, such a trip could be augmented with other regional speciality wildlife such as pygmy crocodile, giant pangolin and other primates if these became reliably observable at a specific site. Many of these species of interest for ecotourism are also species with international conservation concern and are a welcome invitation to work on species specific action plans with the communities.

Even though the Malebo site has a lot of potential thanks to its relatively easy access to wildlife and forest-savannah mosaic, to realise the potential a lot of preparation is needed. This would include making lasting agreements with the local communities, establishing hunting free zones and re-establishing populations of desirable species.

Without details about the preparation, logistics and potential costs of such a trip, we are confident that it does have the potential to be a unique and desirable itinerary for specialised wildlife tourism, arguably aided by the complex history of the Congo river as a focal point for adventurous tourists. We believe that the potential of ecotourism at Malebo represents an opportunity to generate sustainable income for local communities and aid the conservation of the region.

Ecosystem pressure and conservation concerns

Large stretches of intact ecosystems remain in the Malebo region and the impact of logging for hardwood and cattle on savannah ecosystems is, in many places, absent. However, the marked trees for logging and huts on the savannah in preparation for cattle grazing point towards changes in the near future. Hunting and fishing pressure is high and in likelihood unsustainable for some targeted species. At the present rate we expect that most of the remaining species with conservation concern (e.g. dwarf crocodile) will become rare and disappear in the near future. We learned in discussions with our local guides that hunters are shifting from hunting to fishing because it is becoming more difficult to find animals. Targeted conservation initiatives would be needed to protect some larger and internationally endangered animals.

The overall lack of information available for the region is currently a barrier to the effective conservation of the species and the ecosystems they inhabit that live in them. Collecting information on some of the other forest and savannah fragments in the Malebo region, as well as taxon-specific surveys for some of the highly threatened but understudied animals, are an essential first step in understanding the current situation and to set priorities for conservation.

Trade-offs between ongoing development and conservation are inevitable. This is especially the case for developing countries that typically experience a high development pressure, but also host the most biodiverse areas of the planet. The Malebo region and its community forests are, at the moment of writing, well placed in a situation with large stretches of intact ecosystem and most biodiversity components and key species (still) present. The situation however is changing. Now is the moment to refine and extend the conservation priorities to include more species-specific conservation initiatives and durably manage these remarkable ecosystems for future generations.

Figure 26. Flowering *Millettia laurentii*, many large individuals were present close to camp 1. This species is logged for timber (Wenge) and is listed as Endangered by IUCN (2021). (Photo by Niklas Weber)

4 References

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