Biodiversity Express Survey

The Mekong Biodiversity Project

Kratie, Cambodia NOV-DEC 2023

BINCO
Biodiversity Inventory for Conservation

BES 12.1

Biodiversity Express Survey (BES) 12.1
The Mekong Biodiversity Project: A biological assessment of Sambour and Prek Prasab Wildlife Sanctuary in Kratie Province, Cambodia
Biodiversity Inventory for Conservation (BINCO)
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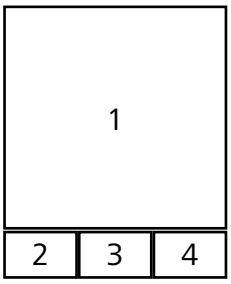

Cover pictures
1. Mekong River Islands in Sambour Wildlife Sanctuary
2. Blunt-headed burrowing frog (*Glyphoglossus molossus*)
3. Common flameback (*Dinopium javanense*)
4. Huntsman spider (Sparassidae) eating a cricket

All images by Michiel van Noppen

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

Five basecamps in and near two wildlife sanctuaries in Kratie, Cambodia were established (Map 1):

1. Prek Prasab Wildlife Sanctuary - Camp 1 (Ranger Station) at an elevation of 30m (N 12.630, E 105.960 / UTM 48N 604389, 1396277)
2. Sambour Wildlife Sanctuary - Camp 2 (Ranger Station, Okork Community Forest) at an elevation of 60m (N 12.998, E 106.102 / UTM 48N 619406, 1437265)
3. Sambour Wildlife Sanctuary - Camp 3 (Ranger Station, Koh Knhe Community Forest) at an elevation of 80m (N 13.138, E 106.101 / UTM 48N 619430, 1452666)
4. Sambour Wildlife Sanctuary - Camp 4 (Mekong Island, Koh Reugnieu) at an elevation of 29m (N 13.089, E 106.018 / UTM 48N 610363, 1447295)
5. Phnom Bak Community Forest - Camp 4 at an elevation of 59m (N 13.138 E 106.180 / UTM 48N 627883, 1452754)

Time in the field

22 November – 14 December 2023 (23 days)

Expedition Members

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Hamer, Matthew T.	Entomologist (UK)
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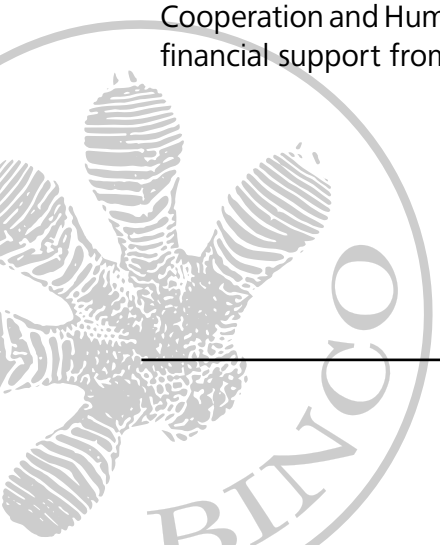
Tranchant, Jeremie	GIS expert (France)
van Berkel, Tim	Expedition leader - Mammalogist (Netherlands)
van Noppen, Michiel	Photographer (Netherlands)
Darith, Lay	GIS, Ministry of Environment (Cambodia)

Permits

Samples were exported with permission from the Ministry of Environment, and with respect to the NAGOYA protocol with permit No. 5278/0824 MoE, issued in Phnom Penh at 26 august 2024.

Financial and logistical support:

This project was funded by the Directorate-General for Development Cooperation and Humanitarian Aid (DGD) with logistical and additional financial support from WWF Cambodia and WWF Belgium.



ACKNOWLEDGEMENTS

This project would not have been made possible without the help, in many different forms, from just as many individuals. Our thanks go out to all of them.

In particular, we would like to thank WWF Belgium and WWF Cambodia for providing the opportunity to collaborate on this project. We are particularly grateful to Veerle Hermans and Thibault Ledecq for putting in the legwork and make it happen.

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We thank the commune chiefs of Boeng Char, O Krieng, and Chhroy Banteay, the district governors of Prek Prasab and Sambour, and the Kratie provincial governor for allowing us to conduct research in their regions.

Thanks also to Arthur Lamolière from the University of Malta for his help with data analysis and the use of a superfast computer to process the many gigabytes of data we collected. Thanks too to Jan Mertens for helping with the layout and presentation of this report.

SUMMARY

The greater Mekong Region holds immense conservation importance, characterised by rich and diverse landscapes, along with a high diversity of flora and fauna. Accelerating social and economic developments are exerting significant pressure on the landscape, positioning the region as one of the world's most threatened biodiversity hotspots. While biodiversity data is crucial for identification of zones of conservation priority, this information is often not available, hampering conservation efforts.

To support WWF and the Ministry of Environment in their ongoing conservation work, we conducted biodiversity surveys and assessed habitat distribution in two understudied, newly protected areas in Kratie Province, Cambodia: Sambour and Prek Prasab Wildlife Sanctuaries. Our main aims were to collect supplementary biodiversity data through standardised surveys for several understudied taxonomic groups and based on available and the newly collected data, make suggestions for high priority conservation zones in Sambour WS.

We conducted a first rapid biodiversity assessment in both sanctuaries at the end of the dry season in 2018. Building on this, we looked at filling some gaps in biodiversity knowledge with a second rapid assessment at the beginning of the 2023 dry season, with the majority of the surveys conducted in Sambour WS and some surveys carried out in Prek Prasab WS. The second survey spanned 23 days in the field and focused on birds, herpetofauna, and invertebrates across five locations (camps). The results discussed here are derived from this second survey.

We recorded 192 bird species. Threatened species included: white-shouldered ibis (*Pseudibis davisoni*), green peafowl (*Pavo muticus*), river tern (*Sterna aurantia*) and great slaty woodpecker (*Mulleripicus pulverulentus*). A further eight species are classified as Near Threatened. Another noteworthy sighting was the fourth record of eyebrowed thrush (*Turdus obscurus*) in Kratie Province. We tentatively recorded 36 species of reptiles and 24 species of amphibians, including nine species that were not directly recorded during previous surveys within the sanctuaries. These included 22 frog, two toad, 17 lizard and 19 snake species. No turtles were recorded this time. We recorded 1 species categorized as Near Threatened (NT), 2 as Vulnerable (VU), and 1 as Data Deficient (DD). All other species are categorized as Least Concern (LC). Some of the identified genera comprise threatened species (e.g. *Sylvirana* spp.), but are not yet reported here because identification is still ongoing.

We collected at least eight subfamilies and 40 ant genera, including at least four new genera records for Cambodia (*Paratopula*, *Bothroponera*, *Vollenhovia* and *Platythyrea*). Butterflies, moths, and other invertebrate samples are still being analysed.

By integrating our findings with data from other surveys, we propose recommendations for establishing core and conservation zones within Sambour Wildlife Sanctuary, focussing on those zones with high conservation priority. We identified the islands and sandbars within the main channel of the Mekong River were identified as the sole core zone, specifically dedicated to safeguarding the nesting and roosting sites of four threatened bird species. Based on a variance analysis of the observations of nests of threatened bird species, we propose designating a 4 km wide riparian buffer along the Mekong River as an inland conservation. This suggestions is further reinforced by the inclusion of good quality forested habitat and presence of Eld's deer (*Rucervus eldii*), green peafowl, white-shouldered ibis and long-tailed macaque (*Macaca fascicularis*). A more detailed analysis is required to refine habitat delineation and include other (non-avian) species. In addition, these results strongly highlight the importance of extending the protected area to incorporate the remainder of the Mekong Islands that is now only partly included in Sambour WS.

1 Introduction

The landscapes of the Greater Mekong Region are of great conservation value due to their rich and diverse landscapes, flora, and fauna. However, rapid and accelerating social and economic developments are putting pressure on these habitats, making the region one of the highest-ranking biodiversity hotspots in the world (WWF, 2024). Even so, new species continue to be described (WWF, 2024b), although these are often already threatened by the time of their discovery. Activities including the illegal wildlife trade, climate change, hydropower dams and habitat conversion all impact the ecosystems and species of the Greater Mekong and concerted conservation efforts are required to counter this biodiversity and habitat loss. This is made even more urgent as most of the more than 300 million people inhabiting the Greater Mekong rely on its ecosystem services for their survival (WWF, 2024).

The Mekong flooded forests and deciduous dry dipterocarp forests situated in Cambodia represent some of the largest remaining lowland ecosystems in South-East Asia. Both habitats are home to threatened species including great and white-shouldered ibis, river tern, Irrawaddy dolphin, Eld's deer and hog deer. However, much of the biodiversity here remains poorly understood, and even basic information on many taxonomic groups, especially reptiles, amphibians and invertebrates, is lacking.

Surveys conducted in 2006 and 2007 (Bezuijen et al. 2008) identified sections of the Mekong River between Kratie and Stung Treng Towns with relatively intact riverine habitats. They confirmed the area's conservation significance due to the presence of a number of priority species, including birds, mammals, reptiles and fish. Further data on the biodiversity value of the region was collected through ongoing WWF surveys, mainly for birds, and in 2018 (Jocque et al. 2018) for birds (Mittermeier et al. 2020), amphibians and reptiles, and several invertebrate groups including dragonflies, tiger beetles (Jocque et al. 2019) and even a new genus of spider (Jocque et al. 2019b). As a result, the Cambodian government established Sambour Wildlife Sanctuary (SBWS, 50,093 ha) and Prek Prasab Wildlife Sanctuary (PPWS, 12,770 ha) in 2018 (**Figure 1)**. The current work adds to biodiversity surveys carried out in SBWS and PPWS by the studies mentioned in this paragraph. Much of the project and area background can be found in these publications.

Protected areas are inherently connected to the communities and people who share their landscapes. In Cambodia, the process of delineating biodiversity-rich regions into protected areas necessitates further refinement through the zoning of these areas into four zones: core zones, conservation zones, sustainable use zones, and community zones (GDANCP, 2017). Of these, the identification of core and conservation zones is particularly critical, as these are intended to safeguard the most ecologically significant and vulnerable habitats and threatened species. To support this process and address gaps in biodiversity knowledge, we conducted a follow-up rapid biodiversity survey, providing essential data to inform and refine conservation efforts.

Aims

The aims of this study were:

1. to document the diversity and distribution of birds, reptiles, amphibians and invertebrates in SBWS and PPWS, with special attention to IUCN Red List threatened species, as well as undescribed species;
2. to identify conservation priority areas in and around SBWS using newly collected data and information available from surveys, literature, and spatial analysis, with the goal of informing and supporting conservation management efforts.

Report structure

Chapter 2 provides an overview of the fieldwork locations and survey logistics. Chapter 3 details the remote sensing techniques applied to develop land cover maps and other variables essential for the zoning process. Chapter 4 focuses on the biodiversity surveys conducted. Finally, Chapter 5 presents zoning recommendations derived from the findings in Chapters 3 & 4.

2 Location and Logistics

Biodiversity surveys were mostly conducted in and around SBWS (4 camps, 16 days), with some surveys conducted in PPWS (1 camp, 5 days) (**Figure 1).**

Our biodiversity surveys concentrated on the least disturbed and largest stretches of habitats, while striving to cover a wide area and include diverse habitat types, guided by a land cover map developed prior to the surveys (see Section 3: Land Cover Mapping). We established camps at accessible locations with water availability and in proximity of the areas to be surveyed (**Figure 1)**. We selected campsites using a combination of Google Earth satellite imagery and knowledge of the area from our collaborating partner WWF Cambodia.

At each study site, a temperature/humidity logger (HOBO Onset U23/001 temp/RH) was deployed to provide descriptive information on local variation on microclimate during our survey time. Two loggers were deployed at each camp, one in the shade and one in the sun at ~5ft above the ground. Temperature and humidity were recorded at 15-minute intervals.

Camp 1: PPWS, WWF Ranger Station 22–26 November 2023

We used the PPWS WWF ranger station as a central base, from which survey sites were accessed, either by motorbike or car, using the sanctuary's track network. It was chosen for its central location and facilities. The area consisted of a mosaic of disturbed dry dipterocarp forest, tall and short grasslands, agriculture in the form of rice paddies and livestock grazing, and plantations, with some degraded evergreen forest along streams.

Temperature (°C): Mean ± sd: 28.3 ± 3.5, Range, 21.0 – 35.5
Relative humidity (%): Mean ± sd: 70.5 ± 9.8, Range: 48.5 – 83.0

Camp 2: SBWS, Main Ranger Station, Okork Community Forest 26 Nov. – 1 Dec. 2023

Like Camp 1, the site was chosen because of its logistical value, and location in good habitat. The area consisted of good quality dry dipterocarp forest with some creeks with riparian forest patches.

Temperature (°C): Mean ± sd: 29.6 ± 9.0, Range, 17.5 – 52.0
Relative humidity (%): Mean ± sd: 70.5 ± 21.5, Range: 26.0 – 99.0

Camp 3: SBWS, Koh Knhe Community Forest 1–6 December 2023

Disturbed dry dipterocarp forest with farmland in between on gentle hills and bamboo thickets along a Mekong tributary.

Temperature (°C): Mean ± sd: 30.3 ± 6.4, Range, 22.5 - 46.0
Relative humidity (%): Mean ± sd: 70.0 ± 17.2, Range: 34.5 – 93.0

Camp 4: SBWS, Koh Reugnieu 6–10 December 2023

The camp was situated on one of the Mekong islands, in a dynamic riverine landscape. The area consisted of large islands with dry dipterocarp forests and semi-deciduous forests, small rocky islets, and sandbars.

Temperature (°C): Mean ± sd: 28.3 ± 7.6, Range, 20.5 – 50.0
Relative humidity (%): Mean ± sd: 78.1 ± 20.4, Range: 30.5 – 99.0

Camp 5: Phnom Bak Community Forest 10–12 December 2023

A hillside with boulders, open dry dipterocarp forests with bamboo cover, and semi-deciduous forests with vines. Ongoing clear-cutting of the forest. This area is outside of SBWS but is of biological interest due to the high-quality evergreen forest. Unfortunately, access was not granted by the community to enter the evergreen forest. It remained unsure whether we were allowed to visit the area, and access to the camp was only granted in the last instance. However, if permission can be granted, this area has the potential to be of high biodiversity value.

Temperature (°C): Mean ± sd: 27.2 ± 3.6, Range, 21.5 – 35.0
Relative humidity (%): Mean ± sd: 69.0 ± 12.2, Range: 41.0 – 85.5

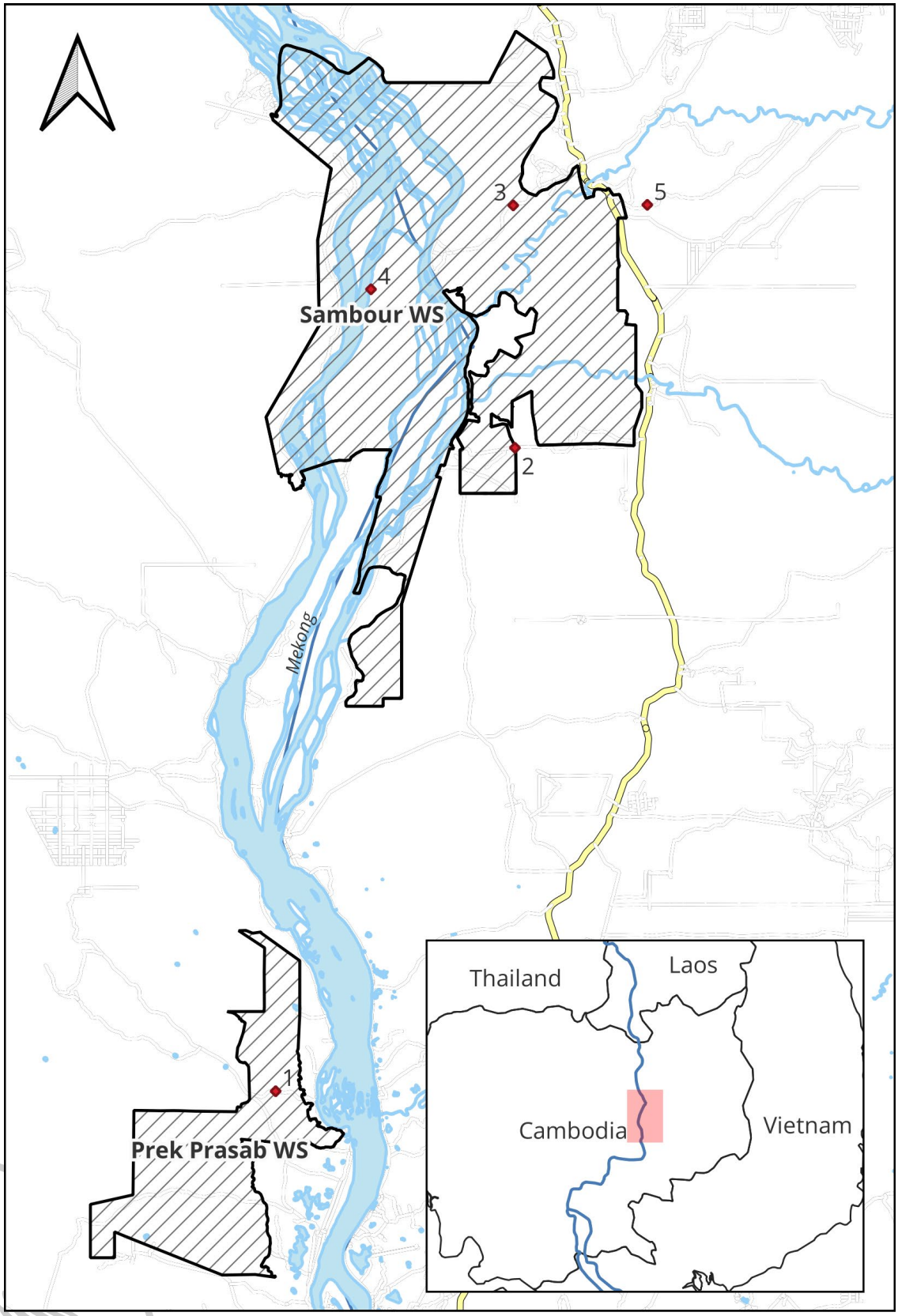

Figure 1. Locations of Prek Prasab and Sambour Wildlife Sanctuaries, showing numbered basecamps.

3 Land Cover Mapping

Jeremie Tranchant, Tim van Berkel

Introduction

Suitable habitat forms the foundation for the continuing existence of all species, but mapping and monitoring land cover have traditionally required a lot of effort. The advent of multispectral satellite imagery changed this, enabling rapid and repeated mapping of large areas, with image resolutions becoming ever more refined. Currently, freely available satellite data has resolutions as high as 10m, enabling meaningful medium-scale habitat classification when combined with accurate ground truthing. We used satellite data from a variety of sources, together with the results from the biodiversity surveys, to help identify high conservation value areas in SBWS and PPWS. Relevant data include tree height, road, settlement, and stream distribution.

We aimed to:

1. create a priori land cover maps to be used by the biodiversity surveys to identify suitable survey sites.
2. create land cover and other relevant maps to help identify high conservation value areas.

Figure 2. Regenerating dry dipterocarp forest. (Photo by Michiel van Noppen)

Methods

Land cover

Training samples of 10 land cover classes were manually created prior to the study from visual inspection of drone RGB orthomosaics acquired over a portion of PPWS in 2018 (van Berkel et al. 2018). These were used to train a Random Forest (RF) classifier over Sentinel-2 L2A imagery (10% max. cloud cover) at 20m resolution and produce a land cover map for the study area.

Tree Height

Tree height distribution for SBWS was derived from the Global Canopy project (https://langnico.github.io/globalcanopyheight/; Lang et al., 2018). We used the most up to date available data at the time of writing, from 2020.

Road distribution

Road distribution data was obtained from OpenDevelopment Cambodia (https://data.opendevelopmentcambodia.net/en/dataset/road-and-railway-networks--in-cambodia).

Results

Nine land cover classes were redefined during the survey to better correspond with the research objectives. Ground-truthing points were acquired opportunistically for each class with the QField mobile application, according to the possibilities left by the terrain. Additional ground-truthing points were created post-mission through visual inspection of the RGB orthomosaics in GIS to obtain a minimum of 30 samples per land cover class. The maps below show the resulting land cover estimate in and around SBWS **Figure 3** and PPWS **Figure 4** for November 2023, including roads, with **Table 1** showing the total extent of each land cover class for PPWS and SBWS. **Figure 5** shows tree height distribution in SBWS.

Table 1. Land cover extent in SBWS and PPWS, November 2023.

	SBWS		PPWS	
Land Cover	**Area (ha)**	**%**	Area (ha)	%
Agriculture/Bare soil	6,800	14	5,705	45
Dry Deciduous Dipterocarp Forest	12,346	25	963	8
Regenerating Dry Deciduous Dipterocarp Forest	3,980	8	945	7
Evergreen forest	9,698	19	270	2
Bamboo forest	1,857	4	576	5
Tall grass	1,485	3	272	2
Medium grass	669	1	64	1
Short grass	2,532	5	609	5
Water	7,898	16	325	3
Plantation	2,818	6	3,032	24
TOTAL	50,083		12,760	

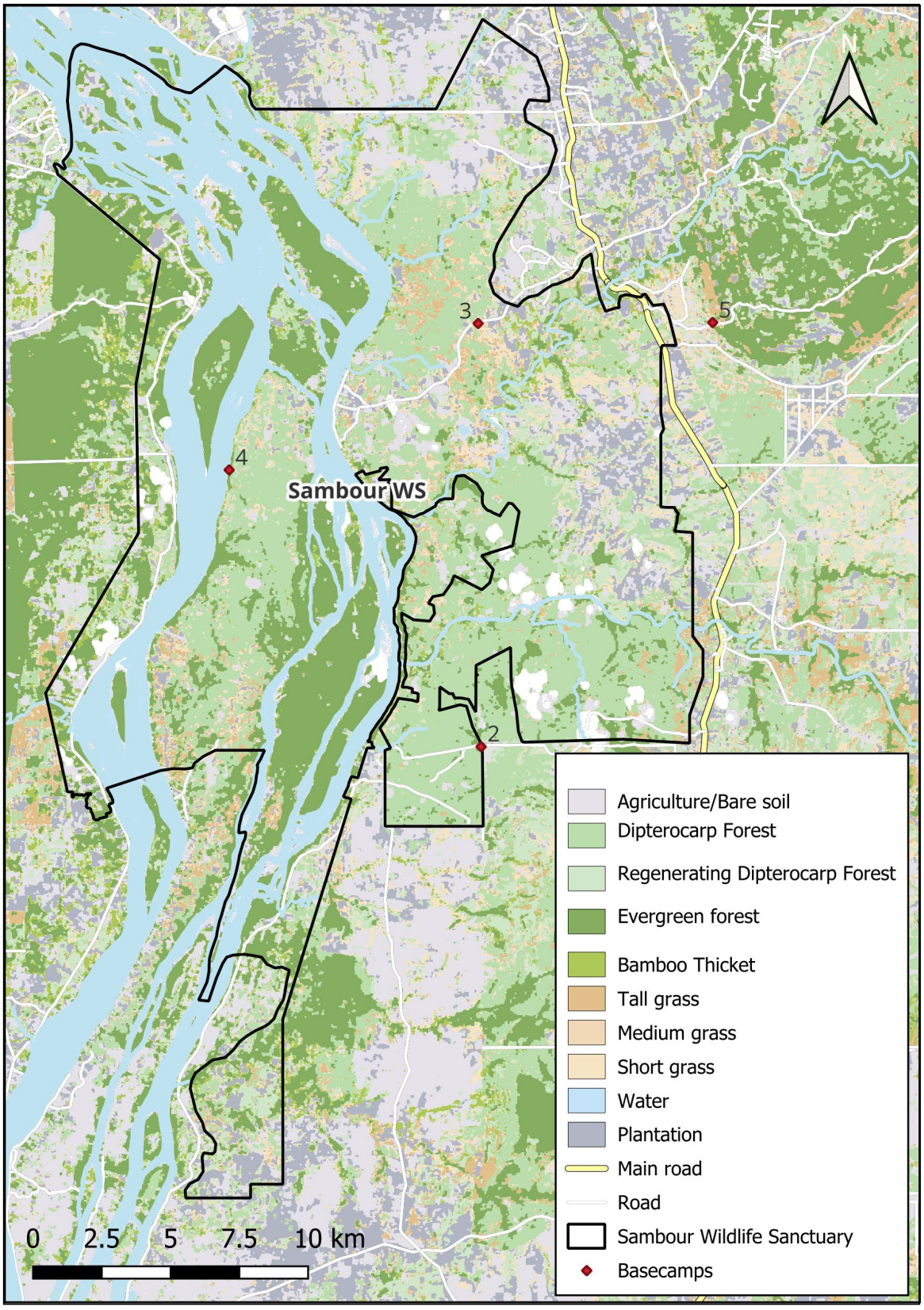

Figure 3. Land cover map of Sambour Wildlife Sanctuary based on Sentinel-2 imagery (11 November 2023, 10% max. cloud cover), using the initial land cover classes. Cloud cover visible as white shapes.

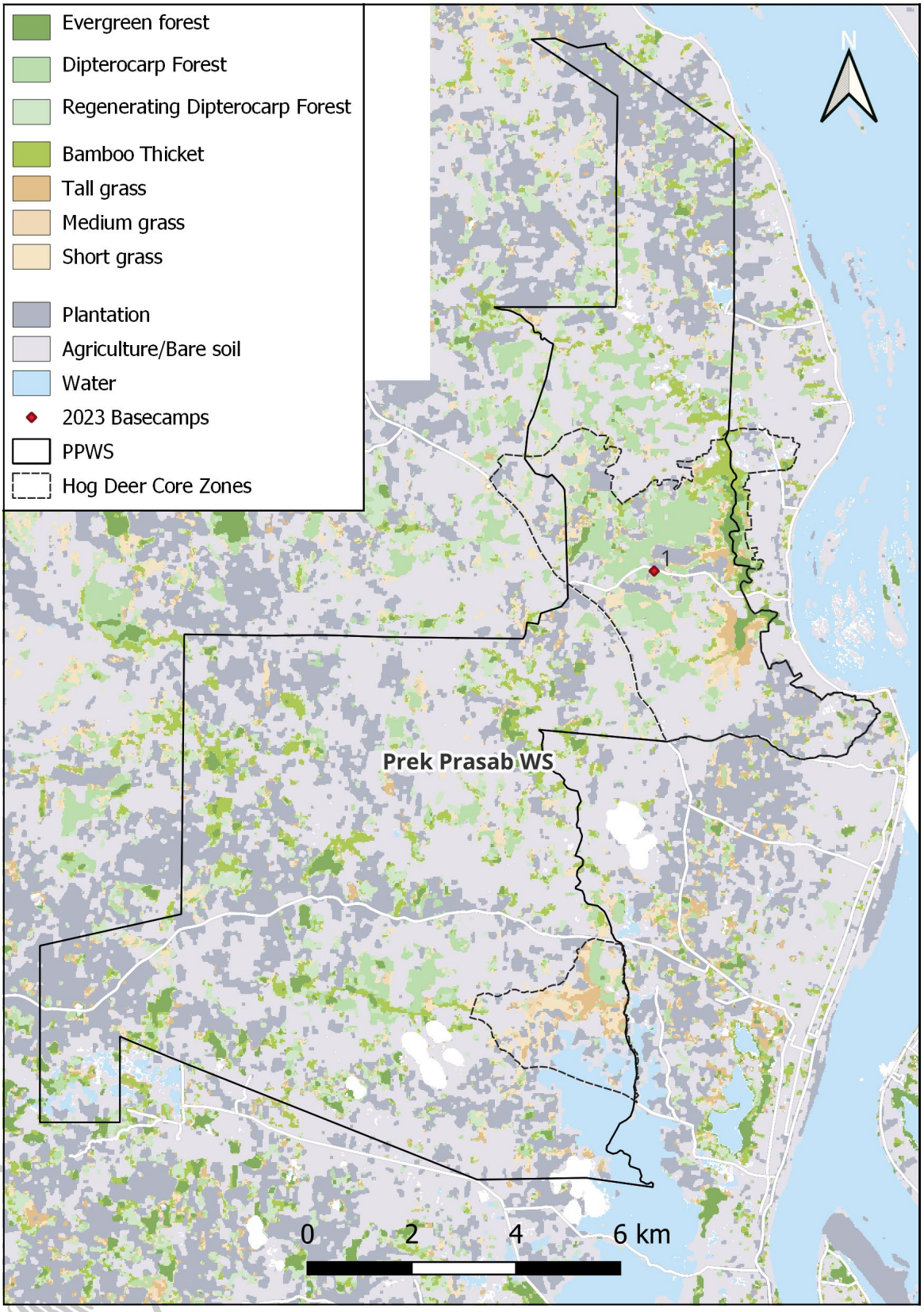

Figure 4. Land cover map of Prek Prasab Wildlife Sanctuary based on Sentinel-2 imagery (11 November 2023, 10% max. cloud cover), using the initial land cover classes. Cloud cover visible as white shapes.

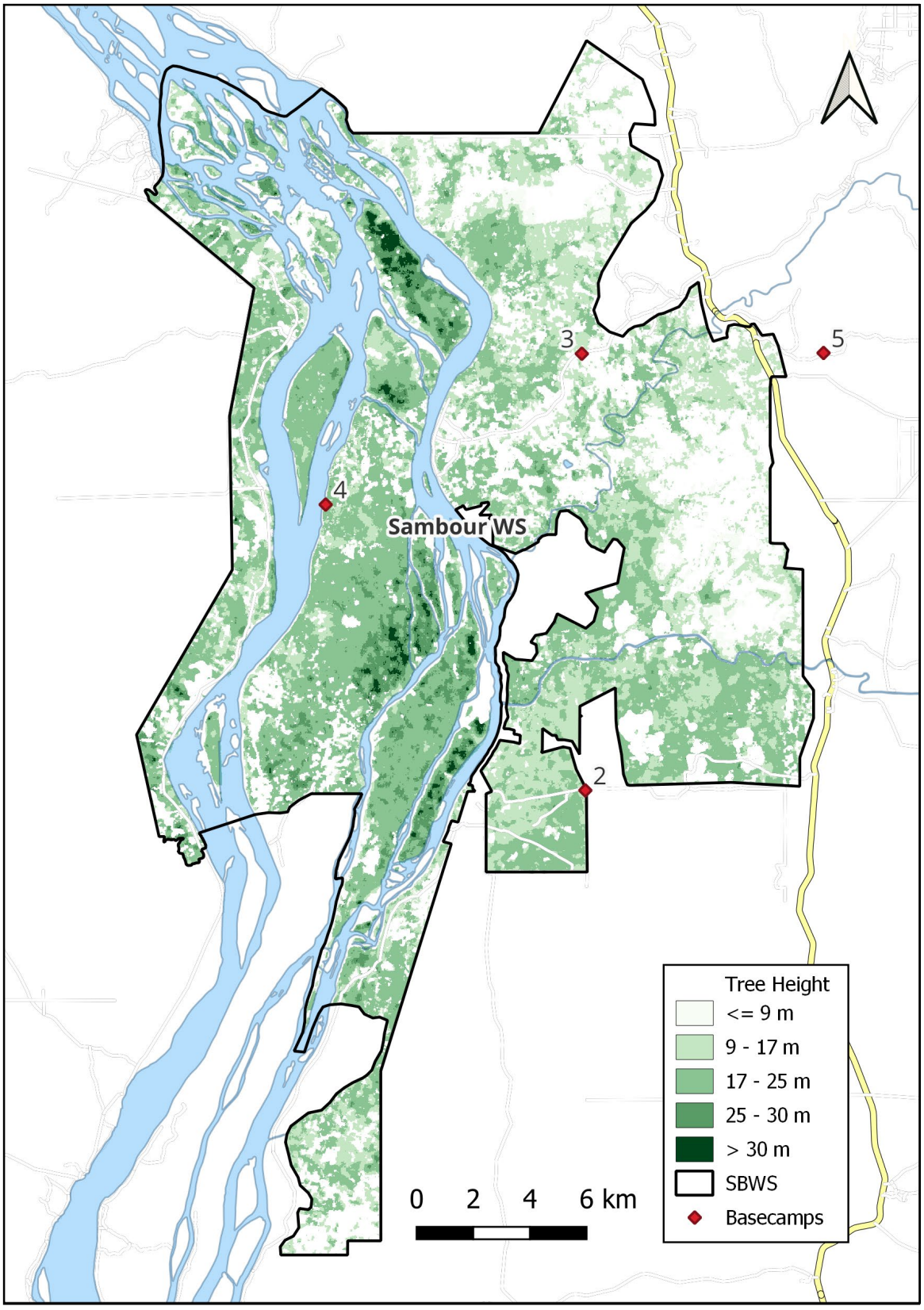

Figure 5. Map of tree canopy height distribution in SBWS. Data is derived from 2020 (Lang et al., 2023). Cloud cover visible as white shapes.

Next Steps

The current land cover classification and map should be used as a good indication of the land cover in SBWS, rather than completely accurate, as we have not yet established the optimum classification approach, which we aim to incorporate in a future version of this report. Once identified, it will be used to derive several measures related to the extent and spatial configuration of land covers. Higher resolution satellite data and more ground truthing points will enable us to provide a finer scale map, with more land cover classes.

We also aim to add additional spatial layers, including human population distribution within SBWS, and a more detailed river and stream network.

4 Biodiversity surveys

4.1 Avifauna

Martin Suanjak

4.1.1 Introduction

Cambodia is known for its diversity of globally threatened bird species, which find a last refuge in a few lowland wetlands, grasslands, and dry dipterocarp forests (Goes, 2013). Despite the lack of high mountain ranges, there have been at least 629 bird species recorded (Cambodia Bird Guide Association (CBGA), 2019). Two rivers, the Tonle Sap and the Mekong, shape the lowland areas in central Cambodia. One of the most biodiverse areas of the Mekong is the so-called central section between the towns of Stung Treng and Kratie (Bezuijen et al., 2008). This highly dynamic riverine system is characterized by large river islands and islets in the Mekong, bordered by patches of semi-deciduous and larger dry dipterocarp forests and small areas of grassland. Avian diversity in this area was studied by Robert Timmins in 2006 and 2007 (Timmins, 2008) and by John C. Mittermeier and Erik M. Sandvig as part of a Biodiversity Express Survey by BINCO in 2018 (Jocque et al., 2018; Mittermeier et al., 2019). Furthermore, a photo booklet with a species list (Nob et al., 2020) has been published to promote the local ecotourism initiative "Koh Samseb Community Based Ecotourism" (https://facebook.com/kohsamsebcbet).

Figure 6. The Critically Endangered white-shouldered ibis (*Pseudibis davisoni*) has one of its main populations along the central section of the Mekong in Cambodia.

Both wildlife sanctuaries are managed by WWF Cambodia under the name of Mekong Flooded Forests (MFF). Globally, this area is critical for the conservation of at least two bird species: white-shouldered ibis (*Pseudibis davisoni*) and Mekong wagtail (*Motacilla samveasnae*) (Timmins, 2008).

The focus of this survey was on the terrestrial habitats along the Mekong, with dry dipterocarp forests as the main habitat type. Only one camp (4) was based on a Mekong island and one camp (5) was based outside of the Wildlife Sanctuaries (**Figure 1)**. The aim of this survey was (a) to add species to the inventory of birds of the area, gain a better understanding of population sizes and habitat requirements for different bird species and, (b) to record abundance data and based on these, make suggestions for the conservation of threatened birds and their habitats.

4.1.2 Methods

The methods used for this survey follow principally those of other Biodiversity Express Surveys (e.g., Jones & Jamie, 2023). The taxonomy uses eBird/Clements (v2022; https://science.ebird.org/en/use-ebird-data/theebird-taxonomy) and the IUCN Red List assessments follows Version 2024-2 (https://iucnredlist.org). All pictures in this report were taken by the author unless stated otherwise.

4.1.2.1 Study area and camps

The study area comprised mostly terrestrial habitats along the Mekong; only one camp (4) was on a Mekong island in a dynamic river habitat. Most camps were in two Wildlife Sanctuaries: Prek Prasab in the south and Sambour in the north. The only camp outside of the Wildlife Sanctuaries was in forests along a hillside (Camp 5).

Cambodia's tropical climate has two seasons, a wet season from April to October and a dry season from November to March. This survey, taking place from 22 November to 12 December, fell into the early dry season, and therefore almost no rain, and temperatures above 30 °C during the day were experienced.

4.1.2.2 Daily log and digital vouchers

All bird observations of each day were summarized every evening in a daily log. This entails maintaining a structured spreadsheet documenting species abundance alongside corresponding numerical counts, supplemented with qualitative remarks, for each day of observation. In addition to my personal observations, I compiled opportunistic bird sightings provided by my colleagues, focusing on threatened or rarely recorded species. This daily log was then fed into the species accumulation curve, the recorded daily species, and into the overall species total. An effort was put into documenting notable bird species with pictures or sound recordings to archive reference material that can be independently examined in the future. All pictures and sound recordings are saved on Cornell University's Macaulay Library (https://macaulaylibrary.org/) and can be accessed via an eBird trip report (https://ebird.org/tripreport/206041).

4.1.2.3 Standardised survey of 1x1 km squares

To delineate 1x1 km squares, the study area's preliminary habitat map was superimposed with a 1x1 km grid. The objective of the ornithological survey within these grid squares was to conduct a minimum of 50 minutes of audiovisual observation under favorable weather conditions. These observations were scheduled either during the morning hours (6-11 a.m.) or late afternoon (3-5

p.m.), as these periods typically exhibit higher bird activity. For logistical reasons, only squares close to the camp were surveyed. In each cell, a complete checklist (following the protocol from ebird.org; https://support.ebird.org/en/support/solutions/articles/48000967748-birding-as-your-primary-purpose-and-complete-checklists) was conducted, which records species, the number of individuals and notes on behaviour or habitat. This easy and replicable method should be a starting point for future surveys in this area.

4.1.2.4 Acoustic recordings

Passive acoustic monitoring (Audiomoths)

Nocturnal Southeast Asian forest species are some of the poorest known species, and thus a particular effort was made to document their presence and song patterns. 'Audiomoths' (passive acoustic monitoring devices; see openacousticdevices.info/Audiomoth) were deployed at locations a minimum of 300 m apart (but typically up to 1 km apart). Each unit was set to record continuously from one hour before sunset until one hour after sunrise (4:27 p.m.–6:57 a.m.) to incorporate additional sampling time as dawn chorus recordings.

A total of 9 units were deployed for a total of 31 recording nights around camps 1–3. At the time of writing, these data are not yet processed, but it is intended to report on them in the final version of the report.

Dawn recordings

Following the methods outlined by Herzog et al. (2016), I used a directional shotgun microphone (Rode NTG5) paired with an audio recorder (Zoom H4n Pro) to make a standardized recording of the dawn chorus. Each survey site was visited during the initial hour of the dawn chorus (around first light at approximately 05:45 am), where a continuous 15-minute recording was captured. During the first 8 minutes of the recording, the sound recorder initially directed the microphone toward the area with the highest vocal activity, gradually rotating it 90 degrees clockwise every minute until completing two full rotations. For the remaining 7 minutes, recordings were made opportunistically, regardless of direction, to document the vocalizations of species not previously recorded or to improve the quality of recordings for species already documented. Each dawn recording site was spaced at least 250 meters apart, in accordance with the recommendations of Herzog et al. (2016) and was typically located in dry dipterocarp forest. This method enabled me to archive the dawn chorus and later identify unidentified species. The recordings will be stored on xeno-canto.org and will contribute to the growing number of dawn recordings worldwide.

4.1.2.5 Mist netting

One 12 m and one 9 m standard mist net were used for catching understorey birds in camps 2 and 3 to document species, collect biometric data, and life history information (age, moult, and brood patches). The following biometrics were measured: maximum and minimum tarsus, maximum (flattened) wing chord, Kipp's distance, tail length, bill tip to anterior nares, bill tip to skull, bill width and depth at anterior nares, body mass, and hind claw. Furthermore, a feather sample (P1) and a set of photographs were taken.

4.1.3 Results

A total of 192 bird species were recorded (**Table 2**). This figure includes two taxa only identified at the genus level due to field identification difficulties (*Aerodramus* sp., *Ardeola* sp.). Four are found on the IUCN Red List: One classified as Critically Endangered (white-shouldered ibis (*Pseudibis davisoni*)), one Endangered (green peafowl (*Pavo muticus*)), and two Vulnerable species (river tern, (*Sterna aurantia*) and great slaty woodpecker (*Mulleripicus pulverulentus*)). A further eight species are classified as Near Threatened.

The species accumulation curve (**Figure 7)** shows no plateau yet, indicating that the survey effort was not sufficient to record all species present in the area. The daily species total was around 50 species, with the most species per day recorded in Camp 4 (with the highest daily total of 83 species on 9 December). The drop on 29 November can be explained by a morning excursion outside the study area to Trapeang Thmor Community Forest.

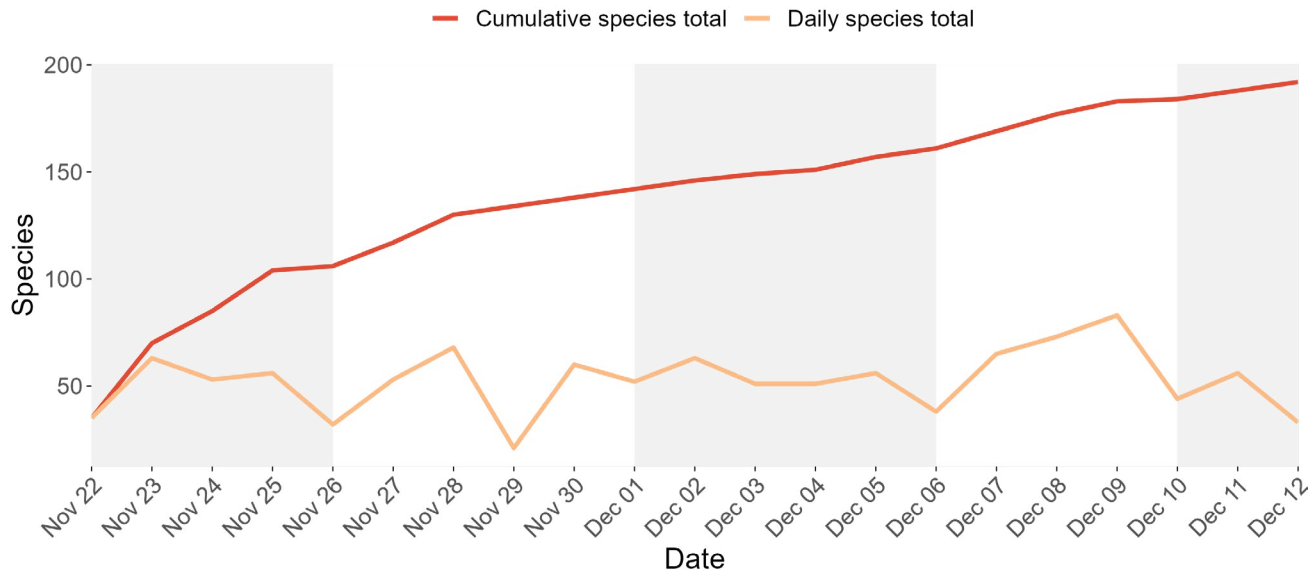

Figure 7. Species accumulation curve (red) and daily species total (orange) curves. The grey and white background indicate different camps.

4.1.3.1 Mixed-species passerine flocks

Mixed-species passerine flocks are a common feature in the non-breeding season in tropical forests (Jiang et al., 2020). Given the limited availability of published data regarding mixed-species flock composition in dry dipterocarp forests in Cambodia, a brief description of the flock's organization is offered here. The flocks were often led by white-browed fantails (*Rhipidura aureola*), which foraged from the ground to the mid-storey. The most abundant participants were little minivets (*Pericrocotus cinnamomeus*), predominantly occupying the upper canopy of the trees, occasionally accompanied by scarlet minivets (*Pericrocotus speciosus*). Common ioras (*Aegithina tiphia*) and common woodshrikes (*Tephrodornis pondicerianus*) were common from the mid-storey to the upper storey but usually not very suspicious. Surprisingly, a study in dry dipterocarp forests in Myanmar also found common wood-shrike, small minivet, and white-browed fantail to be the

most common participants in mixed small passerine flocks (King & Rappole, 2001). Other species occasionally joining those mixed species flocks were woodpeckers (mostly the small grey-capped pygmy woodpecker (*Yungipicus canicapillus*) but also larger species), ashy drongo (*Dicrurus leucophaeus*), velvet-fronted nuthatch (*Sitta frontalis*) and Burmese nuthatch (*S. neglecta*), large woodshrike (*Tephrodornis virgatus*), and cinerous tit (*Parus cinereus*). The only wintering species joining those flocks of resident species were ashy minivets (*Pericrocotus divaricatus*).

4.1.3.2 Standardized survey of 1x1 km squares

A standardized survey was conducted across a total of 33 1x1 squares. Among these, 26 squares predominantly featured dry dipterocarp forest as the primary habitat, while other habitats encompassed farmland (including rice paddies and plantations), grasslands, bamboo forests, and semi-evergreen forests. **Figure 8** shows that sooty-headed bulbuls were the most common species in terms of density and abundance in dry dipterocarp forests. Despite Southeast Asia being a main wintering area for many East Asian passerines (Goes, 2013), only three wintering species (Taiga flycatcher (*Ficedula albicilla*), barn swallow (*Hirundo rustica*), and red-rumped swallow (*Cecropis daurica*)) were recorded among the 29 most common bird species.

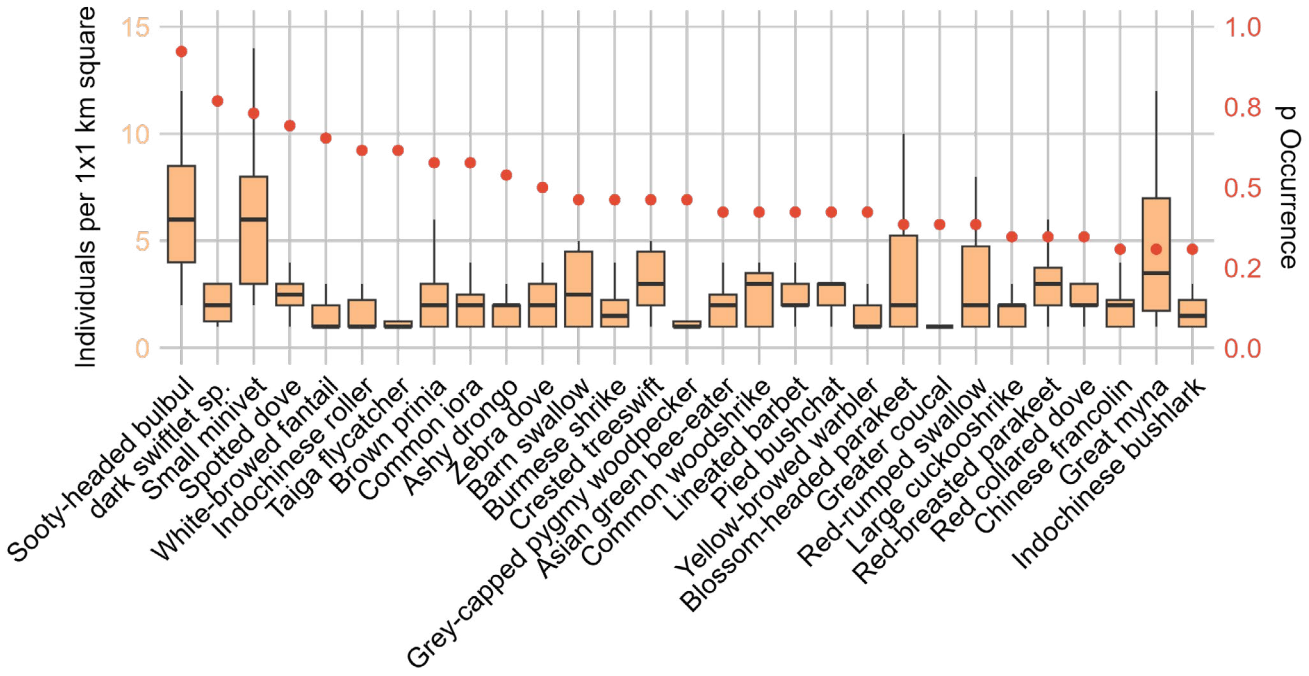

Figure 8. The 29 most common bird species in dry dipterocarp forests near the Mekong determined from standardized surveys in 1x1 km squares (n=26). Red dots indicate the probability of occurrence, and orange box plots show the average number of individuals per square.

4.1.3.3 Mist netting

Opportunistic mist netting took place near camp 2 (dry dipterocarp forest) and camp 3 (edge of a plantation and paddock) for a total of 10 hours. Data on 14 individuals of 9 species was collected (common flameback (*Dinopium javanense*), Indochinese bushlark (*Mirafra erythrocephala*), 2 Oriental magpie robin (*Copsychus saularis*), pied bush chat (*Saxicola caprata*), 2 Radde's warbler (*Phylloscopus schwarzi*), rufescent prinia (*Prinia rufescens*), 2 sooty-headed bulbul (*Pycnonotus aurigaster*), 2 streak-eared bulbul (*Pycnonotus blanfordi*) and 2 taiga flycatcher (*Ficedula albicilla*)). Feather samples are preserved in the bird collection of the Natural History Museum Vienna.

Figure 9. Examples of bird species caught during mist-netting sessions: Oriental magpie robin (*Copsychus saularis*) male (top left), Indochinese bushlark (*Mirafra erythrocephala*) (top right), rufescent prinia (*Prinia rufescens*) (bottom left), common flameback (*Dinopium javanense*) female (bottom right). (Photographs by Michiel van Noppen)

4.1.3.4 Breeding activity

Generally, there was little breeding activity, as most birds start their breeding later in the dry season (Goes, 2013). However, brood patches were recorded for Oriental magpie robins, streak-eared bulbul, and rufescent prinia. Active nests were recorded for lesser adjutants, white-shouldered ibis, grey-headed fish-eagle, and grey-throated martin (see respective species accounts). Additionally, Asian palm swifts (*Cypsiurus balasiensis*) visited probable nesting sites in a palm tree in the Okork Community Forest on 27 November.

4.1.3.5 Trapeang Thmor Community Forest

The morning of 29 November was spent outside of the recording area to visit the Trapeang Thmor Community Forest, another site managed with the help of WWF Cambodia. This site consists primarily of good-quality dry dipterocarp forest with large open patches and small pools. One feature is an established feeding site for vultures which is regularly equipped with cattle carcasses. During the visit, none were attracted to the carcass, but I recorded one red-headed vulture (*Sarcogyps calvus*) (CR) circling low overhead in the forest. Additionally, we were shown colonies of lesser adjutants (NT) with large chicks and Asian woollynecks flew over. The forest was home to interesting dry dipterocarp specialists in the form of yellow-crowned and black-headed woodpecker, Alexandrine parakeet (NT, and not recorded along the Mekong), white-browed fantail (*Rhipidura aureola*), Burmese nuthatch and vinous-breasted myna (*Acridotheres leucocephalus*). Furthermore, it is noteworthy that the iconic giant ibis (*Pseudibis gigantea*), representing one of the most sought-after birding attractions in Cambodia, has been regularly documented here (Sam Un Eam, pers. comm., 2023). Taking all this into consideration, this site has large ecotourism potential as it provides many sought-after bird species in a small area which is less than two hours from Kratie. Local villagers are already involved who know where to find the rare species – the only downside right now is the lack of infrastructure. Establishing an eco-lodge could present a valuable opportunity to generate economic benefits while supporting the conservation efforts of this area.

4.1.4 Selected species accounts

Green peafowl (*Pavo muticus*)

Endangered

Green peafowl were only recorded on Mekong islands, but appear to be relatively common there, although most records were calling males at dawn (heard on Koh Enchey, Koh Reugnieu and Koh Klap). One female flushed from under a fruiting tree and further four females coming to drink to the Mekong were the only visual records. Away from the river islands, only one calling male was recorded in the Phnom Bak Community Forest proving that the species can survive outside of protected areas in the region. Agreeing with previous surveys (Mittermeier et al., 2019; Timmins, 2008), Green peafowl are mostly restricted to large Mekong islands and have become rare in adjacent dry forests. Cambodia has one of the largest populations of this endangered species (McGowan & Kirwan, 2020) which is threatened by poaching and deforestation (Goes, 2013).

As it is currently the second most threatened bird species regularly occurring in Sambour Wildlife Sanctuary, there should be a higher emphasis on recording sightings to know which river islands host that species and in which forests, away from the Mekong, the species still survives in. Ultimately, the aim would be to estimate the population size, which is difficult due to low densities.

Blue-breasted quail (*Synoicus chinensis*)

One male of this small game bird species was flushed from a large, harvested rice paddy near Koh Khnae Community Forest. This species is fairly common around Tonle Sap and localized elsewhere in lowland areas in Cambodia (Goes, 2013). There are only a few records around Kratie and one from Koh Samseb (ebird.org).

Savanna nightjar (*Caprimulgus affinis*)

One individual was flushed during the day from a grassland area in Prek Prasab Wildlife Sanctuary and subsequently photographed to establish its identity. Generally uncommon in Cambodia, Goes

(2013) lists only one record from Kampi and it was not recorded by Mittermeier et al. (2019) and there are only two records prior to 2022 on ebird.org from this area. However, since then, there have been eight records from different locations (ebird.org) proving that this species might be a fairly common species in the area. The distribution map of the newest Cambodian field guide (Cambodia Bird Guide Association (CBGA), 2019) lacks the species from the area, which complicates identification and subsequently might lead to a skewed records by visiting birders.

Dark swiftlet sp. (*Aerodramus* sp.)

Due to the difficulties in the identification of *Aerodramus* swiftlets and releases of other species for swiftlet farming (Goes, 2013), no birds have been identified to species level. Swiftlet-farming in buildings with loudspeakers was very evident in Kratie town and in the two Wildlife Sanctuaries. The ecological impact of this practice is not fully understood (Mursidah et al., 2020).

River lapwing (*Vanellus duvaucelii*) Near Threatened

A local and uncommon resident on riverine sandbars, concentrated on the Mekong and tributaries in Cambodia (Goes, 2013). Both Timmins (2008) and Mittermeier et al. (2019) found the species in sandbars on the central Mekong section. It was recorded fairly regularly on sandbars along the Mekong channels. The largest flock, comprising 18 individuals, was observed in a narrow and frequently traversed channel.

River tern (*Sterna aurantia*) Vulnerable

River terns are one of the most threatened birds in Cambodia. An 80 % population decrease occurred during the past 20 years, leaving only 54–62 mature individuals. it is considered Critically Endangered in Cambodia. The remaining pairs are currently being guarded by local residents as part of nest conservation efforts. The survey was conducted prior to the breeding season, during which River Terns typically migrate downstream to non-breeding foraging habitats around the Tonle Sap (Claassen, 2018). Despite this pattern, one pair was recorded flying downstream near the provincial border to Stung Treng.

Storks (Ciconidae)

Cambodia is home to three Near-Threatened but recovering stork species: Asian woollyneck (*Ciconia episcopu*), lesser adjutant (*Leptoptilos javanicus*), and greater adjutant (*Leptoptilos dubius*). Timmins (2008) found all three species along the Mekong, Mittermeier et al. (2019) only found Asian woollynecks. In this survey, Asian woollynecks were regularly encountered along the Mekong in Sambour Wildlife Sanctuary. Lesser adjutants were encountered mostly in dry forests adjacent to the Mekong in Sambour Wildlife Sanctuary, but one individual was observed outside of the protected area in the Phnom Bak Community Forest and one individual in PPWS. Known nesting colonies were shown to me by the local rangers with large chicks in them. There is a good monitoring system in place, which recorded 39 nests in 2023 (Sam Un Eam, pers. comm., 2024). The lack of lesser adjutant observations by Mittermeier et al. (2019) is probably best explained by more widely ranging birds after the breeding season (Goes, 2013).

White-shouldered ibis (*Pseudibis davisoni*) Critically Endangered

The white-shouldered ibis occurs in two disjunct populations: a tiny population in Borneo and the main population in Cambodia (Matheu et al., 2020). In this survey, white-shouldered ibis were

encountered once in Koh Knhe Community Forest and regularly seen flying along the Mekong. Known nesting sites were shown to me by the rangers, and a potential new nest was found downstream of the camp on Koh Reugnieu on a single tree in the Mekong. Similarly to lesser adjutants, WWF has established a good monitoring system that recorded 52 nests in Sambour Wildlife Sanctuary and surroundings in the 2022-2023 breeding season (Sam Un Eam, pers. comm., 2024).

Two interesting behavioral observations were made: On approach to a known nesting site near Koh Knhe Community on 1 Dec a single white-shouldered ibis (probably female (Matheu et al., 2020)) was circling the nesting tree and calling in distress. The culprit was a juvenile changeable hawk-eagle (*Nisaetus cirrhatus*) that tried to predate the nest and was sitting in the nesting tree. To save the nest of the ibis, we chased the hawk-eagle away. The ibis settled in nearby trees subsequently, but the hawk-eagle made another nest predation attempt, which again led to distress calls and circling by the ibis. We once again chased the hawk-eagle away and left as night fell. In the following days, the nest was not guarded by the ibis, but the hawk-eagle was still present, and a predated eggshell was found. Ultimately, the nest failed (Sam Un Eam, pers. comm., 2024). Changeable hawk-eagle show a varied diet (Clark et al., 2020; Fam & Nijman, 2011), but this appears to be the first reported case of nest predation and eggs as a food source for this species.

Figure 10. Examples of bird species in dry dipterocarp forests: Lesser Adjutant (*Leptoptilos javanicus*, top left), White-rumped Falcon female (*Polihierax insignis*, NT, top right), Brown Prinia juvenile (*Prinia polychroa*, bottom left), White-browed Fantail (*Rhipidura aureola*, bottom right).

The second interesting behavior was a copulation event that was observed near the camp on Koh Reugnieu on 6 Dec during the heat of the day (1:40 a.m.). The copulation was taking place on a dead tree, about 8 m above ground, 70 m from one of the main channels of the Mekong. The male on top was slightly bigger than the female, and typical outdrawn calls were heard during the copulation, which lasted only for about 30 seconds. Afterwards, affectionate behavior was shown which included mutual billing and allopreening. Interestingly, a third Ibis was present on the same tree which did not show any interest in the behavior of the conspecifics. There is little literature on copulation behavior of white-shouldered Ibis. The only account I could find was made by Sözer & van der Heijden (1997), who observed a pair mating on a river bank in Indonesia.

Grey-headed fish-eagle (*Icthyophaga ichthyaetus*) Near Threatened

Grey-headed fish-eagles were found to be very common in the central section of the Mekong by Timmins (2008), but only seen once by Mittermeier et al. (2019). Sadly, confirming the findings of Mittermeier et al. (2019) only two adult birds were seen around the camp on Koh Reugnieu. Even with increased observer coverage, the species is not commonly recorded on ebird.org along the central section of the Mekong and is considered scarce and declining in Cambodia (Clark et al., 2023). As a glimmer of hope for its fate, a nest with an incubating female was found Koh Reugnieu close to the camp. The nest was located on a branch fork in the crown of a broadleaf tree about 8 m above ground, 130 m from the Mekong, in an open dry dipterocarp forest. The nest was fairly conspicuous, but still can be easily missed in the large forest. Probably the best way to find nesting sites is to listen for calling adults at dawn.

The similar but smaller lesser fish-eagle (*Icthyophaga humilis*, NT) was still recorded by Timmins (2008) but it was not found by Mittermeier et al. (2019) or in this study, and they are no recent records on ebird.org. Taking all of this into account, the situation for Icthyophaga fish-eagles in this region appears worrisome, particularly due to the unknown factors contributing to their decline.

Owls (Strigidae)

I recorded five species of owls during this survey. Of significance was a sighting of a pair of brown fish owl (*Ketupa zeylonensis*) flushed from their day roost in the Okork Community Forest, suggesting a breeding site nearby. This species is considered Near Threatened in Cambodia and only occurs along rivers and pools (Goes, 2013). Oriental scops owl (*Otus sunia*) were commonly recorded in dry dipterocarp forest, for example, six calling birds on a three km long transect in the Okork Community Forest. Interestingly, this species was absent in previous surveys (Mittermeier et al., 2019; Timmins, 2008). There are two subspecies present in Cambodia: the resident ssp. *distans* and the wintering ssp. *stictnonotus* (Goes, 2013). High vocal activity suggests that the recorded birds were of the resident *distans* ssp., contrary to the shown distribution map in Birds of Cambodia (Cambodia Bird Guide Association (CBGA), (2019)).

Pied kingfisher (*Ceryle rudis*)

Pied kingfishers have a large distribution (Woodall, 2020), but are only found along large rivers in Southeast Asia. It is declining in Cambodia and is considered Near Threatened (Goes, 2013). In this study, the species was regularly encountered along the Mekong. The highest count of 14 individuals was reached during a 22 km boat survey going upstream on the eastern side of Koh Reugnieu.

Woodpeckers (Picidae)

A notable total of 14 woodpecker species were documented during the survey period. Adding to that, two species recorded in 2018, heart-spotted woodpecker (*Hemicircus canante*) and laced woodpecker (*Picus vittatus*) (Mittermeier et al., 2019), were not recorded during this survey. Therefore, there are at least 16 of Cambodia's 26 woodpecker species (Cambodia Bird Guide Association (CBGA), 2019) present in a relatively small area of dry deciduous and riverine forest. Confirming that Eastern Cambodia and Vietnam are one of the woodpecker diversity hotspots of the world (Vergara Tabares et al., 2018). Two large species were only recorded in this survey: great slaty woodpecker (*Mulleripicus pulverulentus*) and white-bellied woodpecker (*Dryocopus javensis)*. Great slaty woodpecker is considered Vulnerable, but is still fairly common in Cambodia (Goes, 2013). Our observations were made in disturbed dry dipterocarp forests with taller semi-evergreen forest patches in Prek Prasab Wildlife Sanctuary. White-bellied woodpecker is not internationally threatened but is considered Near Threatened in Cambodia (Goes, 2013). One pair was seen twice on a large dead tree on the Mekong river bank next to the camp on Koh Reugnieu. The abundance of woodpecker individuals in this survey shows that four species make up the majority of observed individuals (**Figure 11**): black-headed woodpecker (*Picus erythropygius*), a range-restricted species that is common in disturbed and good quality dry dipterocarp forests; grey-capped pygmy woodpecker (*Yungipicus canicapillus*), a small woodpecker that often joins passerine mixed-species flocks in dry dipterocarp forests; rufous woodpecker (*Micropternus brachyurus*), and common flameback (*Dinopium javanense*) were also quite common in dry dipterocarp forests, with former species showing a preference for the crown areas in trees. Two of the rarer species, yellow-crowned woodpecker (*Leiopicus mahrattensis*) and rufous-bellied woodpecker (*Dendrocopos hyperythrus*), have a restricted range in Southeast Asia and are considered uncommon in Cambodia (Goes, 2013). They were only recorded in good-quality dry dipterocarp that was very open, almost Savannah-like.

Woodpeckers frequently participated in woodpecker-dominated mixed-species flocks. The most common species in those woodpecker flocks were black-headed woodpeckers (**Figure 12**). The largest woodpecker-flock was encountered in a good-quality dry dipterocarp forest in Okork Community Forest and consisted of 9 individuals of 4 woodpecker species of similar sizes (4 black-headed woodpecker, 3 greater yellownape (*Chrysophlegma flavinucha*), 1 common flameback (*Dinopium javanense*), and 1 greater flameback (*Chrysocolaptes guttacristatus*)), accompanied by 2 greater racket-tailed drongos (*Dicrurus paradiseus*). Participation of woodpeckers in mixed-species flocks is readily observed, but mixed-species flocks dominated by woodpeckers seem to be a speciality to woodpecker-rich forests in Southeast Asia (Styring & Ickes, 2001). A study of woodpecker flocks in Malaysia also found Greater Racket-tailed Drongos to follow flocks of large woodpeckers (Styring & Ickes, 2001).

White-rumped falcon (*Neohierax isignis*) Near Threatened

This attractive small falcon species has most of its world population in Cambodia, where it is threatened by habitat loss (Goes, 2013). I found the species to be quite common in dry dipterocarp forests and recorded it at around all camps and in 15 % of all dry dipterocarp squares. Despite being described as unobtrusive or elusive (Gray et al., 2014), I found the species to be rather conspicuous, as it called regularly and was not shy. Most surprisingly, the species was not recorded in previous surveys (Mittermeier et al., 2019; Timmins, 2008) but is depicted in Nob et al. (2020), and there are several other records on ebird.org for the area.

Figure 11. Six of the twelve woodpecker species recorded in this survey: rufous-bellied woodpecker female (*Dendrocopos hyperythrus*, top left), black-headed woodpecker female (*Picus erythropygius*, top middle), yellow-crowned woodpecker (*Leiopicus mahrattensis*, top right), white-bellied woodpecker male (*Dryocopus javensis,* bottom left), great slaty woodpecker male (*Mulleripicus pulverulentus*, VU, bottom middle), rufous woodpecker female (*Micropternus brachyurus,* bottom right).

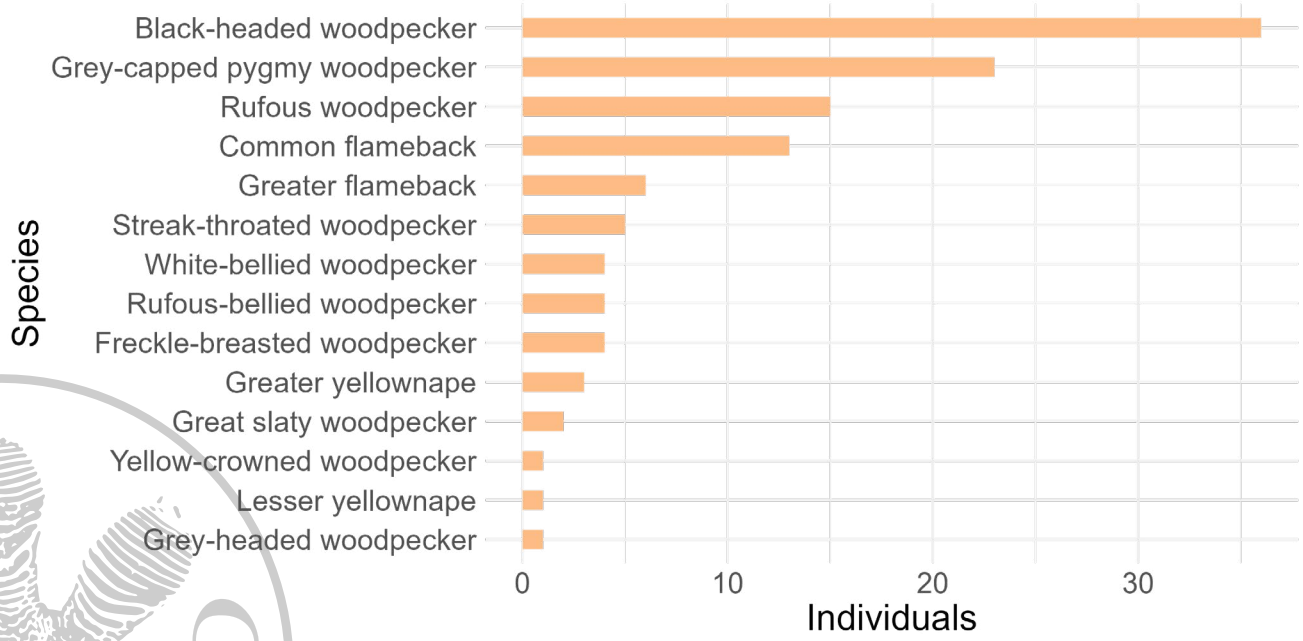

Figure 12. Recorded sum of individuals of different woodpecker species.

Parakeets (*Psittacula* sp.)

Both blossom-headed parakeet (*Psittacula roseata*) and red-breasted parakeet (*P. alexandri*) are considered Near Threatened. In Cambodia, they are locally common (Goes, 2013), and that certainly is the case in the studied area. Both species were commonly found in good-quality but also disturbed dry dipterocarp forests. Breeding was suspected of blossom-headed parakeets as individuals were singing and inspecting nesting holes. Usually small flocks (<15 individuals) were recorded, but one large flock of 50 red-breasted parakeets was recorded in a disturbed area near the Koh Knhe Community Forest. I did not record Alexandrine Parakeet *Psittacula eupatria* (NT) in the study area.

Singing bushlark (*Mirafra javanica*)

This species occurs mostly in grasslands around the Tonle Sap and is considered Near Threatened in Cambodia (Goes, 2013). I confirmed the continued presence of this species in the "irrigation area" in the Prek Prasab Wildlife Sanctuary (Mittermeier et al., 2019).

Figure 13. Examples of riverine bird species that were only encountered along the central section of the Mekong. Top left: Mekong wagtail (*Motacilla samveasnae*), a near-endemic species of Cambodia. Top middle: river lapwing (*Vanellus duvaucelii*), a sand bar specialist. Top right: peregrine falcon (*Falco peregrinus*), a fairly common wintering bird from northern latitudes. bottom: grey-throated Martin (*Riparia chinensis*), a localized species in Cambodia dependent on sand banks for breeding.

Wire-tailed swallow (*Hirundo smithii*)

This nationally threatened species has its stronghold on rocky islets in the central section of the Mekong (Goes, 2013). I never recorded it in great density but it was quite well distributed during the boat surveys on the Mekong. The highest count of 19 individuals in several small groups was reached in the early morning from the camp on Koh Reugnieu. Timmins (2008) estimated less than 100 individuals in this area; I believe this to be a pessimistic estimate.

Eyebrowed thrush (*Turdus obscurus*)

Eyebrowed thrush is a rather uncommon winter visitor and passage migrant in Cambodia (Goes, 2013). On 29 November, I observed one individual near camp in Okork Community Forest as it came to drink in a small creek. It was mostly concealed by foliage; however, the distinctive head pattern with pale supercilium and dark lores was well visible. Unfortunately, the bird flew shortly after uttering a typical chuckling thrush-calls. From Kratie province, there is a record from western Seima Protected Forest (Goes, 2013) and an additional two records from the same area (21 Feb and 13 Dec 2017) on ebird.org. Therefore, this observation likely represents only the fourth record for Kratie Province, fitting well into arrival time of this Siberian breeder (Cambodia Bird Guide Association (CBGA, 2019)).

Mekong wagtail (*Motacilla samveasnae*) Near Threatened

The Mekong wagtail is the wagtail with the smallest distribution and the only wagtail confined to one river system (Alström et al., 2003), making it one of the most unique features of this habitat. The distribution of this Cambodian near-endemic barely stretches into small areas in Thailand, Laos and Vietnam (Tyler & De Juana, 2020). Presently classified as Near Threatened with a stable population, the status of this species could swiftly deteriorate if plans for Mekong dams are implemented. The central section of the Mekong supports one of the largest populations and is therefore of global significance. Fortunately, this species remains common, particularly in fast-flowing stretches characterized by rocky islets with bushes along the Mekong River. These findings support the findings of previous surveys (Mittermeier et al., 2019; Timmins, 2008). The highest count was 17 individuals on a 17 km boat survey from Koh Reugnieu upstream to the provincial border without focusing on the species' habitat.

4.1.5 Discussion

Although it was not the purpose of this study to repeat the efforts of Mittermeier et al. (2019), it is still the most similar study and worth comparing. They recorded more species (219 vs. 192) with the effort of two (rather than one) ornithologists during migration season. The biggest difference in missed species in this study were wetland birds such as bitterns (*Ixobrychus* sp.), waders, rails (Rallidae) and reed warblers (*Acrophalus* sp.). This can be attributed to the wetter conditions experienced in May 2018 (Tim van Berkel, pers. comm., 2023). Six out of the eight species classified as Threatened or Near Threatened, documented by Mittermeier et al. (2019), were not detected during this survey. These species were rare and had patchy distributions, making them prone to being overlooked during surveys. However, two riverine species, Oriental darter (*Anhinga melanogaster*, NT) and great thick-knee (*Esacus recurvirostris*, NT), were encountered several times but were not recorded during this survey. Data from ebird.org suggests that Oriental darter might undertake seasonal movements and is more common in spring and summer (Goes, 2013) in that sector of the Mekong. Great thick-knees are species of extensive sand bars which is a habitat under great human pressure (Goes, 2013; Timmins, 2008), and the lack of records in this survey might hint at an ongoing decline.

This study, on the other hand, added 34 species that were not recorded by Mittermeier et al. (2019) including three IUCN red list species: lesser adjutant (NT), great slaty woodpecker (VU) and white-rumped falcon (NT). Hence, the cumulative species list of two BINCO expeditions in this region now stands at an impressive 252 bird species, reaffirming the remarkable avian diversity of the area (Timmins, 2008).

Mittermeier et al. (2019) argued that several threatened species have declined since the survey of Timmins (2008), and this unfortunately still holds true for the now rare grey-headed fish-eagle and all three vulture species that have vanished. On a positive note, I could confirm the presence of lesser adjutants, of which several nests are monitored and guarded by locals and WWF Cambodia.

The Mekong is certainly the heart of this landscape and harbors the most threatened bird species. However, surrounding good-quality dry dipterocarp forest has also a great value for woodpeckers and other rare specialists and provides nesting trees for storks and large raptors. Threats to this ecosystem include selective logging of large trees and conversion to farmland.

4.1.5.1 **Ecotourism potential**

The high density of threatened species and the overall diversity of birds have a high ecotourism potential. The area is already frequented by visiting birdwatchers, and local ecotourism initiatives such as the "Koh Samseb Community Based Ecotourism" have been established, alongside tours organized by Sam Veasna Conservation Tours (https://samveasna.com/location_sites/kratie/). Probably the most important improvement could be made with an ecolodge (for example, in the Trapeang Thmor Community Fores) to facilitate large groups, promote birdwatching further and show the beauty of a natural, dynamic river landscape.

4.1.5.2 **Conservation recommendations**

Concluding this study, I have three conservation recommendations that largely highlight the same issues encountered by Mittermeier et al. (2019) and Timmins (2008):

1. Improve the knowledge about the population of green peafowl and grey-headed fish eagle by implementing a recording scheme and protecting nesting trees.
2. The remaining dry dipterocarp forests close to the wildlife sanctuary (e.g., Phnom Bak Community Forest) still have a high value, probably act as stepping stones and should be better protected against clear-cutting or selective logging.
3. Protection of sandbars against human disturbance. Several sandbar specialists are at risk or have already been lost (Goes, 2013) due to human disturbance. I noted many holes being dug to harvest large crickets by the locals and temporary settlements on sandbars.

Table 2. Preliminary inventory of species recorded during the survey. 'Bd' = Bird days, represents the number of individual survey days (out of 21 total survey days) on which a given species was recorded, and acts as a proxy for overall abundance of species within the survey period. 'dc' = daily count, is expressed as 'minimum-maximum' number of individuals counted in one day. 'IUCN' = the IUCN status, provided for each species, except when it is classified as 'LC' (Least Concern).

n°	English name	Scientific name	IUCN	dc	Mean count (sd)	Bd
1	Lesser whistling-duck	*Dendrocygna javanica*		1-13	7 (8.5)	2
2	Indian spot-billed duck	*Anas poecilorhyncha*		1-3	2 (1)	3
3	Green peafowl	*Pavo muticus*	EN	1-4	1 (1.3)	5
4	Red junglefowl	*Gallus gallus*		1-1	1 (0)	3
5	Chinese francolin	*Francolinus pintadeanus*		1-6	2 (1.6)	13
6	Blue-breasted quail	*Synoicus chinensis*		2-2	2 (NA)	1
7	Red collared dove	*Streptopelia tranquebarica*		1-5	3 (1.1)	11
8	Spotted dove	*Spilopelia chinensis*		1-25	5 (5.5)	20
9	Asian emerald dove	*Chalcophaps indica*		1-1	1 (NA)	1
10	Zebra dove	*Geopelia striata*		1-14	2 (3.1)	17
11	Thick-billed green pigeon	*Treron curvirostra*		15-15	15 (NA)	1
12	Yellow-footed green-pigeon	*Treron phoenicopterus*		1-6	1 (2.5)	4
13	Green imperial-pigeon	*Ducula aenea*		1-16	4.5 (5.4)	8
14	Greater coucal	*Centropus sinensis*		1-4	2 (0.8)	16
15	Green-billed malkoha	*Phaenicophaeus tristis*		2-2	2 (0)	3
16	Asian koel	*Eudynamys scolopaceus*		1-1	1 (NA)	1
17	Plaintive cuckoo	*Cacomantis merulinus*		1-1	1 (NA)	1
18	Great eared-nightjar	*Lyncornis macrotis*		1-3	2 (1.4)	2
19	Large-tailed nightjar	*Caprimulgus macrurus*		1-2	1 (0.5)	4
20	Savanna nightjar	*Caprimulgus affinis*		1-1	1 (NA)	1
21	Dark swiftlet sp.	*Aerodramus* sp.		3-67	11 (14.7)	21
22	Pacific swift	*Apus pacificus*		2-2	2 (NA)	1
23	Asian palm swift	*Cypsiurus balasiensis*		1-16	1 (5.5)	7
24	Crested treeswift	*Hemiprocne coronata*		1-23	3.5 (7.9)	14
25	Little ringed plover	*Charadrius dubius*		1-1	1 (0)	2

n°	English name	Scientific name	IUCN	dc	Mean count (sd)	Bd
26	River lapwing	*Vanellus duvaucelii*	NT	1-19	15 (8.6)	5
27	Red-wattled lapwing	*Vanellus indicus*		1-2	1 (0.4)	6
28	Common sandpiper	*Actitis hypoleucos*		1-2	1 (0.6)	3
29	Green sandpiper	*Tringa ochropus*		1-1	1 (NA)	1
30	Barred buttonquail	*Turnix suscitator*		2-2	2 (0)	3
31	Small pratincole	*Glareola lactea*		1-4	2 (1.5)	3
32	River tern	*Sterna aurantia*	VU	2-2	2 (NA)	1
33	Asian woollyneck	*Ciconia episcopus*	NT	1-5	2 (1.7)	4
34	Lesser adjutant	*Leptoptilos javanicus*	NT	1-4	1 (1.1)	8
35	Little cormorant	*Microcarbo niger*		2-2	2 (NA)	1
36	Black-crowned night heron	*Nycticorax nycticorax*		1-2	1.5 (0.7)	2
37	Little egret	*Egretta garzetta*		1-19	2 (7.5)	7
38	Striated heron	*Butorides striata*		1-1	1 (NA)	1
39	Pond heron sp.	*Ardeola* sp.		1-9	2.5 (2.6)	8
40	Eastern cattle egret	*Bubulcus coromandus*		1-39	8.5 (13.6)	8
41	Great white egret	*Ardea alba*		1-4	2 (1.5)	3
42	Medium egret	*Ardea intermedia*		1-2	1.5 (0.7)	2
43	Grey heron	*Ardea cinerea*		1-14	3.5 (4.8)	6
44	White-shouldered ibis	*Pseudibis davisoni*	CR	1-3	2.5 (1)	6
45	Osprey	*Pandion haliaetus*		1-7	4 (2.4)	6
46	Black-winged kite	*Elanus caeruleus*		1-2	1.5 (0.6)	4
47	Crested honey-buzzard	*Pernis ptilorhynchus*		2-2	2 (NA)	1
48	Jerdon's baza	*Aviceda jerdoni*		1-1	1 (NA)	1
49	Black baza	*Aviceda leuphotes*		1-1	1 (NA)	1
50	Crested serpent-eagle	*Spilornis cheela*		1-4	2 (1.1)	7
51	Changeable hawk-eagle	*Nisaetus cirrhatus*		1-2	1.5 (0.6)	4
52	Rufous-winged buzzard	*Butastur liventer*		1-2	2 (0.5)	7
53	Pied harrier	*Circus melanoleucos*		1-2	1 (0.6)	3
54	Crested goshawk	*Accipiter trivirgatus*		1-1	1 (NA)	1
55	Shikra	*Accipiter badius*		1-1	1 (0)	3
56	Brahminy kite	*Haliastur indus*		1-8	1.5 (3.4)	4
57	Grey-headed fish-eagle	*Icthyophaga ichthyaetus*	NT	2-5	3.5 (2.1)	2
58	Collared scops owl	*Otus lettia*		1-1	1 (0)	2
59	Oriental scops owl	*Otus sunia*		1-6	1 (2.2)	5
60	Brown fish-owl	*Ketupa zeylonensis*		2-2	2 (NA)	1
61	Asian barred owlet	*Glaucidium cuculoides*		1-7	2 (2.7)	4
62	Brown boobook	*Ninox scutulata*		1-4	2.5 (2.1)	2

n°	English name	Scientific name	IUCN	dc	Mean count (sd)	Bd
63	Eurasian hoopoe	*Upupa epops*		1-4	2 (1)	11
64	Oriental pied-hornbill	*Anthracoceros albirostris*		3-24	19 (9.5)	4
65	Common kingfisher	*Alcedo atthis*		1-4	1.5 (1.2)	6
66	Stork-billed kingfisher	*Pelargopsis capensis*		1-1	1 (0)	4
67	White-throated kingfisher	*Halcyon smyrnensis*		1-7	1 (2.4)	6
68	Pied kingfisher	*Ceryle rudis*		1-16	1 (8.7)	3
69	Asian green bee-eater	*Merops orientalis*		1-257	4 (66.5)	15
70	Blue-tailed bee-eater	*Merops philippinus*		1-1	1 (NA)	1
71	Chestnut-headed bee-eater	*Merops leschenaulti*		1-17	2.5 (5.3)	8
72	Indochinese roller	*Coracias affinis*		1-8	2 (2)	17
73	Dollarbird	*Eurystomus orientalis*		1-1	1 (0)	2
74	Coppersmith barbet	*Psilopogon haemacephalus*		1-3	2 (0.8)	6
75	Blue-eared barbet	*Psilopogon cyanotis*		1-1	1 (NA)	1
76	Lineated barbet	*Psilopogon lineatus*		1-7	3 (2.1)	15
77	Grey-capped pygmy woodpecker	*Yungipicus canicapillus*		1-5	2 (1.2)	12
78	Yellow-crowned woodpecker	*Leiopicus mahrattensis*		1-1	1 (NA)	1
79	Rufous-bellied woodpecker	*Dendrocopos hyperythrus*		1-2	1 (0.6)	3
80	Freckle-breasted woodpecker	*Dendrocopos analis*		1-2	1 (0.6)	3
81	Greater flameback	*Chrysocolaptes guttacristatus*		1-1	1 (0)	6
82	Rufous woodpecker	*Micropternus brachyurus*		1-8	1 (2.5)	8
83	Common flameback	*Dinopium javanense*		1-3	1 (0.9)	8
84	Lesser yellownape	*Picus chlorolophus*		1-1	1 (NA)	1
85	Streak-throated woodpecker	*Picus xanthopygaeus*		1-2	1 (0.5)	4
86	Grey-headed woodpecker	*Picus canus*		1-1	1 (NA)	1
87	Black-headed woodpecker	*Picus erythropygius*		1-6	2 (1.8)	13
88	Greater yellownape	*Chrysophlegma flavinucha*		3-3	3 (NA)	1
89	Great slaty woodpecker	*Mulleripicus pulverulentus*	VU	1-1	1 (0)	2
90	White-bellied woodpecker	*Dryocopus javensis*		1-2	1 (0.6)	3
91	Collared falconet	*Microhierax caerulescens*		1-5	1.5 (1.9)	4
92	White-rumped falcon	*Neohierax insignis*	NT	1-4	1.5 (1.1)	8
93	Peregrine falcon	*Falco peregrinus*		1-3	1 (1.2)	3
94	Blossom-headed parakeet	*Psittacula roseata*	NT	1-14	3 (5)	15
95	Red-breasted parakeet	*Psittacula alexandri*	NT	1-15	5.5 (4.4)	16
96	Vernal hanging-parrot	*Loriculus vernalis*		1-1	1 (NA)	1
97	Small minivet	*Pericrocotus cinnamomeus*		1-57	7 (14.3)	15
98	Scarlet minivet	*Pericrocotus speciosus*		1-6	3 (1.8)	6
99	Ashy minivet	*Pericrocotus divaricatus*		1-2	1 (0.4)	5

n°	English name	Scientific name	IUCN	dc	Mean count (sd)	Bd
100	Brown-rumped minivet	*Pericrocotus cantonensis*		3-3	3 (NA)	1
101	Large cuckooshrike	*Coracina macei*		1-6	2 (1.5)	14
102	Indochinese cuckooshrike	*Lalage polioptera*		1-2	1 (0.4)	6
103	Black-naped oriole	*Oriolus chinensis*		1-4	2 (1.5)	3
104	Black-hooded oriole	*Oriolus xanthornus*		1-2	1 (0.5)	10
105	Large woodshrike	*Tephrodornis virgatus*		2-5	3.5 (2.1)	2
106	Common woodshrike	*Tephrodornis pondicerianus*		1-12	2 (3.3)	12
107	Bar-winged flycatcher-shrike	*Hemipus picatus*		2-4	2.5 (1)	4
108	Common iora	*Aegithina tiphia*		1-9	2 (2.2)	13
109	Great iora	*Aegithina lafresnayei*		1-1	1 (NA)	1
110	Malaysian pied-fantail	*Rhipidura javanica*		1-2	1.5 (0.7)	2
111	White-browed fantail	*Rhipidura aureola*		1-9	3 (2.3)	13
112	Black drongo	*Dicrurus macrocercus*		1-9	2 (2.5)	10
113	Ashy drongo	*Dicrurus leucophaeus*		1-6	2 (1.4)	15
114	Hair-crested drongo	*Dicrurus hottentottus*		1-14	3 (4.9)	6
115	Greater racket-tailed drongo	*Dicrurus paradiseus*		1-7	2.5 (2.3)	6
116	Black-naped monarch	*Hypothymis azurea*		1-6	1.5 (1.5)	10
117	Brown shrike	*Lanius cristatus*		1-3	2 (1.4)	2
118	Burmese shrike	*Lanius collurioides*		1-7	2 (1.8)	12
119	Eurasian jay	*Garrulus glandarius*		1-1	1 (0)	2
120	Red-billed blue-magpie	*Urocissa erythroryncha*		1-6	2 (2.4)	5
121	Rufous treepie	*Dendrocitta vagabunda*		1-1	1 (0)	6
122	Racket-tailed treepie	*Crypsirina temia*		1-2	1.5 (0.7)	2
123	Large-billed crow	*Corvus macrorhynchos*		1-9	1.5 (2.1)	14
124	Grey-headed canary-flycatcher	*Culicicapa ceylonensis*		1-5	1 (1.5)	9
125	Cinereous tit	*Parus cinereus*		1-4	1.5 (1.4)	4
126	Singing bushlark	*Mirafra javanica*		1-1	1 (NA)	1
127	Indochinese bushlark	*Mirafra erythrocephala*		1-12	2 (3.1)	12
128	Common tailorbird	*Orthotomus sutorius*		1-6	1 (1.7)	11
129	Dark-necked tailorbird	*Orthotomus atrogularis*		1-12	1.5 (3.8)	8
130	Brown prinia	*Prinia polychroa*		1-7	2 (1.9)	13
131	Rufescent prinia	*Prinia rufescens*		1-6	2.5 (1.8)	10
132	Grey-breasted prinia	*Prinia hodgsonii*		1-2	1 (0.6)	3
133	Yellow-bellied prinia	*Prinia flaviventris*		6-6	6 (NA)	1
134	Plain prinia	*Prinia inornata*		1-6	2 (2)	5
135	Zitting cisticola	*Cisticola juncidis*		2-2	2 (NA)	1
136	Golden-headed cisticola	*Cisticola exilis*		1-4	2 (1.5)	3

n°	English name	Scientific name	IUCN	dc	Mean count (sd)	Bd
137	Thick-billed warbler	*Arundinax aedon*		2-2	2 (NA)	1
138	Grey-throated martin	*Riparia chinensis*		42-42	42 (NA)	1
139	Barn swallow	*Hirundo rustica*		1-93	11 (23.1)	19
140	Wire-tailed swallow	*Hirundo smithii*		1-44	8 (23.1)	3
141	Red-rumped swallow	*Cecropis daurica*		1-9	4 (2.5)	16
142	Black-headed bulbul	*Microtarsus melanocephalos*		1-4	3 (1.5)	3
143	Black-crested bulbul	*Rubigula flaviventris*		1-3	3 (1.2)	3
144	Streak-eared bulbul	*Pycnonotus conradi*		1-7	2 (2.1)	11
145	Stripe-throated bulbul	*Pycnonotus finlaysoni*		1-3	2 (0.8)	6
146	Yellow-vented bulbul	*Pycnonotus goiavier*		1-2	1.5 (0.7)	2
147	Sooty-headed bulbul	*Pycnonotus aurigaster*		1-81	14 (19.6)	18
148	Yellow-browed warbler	*Phylloscopus inornatus*		1-7	2 (1.9)	15
149	Radde's warbler	*Phylloscopus schwarzi*		1-3	1 (0.9)	5
150	Dusky warbler	*Phylloscopus fuscatus*		1-6	1 (1.8)	7
151	Two-barred warbler	*Phylloscopus plumbeitarsus*		1-2	1 (0.6)	3
152	Chestnut-capped babbler	*Timalia pileata*		2-4	3 (1.4)	2
153	Pin-striped tit-babbler	*Mixornis gularis*		2-9	3.5 (2.5)	6
154	Puff-throated babbler	*Pellorneum ruficeps*		1-1	1 (0)	2
155	White-crested laughingthrush	*Garrulax leucolophus*		2-7	5 (1.9)	5
156	Velvet-fronted nuthatch	*Sitta frontalis*		1-2	1.5 (0.7)	2
157	Burmese nuthatch	*Sitta neglecta*		1-3	1 (0.8)	7
158	Common hill myna	*Gracula religiosa*		1-4	2.5 (2.1)	2
159	Black-collared starling	*Gracupica nigricollis*		1-14	2 (4.5)	7
160	Chestnut-tailed starling	*Sturnia malabarica*		2-6	3 (2.1)	3
161	Common myna	*Acridotheres tristis*		1-2	2 (0.6)	3
162	Vinous-breasted myna	*Acridotheres leucocephalus*		1-57	6 (18.6)	11
163	Great myna	*Acridotheres grandis*		1-114	5 (28.6)	15
164	Eyebrowed thrush	*Turdus obscurus*		1-1	1 (NA)	1
165	Asian brown flycatcher	*Muscicapa dauurica*		1-5	1 (1.4)	12
166	Oriental magpie-robin	*Copsychus saularis*		1-2	1.5 (0.5)	8
167	White-rumped shama	*Copsychus malabaricus*		1-1	1 (NA)	1
168	Hainan blue flycatcher	*Cyornis hainanus*		1-1	1 (NA)	1
169	Indochinese blue flycatcher	*Cyornis sumatrensis*		1-3	1 (1.2)	3
170	Siberian blue robin	*Larvivora cyane*		1-1	1 (NA)	1
171	Taiga flycatcher	*Ficedula albicilla*		1-4	2 (1.3)	14
172	White-throated rock thrush	*Monticola gularis*		1-2	1.5 (0.7)	2
173	Amur stonechat	*Saxicola stejnegeri*		1-7	1.5 (2.9)	4

n°	English name	Scientific name	IUCN	dc	Mean count (sd)	Bd
174	Pied bushchat	*Saxicola caprata*		1-5	3 (1.2)	15
175	Scarlet-backed flowerpecker	*Dicaeum cruentatum*		1-2	1 (0.4)	7
176	Ruby-cheeked sunbird	*Chalcoparia singalensis*		1-1	1 (0)	3
177	Purple sunbird	*Cinnyris asiaticus*		1-2	1 (0.4)	5
178	Ornate sunbird	*Cinnyris ornatus*		1-5	1 (1.8)	5
179	Asian fairy-bluebird	*Irena puella*		1-1	1 (NA)	1
180	Blue-winged leafbird	*Chloropsis moluccensis*		2-2	2 (NA)	1
181	Golden-fronted leafbird	*Chloropsis aurifrons*		1-4	1 (1.2)	6
182	Baya weaver	*Ploceus philippinus*		5-5	5 (NA)	1
183	Scaly-breasted munia	*Lonchura punctulata*		2-6	3 (1.6)	5
184	House sparrow	*Passer domesticus*		9-9	9 (NA)	1
185	Plain-backed sparrow	*Passer flaveolus*		1-24	2.5 (9)	6
186	Eastern yellow wagtail	*Motacilla tschutschensis*		1-1	1 (NA)	1
187	Mekong wagtail	*Motacilla samveasnae*	NT	2-19	8 (7.1)	4
188	Pied wagtail/white wagtail	*Motacilla alba*		1-2	1.5 (0.7)	2
189	Richard's pipit	*Anthus richardi*		1-15	8 (9.9)	2
190	Paddyfield pipit	*Anthus rufulus*		2-4	3 (1)	5
191	Olive-backed pipit	*Anthus hodgsoni*		1-7	2 (2.2)	7
192	Red-throated pipit	*Anthus cervinus*		1-2	1.5 (0.7)	2

4.2 Herpetofauna

Mathias Dezetter, Sinuon Sao

4.2.1 Introduction

Cambodia is home to 191 recorded reptile species and 72 recorded amphibian species, of which 8% are endemic (Poyarkov et al., 2023, 2021). About 13% and 15% of Cambodian reptile and amphibian species, respectively, are categorized as Vulnerable or Threatened by the International Union for the Conservation of Nature (IUCN) (Jocque et al., 2018; Poyarkov et al., 2023). Knowledge about the diversity, the distribution and the taxonomy of these taxa in Cambodia has been rapidly increasing in the past two decades, with both numerous biological inventories targeting reptiles and amphibians (Geissler et al., 2019; Hartmann et al., 2013; Neang et al., 2015, 2011; Ohler et al., 2002; Stuart et al., 2010; Stuart and Emmett, 2006) and a growing number of species descriptions (Grismer et al., 2010, 2007; Hoser, 2014; Neang et al., 2020, 2018, 2014, 2012; Rowley et al., 2015; Stuart et al., 2020). However, the conservation status of many species remains unknown. A good 33% of reptile and 18% of amphibian species in Cambodia are either not evaluated by the IUCN, or categorized as Data Deficient (DD)), while, the systematics of many species remain unsolved, partly due to a high level of undescribed cryptic diversity (Neang et al., 2020; Ngo et al., 2023; Poyarkov et al., 2023, 2021).

Reptiles and amphibians are among the most threatened vertebrates globally (Araújo et al., 2006; Cox et al., 2022; Gibbons et al., 2000; Luedtke et al., 2023). In the tropics, these ectotherms often have small distributions and low dispersal capacities, and are particularly vulnerable to habitat fragmentation and change in microclimate conditions due to climate change (Araújo et al., 2006; Cox et al., 2022; Doherty et al., 2020; Gibbons et al., 2000; Moore et al., 2018; Nowakowski et al., 2018). Rapid changes in climate in the next decades are notably expected to adversely affect amphibians and reptiles in South-East Asia, with high predicted impact in Cambodia (Bickford et al., 2010). A more urgent threat however, is habitat destruction, for instance due to the rapidly accelerating deforestation rates in Cambodia. Primary forests are logged for timber wood and charcoal production and then converted to plantations at an alarming rate, especially in the Mekong floodplains (Grogan et al., 2018; Lohani et al., 2020), with likely adverse impact on reptiles and amphibians (Behm et al., 2013; Wanger et al., 2010). In addition, many species of snakes, turtles and frogs are hunted for food and commercial trade in Cambodia (Brooks et al., 2010, 2007; Heinrich et al., 2020; Ibbett et al., 2021; Platt et al., 2008). Some species also hold cultural significance and are an important resource for rural populations (Coad et al., 2019; Shams, 2007). For a better understanding of the multiple threats that the Cambodian herpetofauna is facing and set strides towards a more effective protection, or at least identify conservation priorities a good understanding is needed of what species are present where. In this context, rapid biological inventories constitute a key methodology to inform management and conservation in areas where data on biodiversity is lacking (Clark et al., 2012; Das, 2016; Patrick et al., 2014; Tanalgo et al., 2019; Vonesh et al., 2010).

Collaborations with local communities and the incorporation of local and traditional knowledge in biodiversity inventories can lead to more efficient science and better conservation outcomes (Copete et al., 2023; Gardner et al., 2022; Ong et al., 2021; Schmiedel et al., 2016; Ward Fear et al., 2019). The implication of local communities in the management of conservation areas is also a crucial component of effective strategies for long term equitable conservation (Andrade and

Rhodes, 2012; Andrade et al., 2022; Dawson et al., 2021; Shanee et al., 2015, 2020). In Cambodia, community forests have been proven to efficiently conserve forest cover, especially in cases where communities rely on forest products for subsistence use and income (Singh et al., 2018). Its effectiveness can however be limited depending on the geographical, social and political context (Ota et al., 2020; Pasgaard and Nielsen, 2016). Including local community participation in reptile and amphibian inventories could therefore both strengthen assessment outcomes, and foster long term partnerships with protected areas such as Wildlife Sanctuaries.

Most biodiversity inventories targeting reptiles and amphibians in Cambodia have focused on the Cardamom Mountains in the South, and in the North-East uplands (Geissler et al., 2019; Ohler et al., 2002; Stuart et al., 2010; Stuart and Emmett, 2006; Thy et al., 2010). The herpetology diversity of the central Mekong River plains has only been scarcely investigated so far (Bezuijen et al., 2009; Hayes et al., 2015; Jocque et al., 2018). Bezuijen et al. 2009 conducted surveys in riverbanks and the interior of Mekong islands, in areas overlapping Sambour Wildlife Sanctuary (SBWS) and close to Prek Prasab Wildlife Sanctuary (PPWS), while Hayes et al., 2015 undertook surveys in Prey Lang, west of SBWS. While most of the species recorded in both studies were representatives of anthropogenically disturbed lowland habitats, these surveys also provided new records for the country (e.g. *Gekko petricolus*, *Hemiphyllodactylus yunnanensis*) and recorded the presence of threatened turtles in the region (e.g. *Cuora amboinensis*, *Heosemys grandis*, *Siebenrockielle crassicollis*, *Amyda cartilaginea*, *Pelochelys cantorii*, *Indotestudo elongata*). Both surveys highlighted the threat of overhunting and organized commercial trade for these turtles and reported the historical presence of the Siamese crocodile (*Crocodylus siamensis*) that is now supposed to be locally extinct because of commercial hunting. The more recent work led by a BINCO and WWF Cambodia within PPWS and SBWS during the dry season of 2018 (see Jocque et al., 2018) reported 23 additional species to observations recorded in Bezuijen et al. (2009), and led to similar conclusions about reptile and amphibian communities dominated by generalist and human-disturbed habitat adapted species. Worth noting is that only one turtle specimen was recorded (Mekong snail-eating turtle, *Malayemys cf. subtrijuga*) during the 2018 BINCO survey, and similar concerns about overharvesting of economically valuable species were discussed.

During this follow-up Biodiversity Express Survey, we aimed to conduct a rapid participatory inventory of reptile and amphibian species within PPWS and SBWS, complementing the findings from previous surveys, in order to inform management and conservation measures. We also aimed to deploy replicable methods for long-term monitoring of species communities, and to build the capacity for the WWF team in these methods, as well as to foster participatory and collaborative work with local community members involved in the management of the Wildlife Sanctuaries. At the end of the dry season of 2023, we conducted surveys for 21 consecutive days in different habitat types within both conservation areas, and employed both active (visual encounter surveys), passive (drift fence with pitfall trap), and opportunistic sampling techniques (Hutchens and Deperno, 2009; Sung et al., 2011).

4.2.2 Material and Methods

4.2.2.1 Visual encounter survey

We actively searched for reptiles and amphibians by conducting visual encounter surveys (VES). We conducted VES daily, at both daytime (morning, in between 8:00 to 11:00; or late afternoon in between 16:00 to 18:30) and nighttime (in between 18:30 to 23:00). During 21 consecutive days of sampling, we conducted 31 VES, cumulating a total of 81 hours of active search (mean VES daytime duration of 1h48min ± 32min; mean VES nighttime duration of 2h59min ± 53min). We surveyed PPWS for 5 consecutive days (21/11/2023 to 25/11/2023), where we led 3 daytime VES and 4 nighttime VES, for a total of 18 cumulated hours of surveying. We surveyed SBWS for 16 consecutive days (26/11/2023 to 12/12/2023), where we led 7 daytime VES and 17 nighttime VES, for a total of 63 cumulated hours of surveying. In both areas, we conducted VES in locations reachable from campsites, and targeted all possible habitat types (i.e. open dry forest, dense closed forest, rocky areas, streams, agricultural fields) in order to detect a broad range of species. Target areas were predetermined in collaboration with WWF team, Wildlife Sanctuaries rangers, and local community members. The identification of habitat types and focal habitats for the surveys was based on the interpretation of satellite imagery, previous records within the areas, and local knowledge transmitted by local partners and community-members during fieldwork.

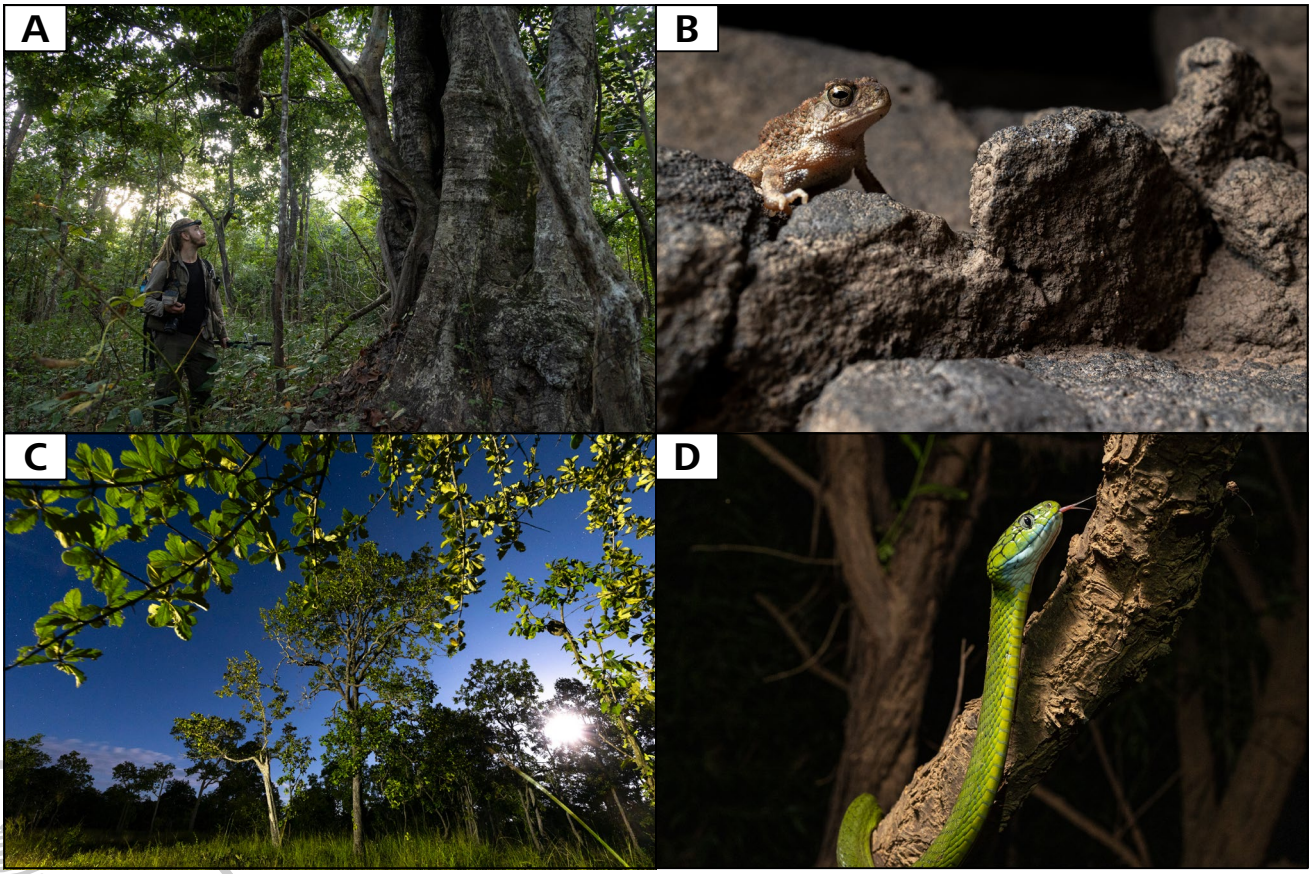

Figure 14. A. VES in an open dry forest, **B.** adult big-eared toad (*Ingerophrynus macrotis*) in its microhabitat, rocks from a stream bed, **C.** open dry forest surveyed at night, and **D.** an adult green cat snake (*Boiga cyanea*) in its microhabitat, a riparian forest along the Mekong River. (Photos by Michiel van Noppen)

During VES, survey effort was extended on specific microhabitats within the focal habitats (**Figure 14**). Typical microhabitats surveyed included rocky areas, large trees with cavities, streams, termite mounds, forest edge and clearings.

During VES, each observed individual was photographed, and coordinates were noted (using a Garmin GPSMAP 64s v1.1). For common species with large numbers of individuals at a single location, only notes and coordinates were taken. A subset of the observed individuals were captured and placed in individual bags (cotton bag for reptiles, plastic bag with moist substrate for terrestrial-phase amphibians) to be further collected (see collection of voucher specimens). We opportunistically recorded vocalizations of anuran amphibians using a digital recorder (zoom H1n).

4.2.2.2 Drift fence with pitfall trap

We set up one array of drift fence with pitfall traps (DFPT) at Camp 1, Camp 2, Camp 3 and Camp 4 in order to detect species potentially overlooked by VES, such as fossorial snakes and other leaf-litter species such as Scincidae (Sung et al., 2011). We deployed arrays in microhabitat favorable to target species in convenient emplacement near campsites. DFPT arrays were set up for 4 days at each camp.

A DFPT array consisted of a 30m linear transect (**Figure 15**). Along that transect, we sunk 5 plastic buckets (20L) into the ground with their rims below ground level (~ 5 cm). We placed shelters (e.g. small logs) in each bucket to prevent stress and overheating/desiccation of trapped animals, and foldable materials (e.g. leaf litter) to prevent drowning in case of flooding by rain. Drift fence consisted of a sheet of vertical plastic (approximately 50cm high) that run along the transect crossing the center of each bucket. We maintained the vertical plastic tensed by fixing it to sticks using serflex cable ties, and we buried a ~10cm lip of plastic sheeting under soil and leaf litter to prevent any gap in the drift fence at ground level.

Once deployed, DFPT arrays were checked 2 to 3 times each day. All trapped individuals were taken out of the buckets, and either released a few meters away from the array, or placed in individual bags to be further collected.

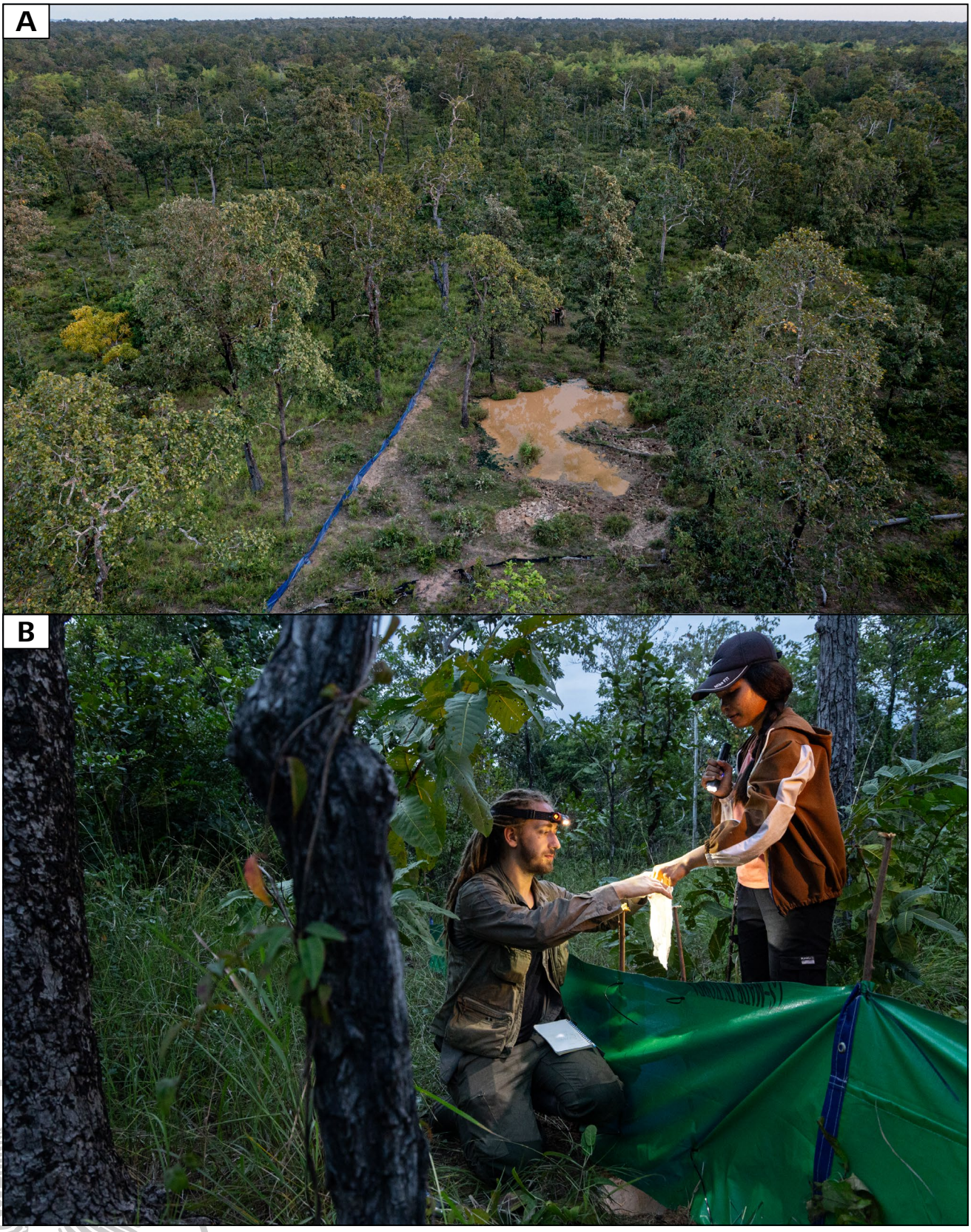

Figure 15. **A.** Aerial view from the DFPT array set up near Camp 4. **B.** Mathias Dezetter and Sao Sinuon removing a lizard from a bucket of the DFPT array set up near Camp 2. (Photos by Michiel van Noppen)

4.2.2.3 Collection of voucher specimens

A subset of individuals observed during VES and removed from pitfall traps were collected in order to archive physical voucher specimens of the species recorded within PPWS and SBWS. This will allow for further specimen examination and molecular analysis to consolidate identifications. Additional specimens were collected for genus with cryptic diversity and unresolved taxonomic issues (e.g. *Dixonius* sp.).

We measured all individuals using either calipers or measuring tape (snout vent length and total length), and weighted them using either an electronic balance or spring scales (PESOLA). For identification purposes, we photographed the coloration of each individual alive using a digital camera with a macro lens (dorsal, lateral and ventral sides). We took white and black-background pictures of most individuals to design educational and outreach materials (**Figure 16**). Parasitic mites were collected from snakes and lizards and stored in 96% ethanol fur further examination and identification.

After morphometry measurements and photography, individuals were euthanized through methods following ethical guidelines for reptiles and amphibians. Amphibians were anesthetized by applying 5% lidocaine prilocaine gel on ventral skin before being euthanized by intracardiac injection of 96% ethanol. Reptiles were appropriately restrained and euthanized by an intracardiac injection of 96% ethanol. Fixation was conducted by 96% injection of ethanol, and specimens were further transferred in 70% and 60% ethanol, for reptiles and amphibians, respectively.

4.2.2.4 Collaboration with local communities and capacity building

VES protocol was adapted to be participative and to include collaboration with Wildlife Sanctuaries rangers and local community members. At the beginning and end of each VES, we exchanged within the team about methodology, target habitat and species, general ecology of reptiles and amphibians and importance of biodiversity inventories for the management of the conservation areas. Rangers and community members were actively involved in the selection of survey areas and their expertise and knowledge of the areas and species allowed us to efficiently target areas of interest. They actively contributed to the search and capture of animals during surveys; following appropriate handling protocols that were previously demonstrated (**Figure 18**). Technical steps such as coordinate acquisition and track recording using GPS were repeated several times to train rangers and community members. Additional time during surveys was dedicated to highlight interesting findings and microhabitats of interest. Volunteering rangers and community members assisted in data acquisition on collected individuals at campsites. Sao Sinuon (Master student from the Center for Biodiversity Conservation program at the Royal University of Phnom Penh) was mentored through the fieldwork and was trained on all the survey methodologies.

Figure 16. White-background pictures of an adult long-tailed grass lizard (*Takydromus sexlineatus*) from SBWS: **A.** lateral side, **B.** dorsal side and **C.** ventral side. (Photos by Michiel van Noppen)

Figure 17. Data acquisition at Camp 3 of an adult balloon frog (*Glyphoglossus molossus*): **A.** measurement of snout-vent length using a caliper, **B.** Measurement of body mass using an electronic balance, and **C.** view on the set-up for data acquisition and collection of voucher specimens. (Photos by Michiel van Noppen)

4.2.2.5 Opportunistic data collection

Other researchers from the team opportunistically recorded sightings of reptiles and amphibians (photographic voucher and coordinates) during their own surveys. When possible, lizards and frogs were captured and brought to campsites in individual bags for further identification and eventual collection.

During VES targeting reptiles and amphibians, we actively collected beetles (Carabidae, Cerambycidae, Chrysomelidae, Tenebrionidae and Curculionoidea) and ants (*Leptogenys* sp.) and handled voucher specimens to Jonas Merckx and Matthew Hamer, respectively. When DFPT were dismantled, the buckets were handed to Jonas Merckx and Matthew Hamer in order to collect arthropods from the substrate. Shrews trapped in the DFPT or observed during VES were collected. During VES, we opportunistically recorded pictures and coordinates from observations of other taxa (mammals, birds, arachnids, myriapods, crustaceans, plants). Mammals and bird sightings were shared with other researchers from the team. Sightings from taxa that were not targeted during this expedition were publicly posted online to INaturalist.

Figure 18. Rangers from PPWS actively participating in a VES in an open grass land habitat near camp1. (Photo by Michiel van Noppen)

4.2.3 Preliminary results

4.2.3.1 Species list

We tentatively recorded 36 species of reptiles and 24 species of amphibians (**Table 3**). These comprise 22 species of frog, 2 species of toad, 17 species of lizard and 19 species of snake. We did not record any species of turtle. Our identifications remain preliminary and are based on observations made during fieldwork. Examination of pictures, collected voucher specimens, and molecular analysis will be conducted to consolidate identifications.

Table 3. Preliminary list of reptiles and amphibians species recorded at each sampling location (C1: Camp1; C2: Camp2; C3: Camp3; C4: Camp4; C5: Camp5). The letter "X" indicate that the species has been recorded in the given location. "Y" indicates that voucher specimens were collected for the given species, while "N" indicates that no voucher specimen was collected (record based on observation or photographic voucher).

			PPWS	SWBS				
n°	Class | Family	Species	C1	C2	C3	C4	C5	Voucher specimens
	Amphibia							
1	Bufonidae	*Duttaphrynus melanostictus*	x	x	x	-	-	Y
2	Bufonidae	*Ingerophrynus macrotis*	-	x	x	x	x	Y
3	Dicroglossidae	*Fejervarya limnocharis*	x	x	x	x	x	Y
4	Dicroglossidae	*Occidozyga lima*	x	x	x	x	x	Y
5	Dicroglossidae	*Occidozyga martensii*	x	x	x	x	x	Y
6	Microhylidae	*Glyphoglossus guttulatus*	-	x	x	x	x	Y
7	Microhylidae	*Glyphoglossus molossus*	-	-	x	-	x	Y
8	Microhylidae	*Kalophrynus interlineatus*	x	-	-	-	-	Y
9	Microhylidae	*Kaloula mediolineata*	-	x	-	-	-	Y
10	Microhylidae	*Kaloula pulchra*	-	x	-	x	-	Y
11	Microhylidae	*Microhyla butleri*	x	-	-	-	-	Y
12	Microhylidae	*Microhyla heymonsi*	x	-	-	-	-	Y
13	Microhylidae	*Microhyla malcolmi*	-	x	-	x	-	Y
14	Microhylidae	*Microhyla mukhlesuri*	x	x	x	x	-	Y
15	Microhylidae	*Microhyla pulchra*	x	x	x	x	-	Y
16	Microhylidae	*Microhyla* sp.	x	x	x	-	x	Y
17	Microhylidae	*Micryletta erythropoda*	x	x	x	x	-	Y
18	Rhacophoridae	*Chirixalus nongkhorensis*	-	-	x	-	-	Y
19	Rhacophoridae	*Polypedates* sp.	x	x	x	x	x	Y
20	Ranidae	*Hoplobatrachus rugulosus*	x	x	x	x	x	Y
21	Ranidae	*Hylarana erythraea*	-	-	-	x	-	Y
22	Ranidae	*Hylarana macrodactyla*	x	-	-	-	-	Y
23	Ranidae	*Hylarana* sp.	x	x	x	x	-	Y
24	Ranidae	*Sylvirana* sp.	-	x	-	-	x	Y

n°	Class | Family	Species	PPWS C1	SWBS C2	SWBS C3	SWBS C4	SWBS C5	Voucher specimens
	Reptilia							
25	Agamidae	*Calotes* sp.	-	-	-	x	x	Y
26	Agamidae	*Calotes versicolor*	x	x	x	-	x	Y
27	Agamidae	*Leiolepis* sp.	-	-	-	-	x	Y
28	Agamidae	*Physignathus cocincinus*	-	-	-	x	-	Y
29	Colubridae	*Ahuatella* sp.	x	-	-	-	-	Y
30	Colubridae	*Boiga* sp.	-	-	x	-	-	Y
31	Colubridae	*Boiga cyanea*	-	-	-	x	x	N
32	Colubridae	*Chrysopelea ornata*	x	-	-	-	-	Y
33	Colubridae	*Dendrelaphis pictus*	x	-	-	-	-	Y
34	Colubridae	*Fowlea* cf. *piscator*	x	-	-	-	-	Y
35	Colubridae	*Lycodon* sp.	-	x	x	-	x	Y
36	Colubridae	*Oligodon* sp.	x	-	x	x	-	Y
37	Colubridae	*Oligodon fasciolatus*	-	-	-	x	-	N
38	Colubridae	*Ptyas mucosa*	-	x	-	-	-	N
39	Elapidae	*Bungarus fasciatus*	x	-	-	-	-	N
40	Elapidae	*Naja* cf. *siamensis*	-	x	x	-	-	N
41	Gekkonidae	*Dixonius* sp.	x	x	x	x	x	Y
42	Gekkonidae	*Gehyra* sp.	-	-	x	-	-	Y
43	Gekkonidae	*Gekko gecko*	x	x	x	x	x	Y
44	Gekkonidae	*Gekko* sp.	-	x	-	-	-	Y
45	Gekkonidae	*Hemidactylus frenatus*	x	x	x	x	x	Y
46	Gekkonidae	*Hemidactylus platyurus*	x	x	x	x	x	Y
47	Homalopsdiae	*Homalopsis* sp.	-	-	-	x	x	Y
48	Homalopsdiae	*Hypsiscopus plumbea*	x	x	x	-	-	Y
49	Lacertidae	*Takydromus sexlineatus*	-	x	-	x	-	Y
50	Lamprophiidae	*Psammodynastes pulverulentus*	-	-	-	x	-	Y
51	Pythonidae	*Malayopython reticulatus*	-	-	-	-	x	N
52	Scincidae	*Eutropis* cf. *macularia*	x	x	x	x	x	Y
53	Scincidae	*Eutropis* cf. *multifasciata*	x	-	-	-	x	Y
54	Scincidae	*Eutropis* sp.	-	x	-	x	-	Y
55	Scincidae	*Lipinia* sp.	-	-	-	x	x	Y
56	Scincidae	*Lygosoma* cf. *bowringii*	x	-	x	x	x	Y
57	Scincidae	*Lygosoma* cf. *siamensis*	-	x	x	x	-	Y
58	Typhlopidae	*Indotyphlops* sp.	-	-	-	x	-	Y
59	Viperidae	*Calloselasma rhodostoma*	-	x	x	x	x	N
60	Xenopeltidae	*Xenopeltis unicolor*	-	-	x	x	-	Y

We recorded 4 species of reptile and 2 species of amphibian from DFPT arrays (**Table 4**). As targeted, most individuals trapped were Scincidae and Geckonidae. While all these species were also recorded during VES, DFPT allowed for the detection of a larger number of individuals from these species.

Table 4. Summary of species trapped in DFPT arrays at each camp location (Camp1 to Camp4). The letter "X" indicates that the species has been recorded in the given location.

			PPWS	SWBS		
n°	Class | Family	Species	C1	C2	C3	C4
	Amphibia					
1	Dicroglossidae	*Fejervarya limnocharis*	x	x	x	x
2	Microhylidae	*Microhyla pulchra*	x	x	-	-
	Reptilia					
3	Gekkonidae	*Dixonius* sp.	-	x	-	-
5	Scincidae	*Eutropis* cf. *macularia*	x	x	x	-
6	Scincidae	*Lygosoma* cf. *bowringii*	-	-	x	-
7	Scincidae	*Lygosoma* cf. *siamensis*	-	x	x	-

4.2.3.2 New records for PPWS and SBWS

We recorded nine species that were not directly observed and recorded during previous surveys within the area (Jocque et al., 2018, Bezuijen et al., 2009). These comprise five species of snakes, three species of lizards and 1 species of frog (**Table 5**).

Table 5. Summary of species recorded for the first time in PPWS and SBWS. The letter "X" indicates that the species has been recorded in the given location.

n°	Class | Family	Species	PPWS	SWBS
	Amphibia			
1	Microhylidae	*Kaloula mediolineata*	-	x
	Reptilia			
2	Agamidae	*Leiolepis* sp.	-	x
3	Colubridae	*Ahuatella* sp.	x	-
4	Colubridae	*Boiga* sp.	-	x
5	Gekkonidae	*Gehyra* sp.	-	x
6	Gekkonidae	*Gekko* sp.	-	x
7	Elapidae	*Bungarus fasciatus*	x	-
8	Elapidae	*Naja* cf. *siamensis*	-	x
9	Xenopeltidae	*Xenopeltis unicolor*	-	x

4.2.3.3 Species of conservation concern

We recorded 1 species categorized as Near Threatened (NT) by the IUCN, 2 threatened species categorized as Vulnerable (VU), and 1 species categorized as data deficient (DD). All other species are categorized as Least Concern (LC). Some of the identified genera comprise threatened species (e.g. *Sylvirana* spp.), but are not yet reported here because identification is still pending.

Chinese water dragon (*Physignathus cocincinus*) Vulnerable

We observed 3 individuals during nighttime, 1 sub adult and 2 adults (**Figure 19C**). All individuals were found in dense forest riparian to the Mekong River, and were sleeping on tree and bushes branches. Chinese water dragon populations are declining because of habitat loss, habitat degradation (i.e. selective logging) and overhunting. The forests riparian to the Mekong River, notably on Mekong islands, are of high priority for the conservation of this threatened species.

Indochinese spitting cobra (*Naja cf. siamensis*) Vulnerable

We observed 3 adult individuals and photographed 2 (**Figure 19A**). 2 were observed actively foraging during daytime in stream beds with bamboo riverine forest, 1 was active at night in open dry forest near a termite mount. Several shed skins were also found around termite mounds.

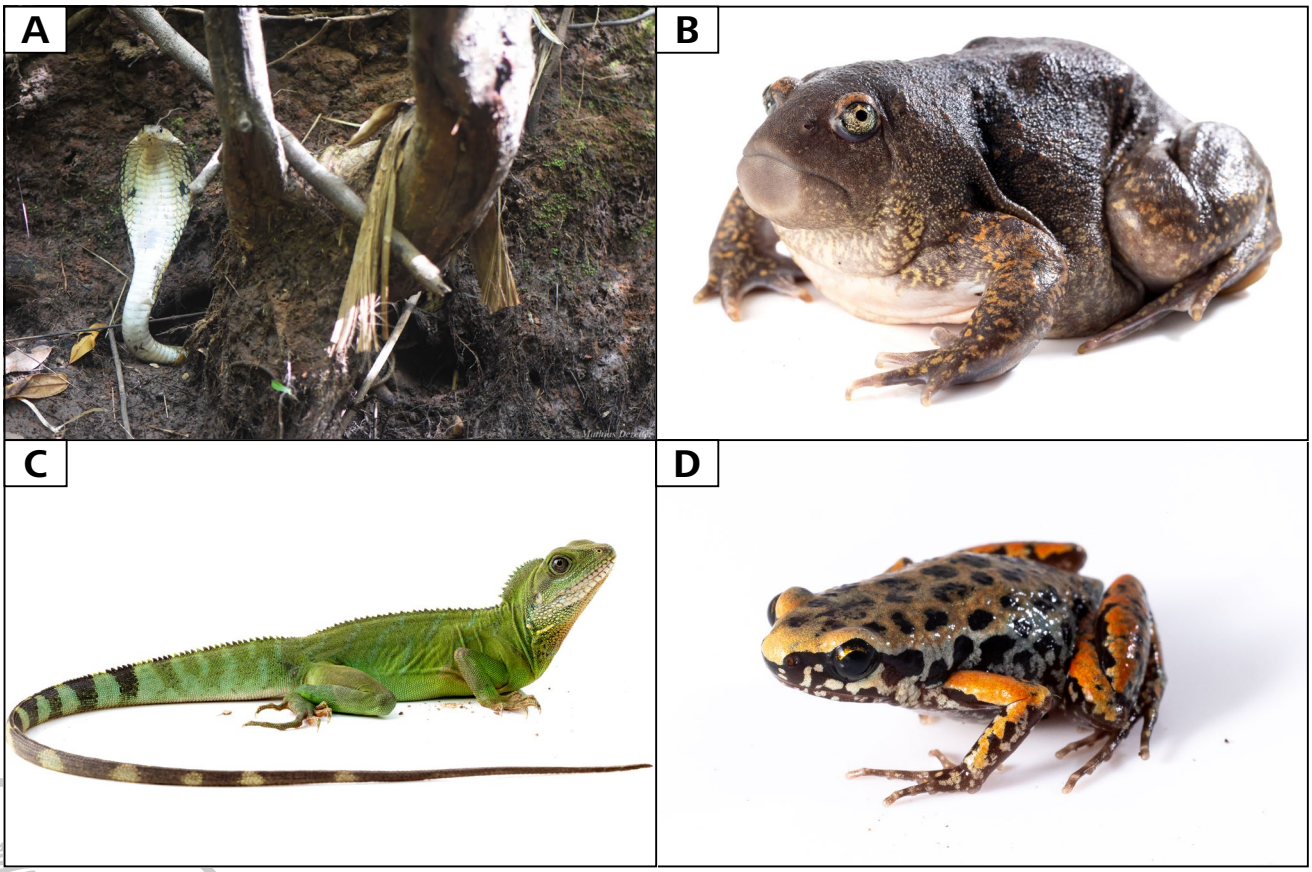

Figure 19. A. Adult Indochinese spitting cobra (*Naja cf. siamensis*) observed in a stream bed in SBWS, and white-background pictures of the lateral sides of **B.** an adult blunt-headed burrowing frog (*Glyphoglossus molossus*), **C.** an adult Chinese water dragon (*Physignathus cocincinus*), and of **D.** an adult mada paddy frog (*Micryletta erythropoda*), found in SBWS. (Photos by (A) Mathias Dezetter and (B,C,D) Michiel van Noppen)

Blunt-headed burrowing frog (*Glyphoglossus molossus*) Near Threatened

We observed 2 adult individuals (**Figure 19B**) during nighttime, at the surface of sand beaches near streams. Community members reported knowledge about explosive breeding activity after the first rains at the start of the wet season, usually in March. It was also mentioned that this species is commonly hunted for self-consumption by local community members during these events.

Mada paddy frog (*Micryletta erythropoda*) Data Deficient

We observed 8 adult individuals during nighttime, in closed dense forests, in bamboo riverine forests and in stream beds (**Figure 19D**).

4.2.3.4 Notable records

We observed a high density of paddy field frogs (*Fejervarya limnocharis*, **Figure 20A**) in all habitat types, including degraded forest, agricultural crops, and heavily grazed pastures. Hundreds of individuals were found, including calling males, in agricultural ponds within cows and water buffaloes' pasture. Local community members commonly hunt this species for self-consumption (**Figure 20B**).

Chinese edible frogs (*Hoplobatrachus rugulosus*) were also common and mostly observed near streams and deeper water bodies (**Figure 20C**). This species was also commonly hunted by local team members for consumption.

4.2.3.5 Collaboration with local partners, capacity building and mentoring

A total of 32 local community members and rangers contributed to at least 1 VES. Between 2 and 8 persons participated in each VES (**Figure 21**). During these participative VES, local partners were trained in VES methodology, identification of some species of reptiles and amphibians, and data and coordinates acquisition in the field. Between 4 and 6 persons contributed to the set-up of DFPT arrays at camp 1 to 4, and were trained on how to set up arrays and replicate this methodology.

In addition to local partners contributing and learning fieldwork methodology during VES, other community members opportunistically engaged with the team during the photography and measurements of individuals at campsites. Outreach and interactive exchanges about our collaborative work and research were thus opportunistically led at campsites and allowed mutual learning between researchers and local community members. WWF team members and rangers from the Wildlife Sanctuaries were briefly trained to replicate technical tasks under guidance (e.g. handling non venomous snakes, **Figure 22A,B**).

Sao Sinuon (Master student from the Center for Biodiversity Conservation program at the Royal University of Phnom Penh) was mentored through the entire period of fieldwork and contributed to all steps of the protocol. She progressively learned VES and DFPT methodologies, as well as morphometry measurement and collection of voucher specimens, which she was able to fully conduct by the end of fieldwork (**Figure 22C,D**).

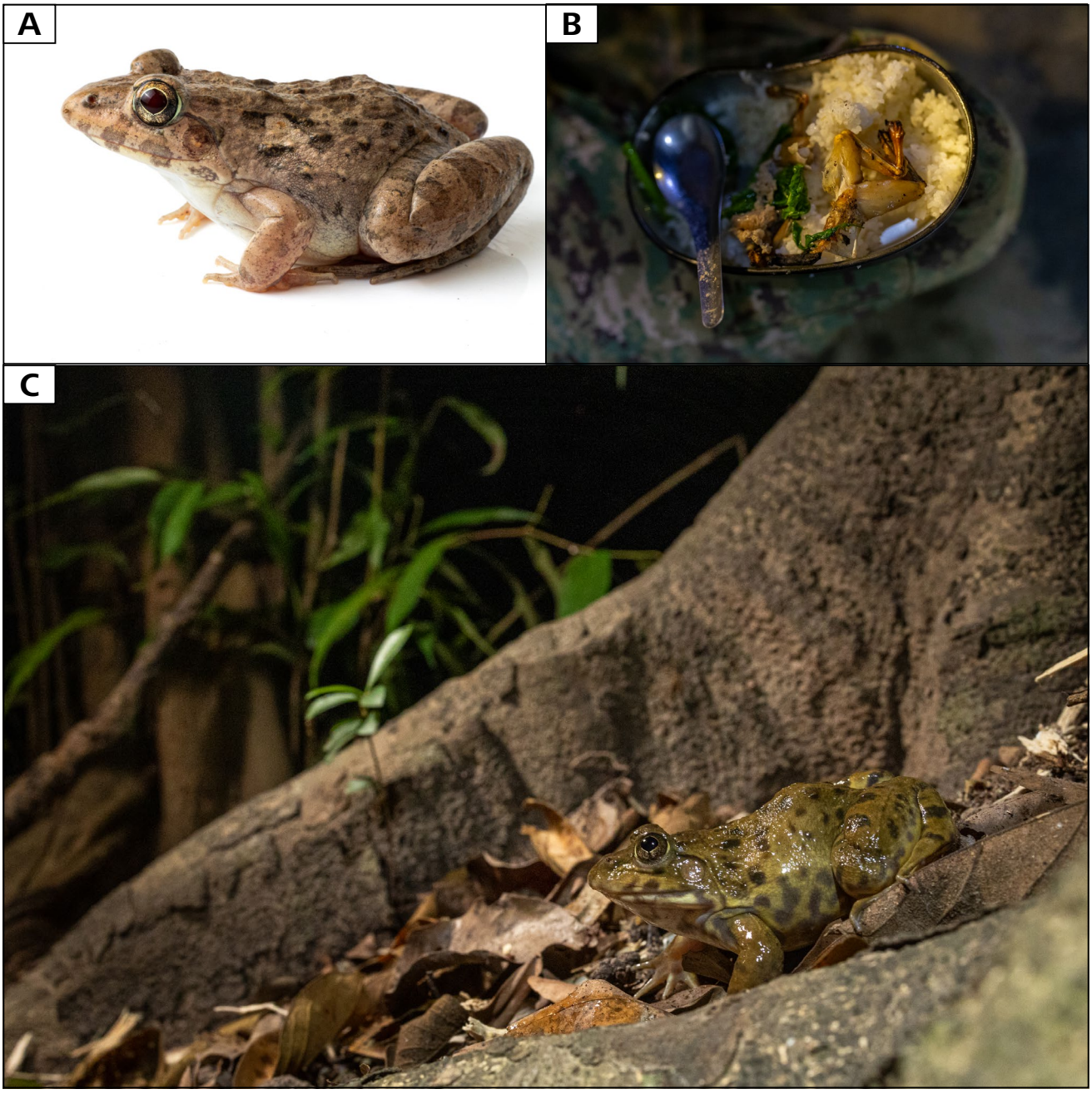

Figure 20. A. White-background picture of the lateral side of an adult paddy field frog (*Fejervarya limnocharis*), **B.** fried paddy field frog (*Fejervarya limnocharis*) cooked by a local community member, and **C.** an adult Chinese edible frog (*Hoplobatrachus rugulosus*) in its natural habitat near a stream in SBWS. (Photos by Michiel van Noppen)

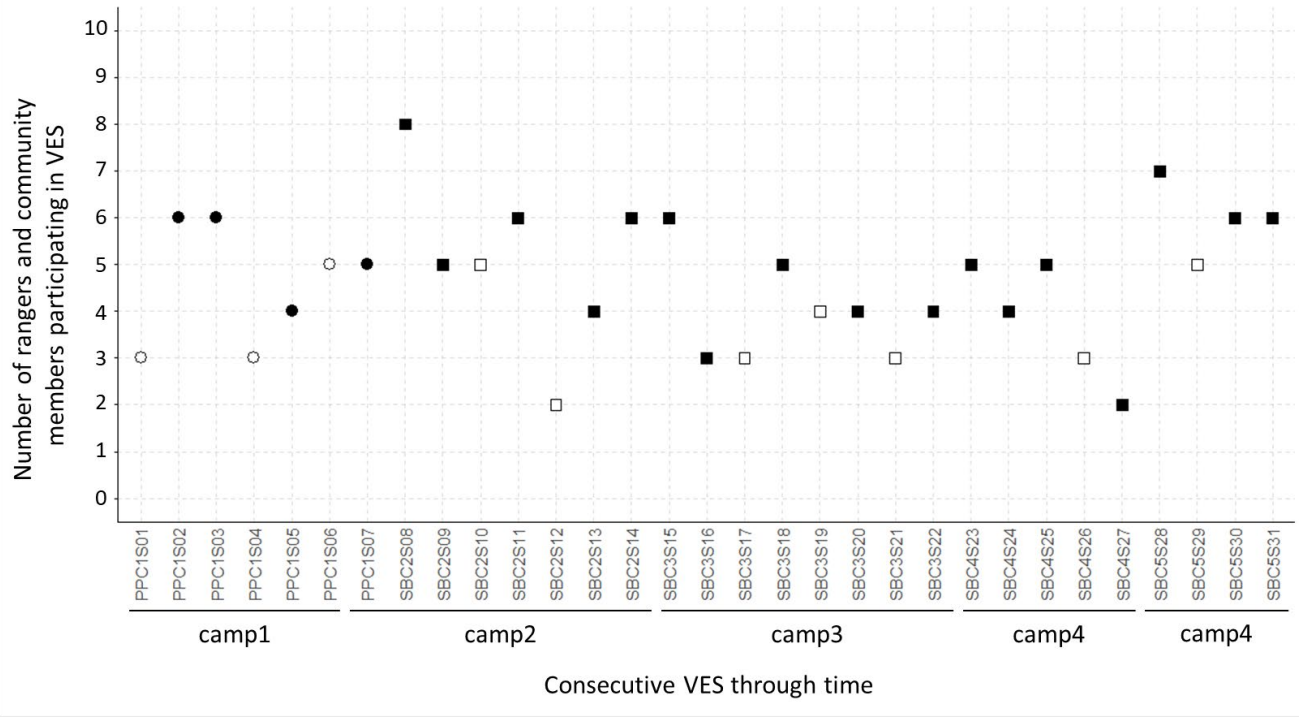

Figure 21. Number of Wildlife Sanctuary rangers and local community members participating in VES, through consecutive VES during the expedition. Points for values during VES at PPWS are shaped as circles, and are shaped as squares for values during VES at SBWS. Points are filled (black) for nighttime VES and empty (white) for daytime VES.

Figure 22. A-B. WWF team and rangers being trained on how to tube a non-venomous snake (*Xenopeltis unicolor*); **C.** Sao Sinuon taking notes during a VES and **D.** Tubing a non-venomous wolf snake (*Lycodon* sp.). (Photos by Michiel van Noppen)

4.2.3.6 Opportunistic records

On December 14th in Kratie, we recorded 2 Critically Endangered adult elongated turtles (*Indotestudo elongata*, **Figure 23**) traded at the Samaki Market (ផ្សារសាមគ្គី).

We opportunistically collected 3 shrews, multiple samples of ants (*Leptogenys* sp.), beetles, and parasitic mites from *Hemidactylus* sp. and *Eutropis* sp.

Sorting and identification of opportunistic observations of non-targeted taxa (plants, crustaceans, myriapods, etc.) is still pending, 93 records of at least 70 species have already been publicly shared using iNaturalist (www.inaturalist.org).

Figure 23. Two Critically Endangered adult elongated turtles (*Indotestudo elongata*) for sale at Kratie's Samaki market. (Photo by Michiel van Noppen)

4.2.4 Discussion

Consolidation of observed species identification is ongoing. Results and interpretations are preliminary and subject to change. These will be included in future versions of this report or as published journal articles. Here, we provide general preliminary appreciations of our results based on fieldwork observations.

Most of the species that we observed are typical for anthropogenically modified low-land floodplains. Among the species that were more frequently observed, and with higher density, are some common species with large distribution such as tree frogs (*Pelopedates* sp.), paddy field frogs (*Fejervarya limnocharis*), beautiful narrow-mouthed frogs (*Microhyla pulchra*), bronze mabuyas (*Eutropis cf. macularia*), and rice paddy snakes (*Hypsiscopus plumbea*). While most of these common species were observed in most sites and habitat types, some other species were only observed in specific habitats. Burrowing frogs (*Kaloula pulchra*, *Kaloula mediolineata*, *Glyphoglossus molossus*, *Glyphoglossus guttulatus*) were only found in open dry forest and sandy streams and riverbanks, and Ma Da paddy frogs (*Micryletta erythropoda*) were only observed in riparian closed forests along streams and rivers. Managers should however pay attention to the conservation of these widespread and common species. It is likely that the conserved forests and grasslands from PPWS and SBWS constitute important refuges with high densities of individuals and high species diversity compared to the fragmented and disturbed agricultural landscapes bordering the conservation areas. Our knowledge of long-term population trends, ecological traits and vulnerability to habitat change and climate change remains deficient, even for these widespread species in South-East Asia (Bickford et al., 2010; Rowley et al., 2010).

We recorded 9 additional species for PPWS and SBWS, for 5 of which identification is pending. Among the newly recorded species for which identification is reliable, one is of conservation concern (*Naja cf. siamensis*, VU), and 3 are more common species whose presence could be expected in the area, but were not yet recorded (*Kaloula mediolineata*, *Xenopeltis unicolor*, *Bungarus fasciatus*).

Despite numerous habitats highly favourable to turtles and tortoises (e.g. open forest with grass, small rocky streams, and sand banks), we did not observe a single turtle during the 21 consecutive days of surveys. Local community members involved in the VES helped us to target specific habitats where turtles were observed previously, however they reported that they had not seen any individuals themselves in the past 3 years. Overhunting for commercial trade was also mentioned by community members and Wildlife Sanctuaries rangers as occurring in the area and being potentially responsible for the decline of turtle species. These indirect reports and the absence of turtle detections during our survey suggest that previously recorded turtle populations might be locally near-extinct or extinct. Additional surveys effort should target these taxa to locate remaining populations and inform appropriate conservation measures and strategies to mitigate hunting pressures.

We observed several species of burrowing frogs (*Kaloula pulchra*, LC; *Kaloula mediolineata*, LC; *Glyphoglossus molossus*, NT; *Glyphoglossus guttulatus*, LC). They are terrestrial frogs that cope with seasonal variation in humidity by burrowing into the soil to find sufficient moisture (Bickford et al., 2010; Srifa and Lauprasert, 2023). They are explosive breeders which actively reproduce during the wet season and depend on the availability of ephemeral water bodies (Altig and Rowley, 2014; Vassilieva, 2021). Local community members reported that these frogs were commonly hunted for

consumption, especially during the first rains of March, and were opportunistically collected during the rest of the year. *Glyphoglossus molossus* and *Kaloula mediolineata* have been reported to be potentially threatened by overhunting throughout their distribution range (Boontham and Naritoom, 2015; Nonsrirach and Lauprasert, 2019; Srifa and Lauprasert, 2023), and *Glyphoglossus molossus* is categorized as VU for this reason. Whether hunting pressures in PPWS and SBWS are sustainable or not for these species is unknown and should be investigated. Similarly, community members were reported to opportunistically collect large snakes for consumption, especially as bycatch from fish traps. Butterfly lizards (*Leiolepis* spp.) are often excavated from their burrows.

We observed several Indochinese spitting cobras (*Naja siamensis*, VU), a species that thrives well in all types of open dry forest habitats. Multiple shed skins were found near termite mounds. This species has experienced high rates of decline throughout its range and is threatened by habitat loss and overharvesting (Stuart et al., 2012). In PPWS and SBWS, anecdotal reports from rangers and community members during our surveys suggest that the species is not hunted in the area. According to them, residents from the local communities are usually well aware of recognition criteria for this species, as well as for other venomous species that are not usually hunted. We frequently observed numerous Malayan pit vipers (*Calloselasma rhodostoma*, LC, **Figure 24**) and reported an observation of banded krait (*Bungarus fasciatus*, LC), two other medically important snakes (Chanhome et al., 2011; Hia et al., 2020; Viravan et al., 1992; Wongtongkam et al., 2005). A more in-depth study to assess snakebite exposure and potential human-snake conflict within the Wildlife Sanctuaries would be valuable and provide a strong addition to appropriate planning of management and conservation measures, as well as to develop mitigation strategies when needed.

Figure 24. Malayan pit vipers (*Calloselasma rhodostoma*) observed in open dry forests during VES near Camp 2 (left) and near Camp 4 (right). (Pictures by Mathias Dezetter)

Patches of closed forest bordering streams and the Mekong River (**Figure 25**) are of high conservation priority for reptiles and amphibians in PPWS and SBWS. Some species were only observed in these habitats (e.g. *Micryletta erythropoda*, *Boiga cyanea*, *Indotyphlops* sp., *Physignathus cocincinus*). Breeding activity of numerous frog species (e.g. *Sylvirana* spp., *Microhyla berdmorei*, *Occidozyga* spp., *Hylarana* spp.) in the remaining water bodies from partially dried streams within these forests were observed. In forest patches with large trees, we observed a higher diversity of reptile and amphibian species compared to patches were selective logging occurred. Some of the open

dry forest surveyed seemed degraded and overgrazed by cows and water buffaloes, and lacked undergrowth and grass vegetation layers, leading to dry bare ground areas where fewer reptiles and amphibians were recorded. The rocky hills near camp 5 comprise large patches of dense forest that are likely to be favorable habitats to different species than in the rest of SBWS. Geckonidae such as *Cyrtodactylus* sp. could be present in these rocky forest habitats. Parts of these forests are locally considered as sacred and community-forest and we were not able to survey these areas yet. Local community leaders who contributed to our work seem enthusiast about collaborating with managers to engage in biodiversity inventories, but further discussion is needed to define the partnership and discuss authorizations to enter these forests. Recent agricultural expansions and selective logging is currently occurring in these forests.

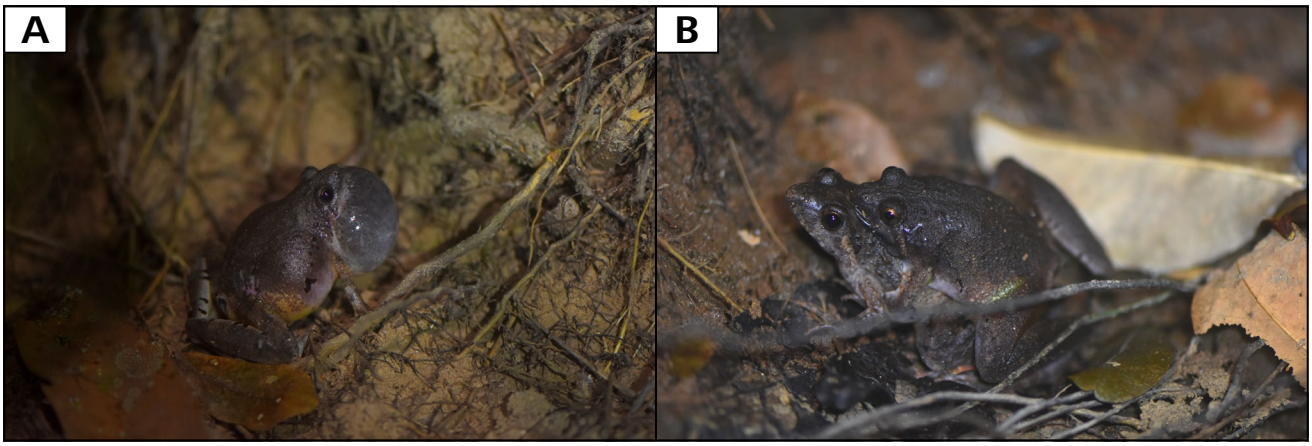

Figure 25. A. Adult male *Microhyla malcolmi* calling, and **B.** amplexus of *Microhyla malcolmi* observed in a patch of closed forest bordering a stream.

Collaboration and partnership with local community members improved the outcome of our survey facilitating the selection of target habitat of interest, exchanging information and knowledge, and mutually learning from our different perspectives. We did not conduct any standardized surveys on community member knowledge, perception or appreciation of reptiles and amphibians. However, through opportunistic exchanges, we witnessed that a great importance was given by community members to the preservation of consumption of forest resources, including the hunt of common and widespread species of frogs such as *Fejervarya limnocharis* and *Hoplobatrachus rugulosus*. The potential for sustainable hunting of frogs to drive the communities' willingness to conserve amphibians and their habitat should be considered by managers to foster equitable conservation strategies and partnerships with local communities (Singh et al., 2018).

Based on our experiences in the field and collaboration with local partners and community members we have a couple of suggestions that could be considered to increase awareness about amphibian and reptile conservation in the area. First, we recommend designing and using outreach materials to share the results of the inventories through outreach and capacity-building activities with community members. This could promote reptiles and amphibians conservation, foster participation and implication of local communities and give tools to build up projects that could generate local incomes (e.g. ecotourism, collaborations with local researchers and students) (Chen et al., 2019; Şekercioğlu, 2012). The white and black-background pictures that we took during the survey could

be used to design guides, posters (**Figure 26**) and other materials about local species. These materials should be translated in all the languages spoken within the communities from PPWS and SBWS.

Second, we suggest organizing exchanges and discussions with community members to adjust further research and conservation actions to their needs and to incorporate their questions and knowledge in conservation and ecology research within the Wildlife Sanctuaries (Ainsworth et al., 2020; Brook and McLachlan, 2008; Görg et al., 2014; Loch and Riechers, 2021). Fostering collaborations with local researchers and Universities, such as the Center for Biodiversity Conservation program at the Royal University of Phnom Penh, would facilitate the long-term monitoring of reptiles and amphibians diversity and the development of ecology and taxonomy research within PPWS and SBWS.

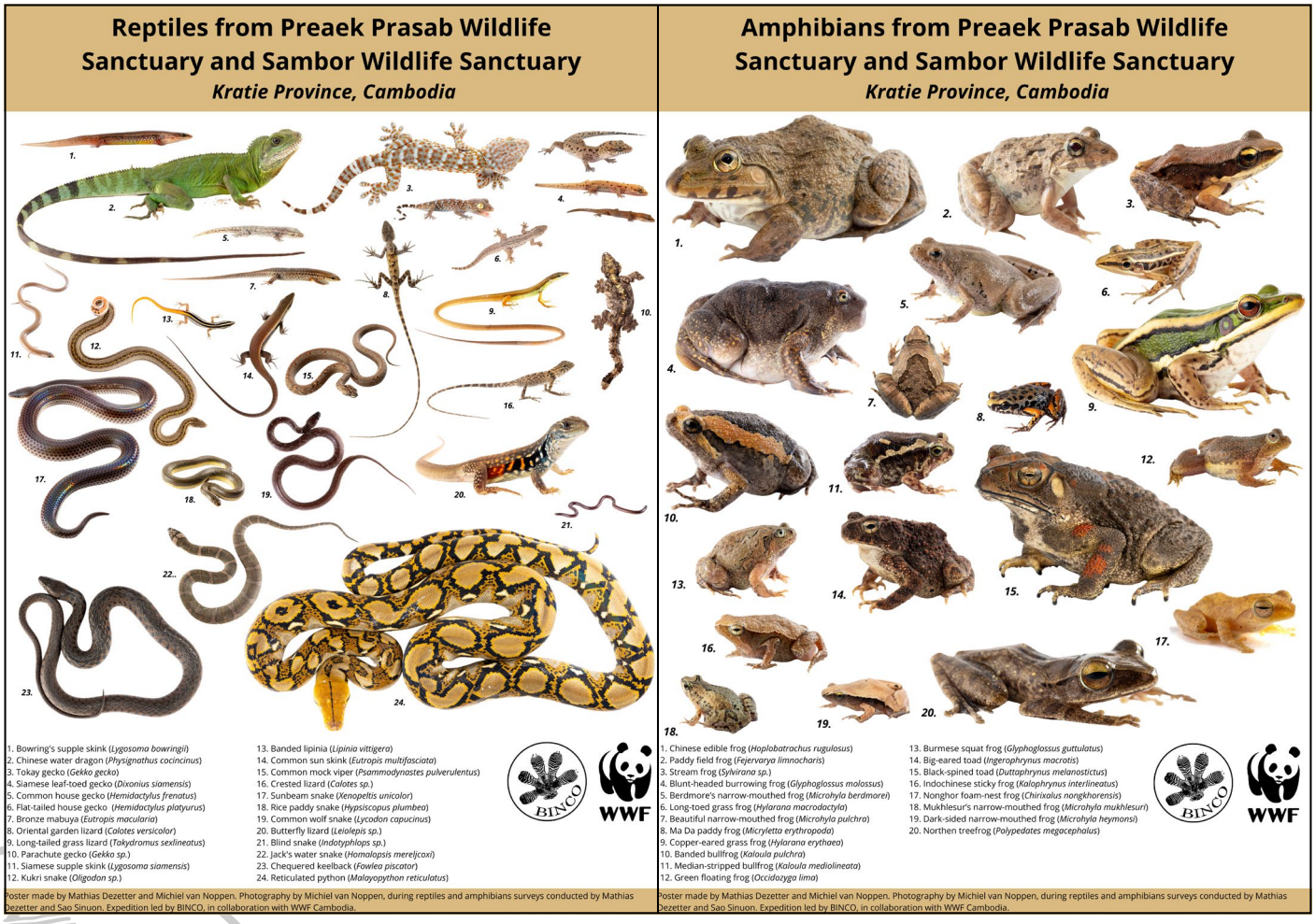

Figure 26. Example of a first draft of outreach materials that could be designed in order to raise awareness about reptiles and amphibians from PPWS and SBWS and to vulgarize inventories results to collaborators from local communities. These are two A0 posters presenting white-background pictures from a subset of reptiles and amphibians observed during our survey. (Conception by Mathias Dezetter and Michiel van Noppen, Pictures by Michiel van Noppen)

Recommendation for zoning and management

Here, we provide general recommendations for zoning and management of the Wildlife Sanctuaries, based on the preliminary identification of species and the currently available data for reptiles and amphibians.

Within both PPWS and SBWS, we identified isolated patches of dense and closed forests within the landscape of mostly open dry forests (see examples in **Figure 27**). These patches offer heterogeneous and complex micro-habitats as well as wetter conditions, small ponds, and streams. We recorded the highest reptiles and amphibian diversity within these ecosystems, and observed breeding activities of several amphibian species (e.g. *Sylvirana* spp., *Microhyla malcolmi*, *Occidozyga* spp., *Hylarana* spp., see **Figure 25**). These habitats are of high conservation value for reptiles and amphibians within the Wildlife Sanctuaries, but also seemed to be already impacted and partially degraded by human activities. We observed recently logged trees, signs of overgrazing, and pond modification by cows and buffalo, which could negatively impact the persistence of reptiles and amphibians populations in these habitats. We recommend conserving these habitats and to implement management measures fostering sustainable harvest of non-timber forest products instead of logging; and to evaluate the potential effects of these activities on reptiles and amphibians.

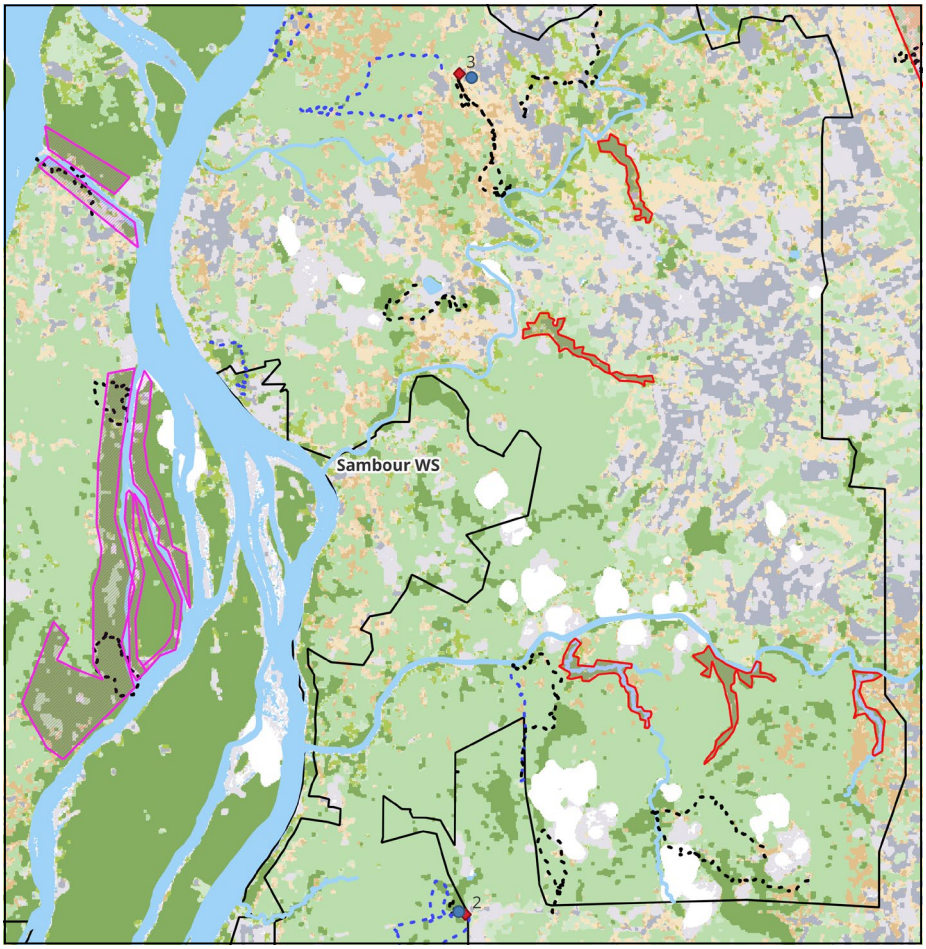

Figure 27. Map indicating examples of evergreen forest patches of high conservation priority in Sambour WS. Red diamonds indicate camp locations. Black line indicates SBWS boundary. Daytime and nighttime VES are represented by blue and black dotted lines, respectively.

Patches of dense closed forest riparian to the Mekong River (see examples in **Figure 27**) also offer very diverse and complex habitats, and some species were mostly observed in these areas (e.g. *Boiga cyanea*, *Physignathus cocincinus*). Similar habitats within other Mekong Islands are likely to be of similar conservation priority, but were not surveyed. These riparian forests are essential to the conservation of the threatened Chinese water dragon (*Physignathus cocincinus*, VU). Similarly to inland closed forests, we witnessed signs of selective logging of large trees, which is likely to impact the conservation of reptiles and amphibians; we also recommend restricting extractive activities to the sustainable harvest of non-timber forest products.

The forest habitats riparian to small streams within dry forest habitats are of high conservation priority for reptiles and amphibians (see examples in **Figure 27**). We recorded a high diversity of species within these areas, several species of amphibians were found in higher densities in these habitats (e.g. *Sylvirana* spp., *Microhyla malcolmi*, *Occidozyga* spp., *Hylarana* spp.) where they reproduce. The two individuals of Blunt-headed burrowing frog (*Glyphoglossus molossus*, NT) that we observed were found in sandbanks in these habitats. Indochinese spitting cobras (*Naja siamensis*, VU) were also observed during the day using these habitats to forage. We recommend prioritizing the conservation of the riverine forest along small streams in both Wildlife Sanctuaries. Overall, open dry forest habitats within both Wildlife Sanctuaries offer important habitat for several common species (*Eutropis* spp, *Dixonius* spp.). Some areas were, however, overgrazed with reduced grass, and low vegetation cover, leading to homogenized micro-habitats, and dryer and warmer conditions. We observed fewer individuals and lower diversity in these degraded habitats. We further recommend implementing management measures to mitigate the detrimental effects of grazing in partnership with local communities.

The hilly forests near camp 5, east of the SBWS boundaries (**Figure 28**), constitute a unique habitat of very dense forest with rocky terrains, multiple caves, cliffs, and rocks. These areas are recognized by the local community as sacred and traditional forests and some rocks and caves are of high cultural significance and importance. We were only able to conduct preliminary scouting of the areas, because access to conduct proper inventories would require formal authorization from local communities and to build up a partnership and equitable collaboration. We suggest conducting participatory inventories together with local community members in order to properly assess the biodiversity within this area. The neighboring habitats that we were authorized to survey together with the description of forests by community members suggest very interesting habitat of high conservation value, which could be inhabited by unrecorded cryptic biodiversity, such as micro endemics geckos (*Cyrtodactylus* sp., *Cnemapis* sp.) and other cave adapted species. Local community members involved in our preliminary fieldwork also reported that recent human migrations in the area recently led to invasion of forest areas for crop production, selective logging, and hunting. The local extinction of big mammals such as the Asian elephant and tiger occurred a few decades ago according to community members. The formal recognition of these forests traditionally conserved by some local communities could allow the efficient conservation of these high priority habitats. Local community members should be actively involved in the zoning process, governance, and leadership of the conservation planning of these areas. Other forests within this rocky massif could also be of high conservation importance, and we recommend planning for further biodiversity inventories and community members' involvement in this broader area.

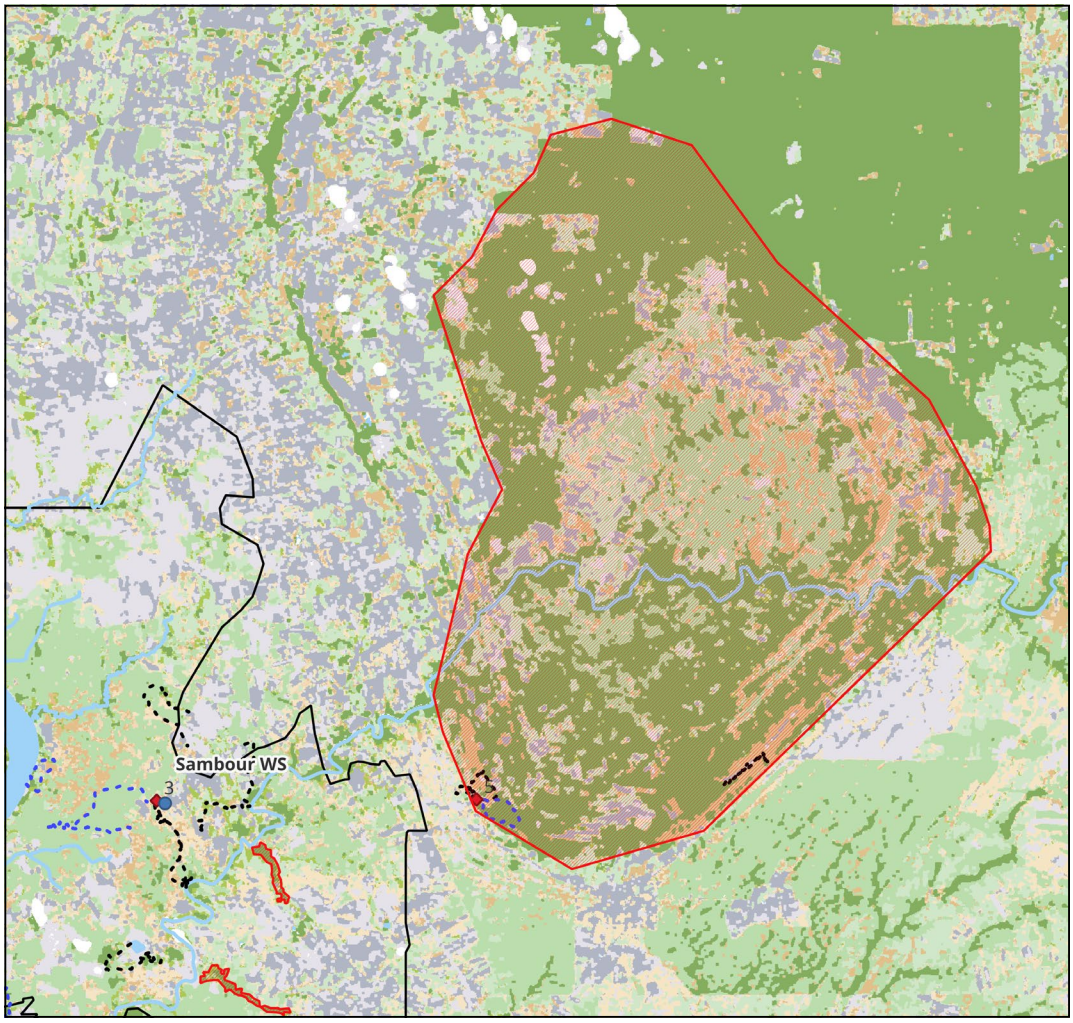

Figure 28. Map indicating the location of hilly evergreen forests with rocky terrain, indicated by the red dashed polygon, the broader area of interest, delimited by the red dotted line. Red diamonds indicate camp locations, and blue circles indicate drift fence pitfall trap array locations. Boundary of Sambour WS is indicated by the black line. Daytime and nighttime VES are represented by blue and black dotted lines, respectively.

The areas and habitats highlighted on the maps detailed here (**Figure 27** - **Figure 28**) are approximate and based on the fieldwork team's appreciation given the observed individuals during VES. Other similar habitats within PPWS and SBWS that were not surveyed might be of similar or higher conservation priority. We recommend considering and incorporating the areas mentioned here when designing zoning and management plans for the Wildlife Sanctuaries. However, managers should take into account the lack of biodiversity data for large areas of the Sanctuaries, and we recommend conducting additional surveys as well as incorporating local knowledge to improve and assign zones. The areas highlighted as examples here could be used to classify similar areas of high conservation priority for reptiles and amphibians, based on habitat types and biodiversity data for other taxa.

4.3 Formicidae

Matthew T. Hamer

4.3.1 Introduction

Ants (Hymenoptera; Formicidae) are a ubiquitous and ecologically dominant group of eusocial insects. Currently there are 14,171 known ant species, and an estimated 20 quadrillion individuals which are predominantly distributed in the tropics and subtropics (Schulthesis et al., 2022; Bolton 2023). Their sheer numbers, biomass and rich life histories make the group an important ecosystem component, being not only food for other animals but also seed dispersers, predators, decomposers and soil aerators (Lach et al., 2009). Their strong ecological influence, coupled with their stationary and near perennial nests, as well as their easy sample ability, make ants a useful organism to understand ecosystem change following anthropogenic habitat disturbance (Lach et al., 2009).

Although our understanding of global ant diversity is relatively well documented, local richness and diversity is often poorly understood across many countries (Janicki et al., 2016; Guénard et al., 2017; Economo et al., 2018; Kass et al., 2022). Such countries have had historical poor survey efforts and therefore our understanding of the local ant diversity is sparse and fragmented. One such country is Cambodia, which has comparatively poor ant richness relative to neighbouring Thailand and Vietnam with only 93 species recorded (Janicki et al., 2016). Survey and taxonomic effort that have been carried out, focused on non-native species (Hosoishi et al., 2022), community composition and ecology (Hosoishi et al., 2013; Hosoishi et al., 2017), and taxonomy (Hosoishi & Ogata 2014; Hosoishi 2015; Hosoishi 2019; Hosoishi et al., 2021; Hosoishi et al., 2022). However, all such studies are relatively contemporary with much yet still to understand about the ant diversity of Cambodia.

Here we present initial results from a rapid ant diversity survey from Kratie Province, Cambodia. Survey effort focused on three habitat types in the dry forests of Prek Prasab, and Sambour Wildlife Sanctuaries. Surveys utilised both standardised plot surveys using pitfall traps and baits, as well as non-standardised hand collections across both sanctuaries. After an extensive database and literature review, it was established that data relating to ant richness and diversity from Kratie Province did not exist prior to this survey. This survey is important for future efforts to understand not only the local ant richness by providing baseline data for the region and Cambodia at large, but also community structure and environmental pressures structuring ant communities in the region.

4.3.2 Methods

Ants show strong community turnover with habitat change. To sample the ant community as deeply as possible (i.e. obtain as many species as possible) we sampled three broad habitat types across region; grassland (both degraded and non-degraded), **Figure 29**), open woodland (new and old growth), and closed forests (bamboo and mixed broadleaf forests). Surveys included both standardised and non-standardised methods. Standardised methods used a 20×20 metre plot within each habitat type, positioned at least 200 metres away from one another. A pitfall trap was placed in each plot corner, filled 1/5th with 50% ethanol and left for 48 hours (**Figure 30C,D**). Upon return, all four pitfall trap samples were pooled into the same sample and labelled. In addition, a bait station was deployed within 1 meter of each pitfall (**Figure 30E**). Bait included rice mixed with honey, or tuna tomato sauce mix depending on availability. As bait traps often become dominated

by aggressive species if left too long, each station was sampled within 20 minutes to maximise species richness and reduce the effect of over dominant species. GPS coordinates and habitat type were recorded for each plot.

Non-standardised methods included the use of leaf-litter sifting and extraction for 48 hours using Winkler extractors (**Figure 30A,B**), and ad-hoc hand collection involving searching for ants inside wood, under bark, logs, and rocks as well as collecting general foraging workers, digging up nests or from camp light traps. Further pitfall trapping was also used at specific sites to obtain more specimens involving 3×3 pitfall grid and was left for either 48 hours, or three-four days depending on time availability. Additional specimens were collected from herpetological pitfall traps from each camp upon trap collection.

4.3.3 Initial results

Across the expedition, two wildlife sanctuaries and three field camps were visited specifically for ants. A total 40 sites were surveyed comprising 14 closed woodland, 14 open woodland, and 12 grasslands, totalling a combined 316 pitfalls and baits (160 and 156 respectively) (**Table 6**). A further 10 leaf litter samples were taken in mostly closed forest sites, which had sufficient leaf litter compared to other habitat types (**Table 6**) Of the 154 bait samples, 88.5% had 1 or more ants. A further 130 ad-hoc hand collections also took place across both wildlife sanctuaries, field camps and sites. These collections either contained one species, or many species collected at once.

Though still anecdotal, a distinct ant community turnover was noted across the three habitat types. Grasslands often had a lower species richness and invasive species such as *Solenopsis geminata* (Fabricius, 1804) and *Paratrechina longicornis* (Latreille, 1802), which were frequently encountered. Such species are disturbance specialists, and often associated with degraded habitat. Closed forest sites did not contain such species as far as we are aware, potentially indicating the reduced disturbance of such habitats. A few open woodland sites did contain invasive species, particularly *P. longicornis*, but some other sites did not. Open woodland is likely positioned somewhere between grassland and closed canopy sites in terms of community composition. Closed forest could be of higher conservation value, with many genera and species (e.g. *Centromyrmex* Mayr, 1866, *Leptogenys* Roger, 1861 and *Odontoponera* Mayr, 1862) found only within this habitat.

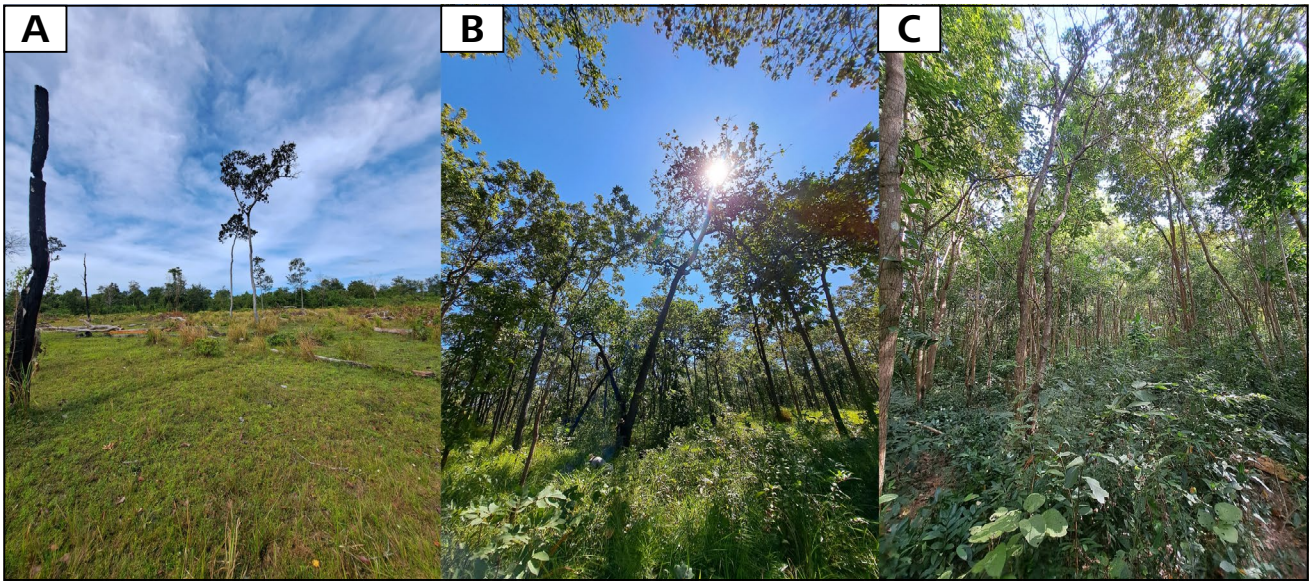

Figure 29. Habitat types sampled across both Prek Prasab and Sambor Wildlife Sanctuaries. **A.** Grasslands, **B.** Open woodland, **C.** Closed woodland.

Figure 30. A. Winkler extractors in Prek Prasab, **B.** leaf litter sifting, **C.** pitfall trap with lid, **D.** sanctuary rangers deploying pitfall trap, **E.** *Crematogaster inflata* group on tuna bait.

Table 6. Breakdown of sample sites across two sanctuaries and three field camps. P = Pitfall, B = Bait, W= Random-Winkler.

Site	Sanctuary	Camp	Habitat type	Coll. Method	Coordinate (DD)
CMB-01	Prek Prasab	1	Open Woodland	P, B, W	12.6288, 105.9617
CMB-02	Prek Prasab	1	Closed Woodland	P, B, W	12.6347, 105.9484
CMB-03	Prek Prasab	1	Closed Woodland	P, B, W	12.6338, 105.9467
CMB-04	Prek Prasab	1	Open Woodland	P, B	12.6333, 105.952
CMB-05	Prek Prasab	1	Open Woodland	P, B, W	12.6204, 105.9521
CMB-06	Prek Prasab	1	Closed Woodland	P, B, W	12.6375, 105.9738
CMB-07	Prek Prasab	1	Open Woodland	P, B, W	12.6388, 105.9667
CMB-08	Prek Prasab	1	Closed Woodland	P, B, W	12.6334, 105.9741
CMB-09	Prek Prasab	1	Open Woodland	P, B	12.6242, 105.9656
CMB-10	Sambour	2	Open Woodland	P, B	12.9861, 106.1015
CMB-11	Sambour	2	Grassland	P, B	12.9864, 106.0953
CMB-12	Sambour	2	Grassland	P, B	12.9912, 106.0951
CMB-13	Sambour	2	Grassland	P, B	13.0004, 106.1024
CMB-14	Sambour	2	Open Woodland	P, B	13.0054, 106.1009
CMB-15	Sambour	2	Closed Woodland	P, B, W	13.0036, 106.0988
CMB-16	Sambour	2	Open Woodland	P, B	12.9986, 106.1007
CMB-17	Sambour	2	Grassland	P, B	13.0012, 106.1708
CMB-18	Sambour	2	Grassland	P, B	13.0076, 106.1686
CMB-19	Sambour	2	Closed Woodland	P, B	13.0075, 106.1526
CMB-20	Sambour	2	Open Woodland	P, B	13.0046, 106.1507
CMB-21	Sambour	2	Closed Woodland	P, W	13.0058, 106.1522
CMB-22	Sambour	3	Closed Woodland	P, B, W	13.1699, 106.0942
CMB-23	Sambour	3	Grassland	P, B	13.1699, 106.0942
CMB-24	Sambour	3	Closed Woodland	P, B	13.1663, 106.1007
CMB-25	Sambour	3	Grassland	P, B	13.1614, 106.1007
CMB-26	Sambour	3	Open Woodland	P, B	13.1597, 106.0947
CMB-27	Sambour	3	Closed Woodland	P, B	13.1593, 106.0909
CMB-28	Sambour	3	Open Woodland	P, B	13.1315, 106.1067
CMB-29	Sambour	3	Grassland	P, B	13.1302, 106.1102
CMB-30	Sambour	3	Open Woodland	P, B	13.1231, 106.1055
CMB-31	Sambour	3	Grassland	P, B	13.1157, 106.1067
CMB-32	Sambour	3	Grassland	P, B	13.1129, 106.1075
CMB-33	Sambour	3	Closed Woodland	P, B	13.1125, 106.1029
CMB-34	Sambour	3	Open Woodland	P, B	13.1219, 106.1067
CMB-35	Sambour	3	Grassland	P, B	13.1385, 106.1019
CMB-36	Sambour	3	Closed Woodland	P, B	13.1009, 106.091

Site	Sanctuary	Camp	Habitat type	Coll. Method	Coordinate (DD)
CMB-37	Sambour	3	Closed Woodland	P, B	13.0999, 106.0882
CMB-38	Sambour	3	Closed Woodland	P, B	13.0949, 106.0907
CMB-39	Sambour	3	Open Woodland	P, B	13.1094, 106.0954
CMB-40	Sambour	3	Grassland	P, B	13.1185, 106.0905

At the time of writing, specimens are still being analysed. Many thousands of individuals were collected, comprising 8 subfamilies and at least 41 ant genera (**Table 7**), including three new genera records for Cambodia (*Paratopula* Wheeler, 1919, *Bothroponera* Mayr, 1862, *Vollenhovia* Mayr, 1865 and *Platythyrea* Roger, 1863). More new genera and species records, as well as new species to science, will likely be made after examining specimens.

Table 7. Preliminary genera richness by ant subfamily across both sanctuaries and camps.

Subfamily	# genera collected
Amblyoponinae	2
Dolichoderinae	3
Dorylinae	2
Ectatomminae	1
Formicinae	7
Myrmicinae	15
Ponerinae	10
Pseudomyrmicinae	1
Total	41

4.3.4 Zoning Recommendations

Despite the lack of specimen identifications, preliminary recommendations on conservation zoning across both sampled sanctuaries can be made. Readers should be aware however that these conclusions are based on mostly anecdotal evidence from preliminary subfamily and genera lists produced in the field, visual inspection of samples whilst in the field, and from preliminary sorting of samples. It should also be noted that the possibility of unique species (excluding invasive species) occurring in each habitat cannot yet be ruled out.

4.3.4.1 Habitats and faunal communities

Ants are sensitive to habitat change, with the potential for different communities occurring in relatively small spatial areas. Ant community turnover was noted between grassland, open woodland (dry dipterocarp forest), and closed forest (including riparian forests) in habitats surrounding camps sampled (Camps 1, 2 & 3). Grasslands were noted to be of relatively low richness and diversity, and often harboured invasive species (see invasive species section). Such grassland sites were either post-farming degraded land or post-clear-cut sites that were either open woodland or closed forest habitat in the past (evidenced by tree stumps). Open woodland (dry dipterocarp forests)

harboured slightly higher richness and diversity than grassland, with some sites containing invasive species. Such sites were often closer to roads, farmlands, and grasslands, where invasive species were more prevalent. Some species occurring in open woodland also occurred in older grasslands sites, suggesting a growing ant community similarity with habitat succession. Closed forests had the strongest and most obviously unique ant community composition with many genera seemingly absent from grassland and open woodland. Such genera included *Centromyrmex* Mayr, 1866, *Leptogenys* Roger, 1861, Odontoponera Mayr, 1862, *Stictoponera* Mayr, 1887, and *Bothroponera* Mayr, 1862, among others. Importantly, such habitats were capable of catering to multiple colonies of raid specialist species (i.e. *Leptogenys processionalis* group and *Carebara* Westwood, 1840 (subgenus *Pheidologeton* Mayr, 1862)) that require large quantities of insect prey to survive. However, closed canopy sites that were adjacent or growing near river systems or streams seemed to have slightly lower ant richness – likely because of annual flooding which would stop ground dwelling ants from colonising.

4.3.4.2 Invasive species

Non-native invasive ant species pose significant socioeconomic and ecological challenges to regions they invade. Organisms at all trophic levels are impacted by ant invasions, causing cascading ecosystem wide consequences. Invasive species predominantly occur in anthropogenically disturbed environments, such as many grasslands sites including short, medium, and tall grass, as well as agricultural/bare soil habitats. *Solenopsis geminata* (Fabricius, 1804), *Paratrechina longicornis* (Latreille, 1802) and *Trichomyrmex destructor* (Jerdon, 1851) were the three most dominant encountered non-native species. Grassland pitfall traps often had at least one of the three non-native species (table 3), and often in high abundance. Further, bait samples were dominated by one of these species, particularly *S. invicta* or *T. destructor*, even 20 minutes post deployment. Their often-large numbers and high competitiveness, as indicated by the numbers occurring in pitfalls, and their rapid recruitment to bait indicates how dominant these invasive species can be. Their dominance will have consequences for local native grassland ant fauna, where invasive species will easily be outcompeted. A few open woodland sites contained such invasive species, particularly *P. longicornis*, but some other sites did not (**Table 8**). Closed forest sites, as far as we are aware, did not contain such species - potentially indicating the reduced anthropogenic disturbance of such habitats (**Table 8**).

Table 8. Invasive species across the three habitat types sampled.

Invasive species	Grassland	Open woodland	Closed forest
Paratrechina longicornis	x	x	-
Solenopsis geminata	x	x	-
Trichomyrmex destructor	x	-	-
Total	3	2	0

4.3.4.3 Zoning Recommendations and conclusions

Forests with a closed canopy undoubtedly hold the most unique ant faunal assemblage sampled during this survey. Numerous genera and species were encountered in these habitats that seemed to be absent in grasslands and open woodlands. Their occurrence within this habitat is likely attributable to the more stable microclimatic conditions (e.g. stable temperatures, higher humidity and retention of ground moisture) which many ant species prefer. The absence of invasive species in these sites might indicate their resilience to invasion – being unsuitable for such species and therefore may act as natural barriers to their dispersal. Sampled closed canopy sites of particular interest were CMB2-3 (Prek Prasab); CMB19 & CMB21, CMB36-38 (SBWS) (**Table 6**; **Figure 31**). These sites harboured numerous unique genera for the region that were not encountered elsewhere. Of particular note is CMB21 (**Figure 31**), where a mining operation significantly jeopardises this site and a potential new *Leptogenys* species was collected. Further, the rarity of closed woodland in Prek Prasab was noteworthy (only four sites could be located and accessed), highlighting the need to protect the current sites in the region. However, the protection and expansion of all closed woodland habitats, particularly those indicated above, should be of a priority and included in any zoning plans due to their unique ant communities, scarcity in the region, and their high vulnerability to anthropogenic disturbance.

Open woodland (i.e. dry dipterocarp forests), the most ubiquitous habitat, housed a transitory ant assemblage between grassland and closed woodland sites. However, it was noted that whenever paths and roads penetrated open woodland, the adjacent woodland was often invaded by invasive ant species. Expansion of roads into and within open woodlands should be reduced to halt the invasive ant species spread. This, alongside the reduction of these open woodland habitat conversion, will also contribute to the reduction of invasive ant spread in the region.

Restoration and zoning efforts should focus on the highly degraded grassland sites, particularly those abandoned after farming activities, of which are currently of low conservation value. Restoring such sites will help to reduce invasive species spread in the region, and hopefully allow for local native ant fauna to reestablish a foothold, ideally from adjacent open and closed woodlands. Such sites include the grasslands around CMB17 and CMB23 (SBWS; **Table 6**; **Figure 31**), which were of the notable low quality and harboured an overwhelming abundance of invasive species and next to no native ant fauna.

Restoration and zoning efforts should focus on the highly degraded grassland sites, particularly those abandoned after farming activities, of which are currently of low conservation value. Restoring such sites will help to reduce invasive species spread in the region, and hopefully allow for local native ant fauna to reestablish a foothold, ideally from adjacent open and closed woodlands. Such sites include the grasslands around CMB17 and CMB23 (SBWS; **Table 6**; **Figure 31**), which were of the notable low quality and harboured an overwhelming abundance of invasive species and next to no native ant fauna.

4.3.5 Future work

Once specimens are received, samples will be sorted to morphospecies and identified to the lowest taxonomic rank possible. Where specimens cannot be identified to species a morphospecies number will be applied. Given the lack of taxonomic sampling resolution in the region, many specimens will likely remain identified to morphospecies only. Nevertheless, morphospecies sorting has proven to be an adequate method to understand richness and diversity of ants in regions where taxonomy is currently deficient (Lach et al., 2009). A species checklist will be generated once all data has been collated, with novel findings highlighted.

Given the use of standardised sampling methodology a hypothesis driven comparison between each habitat type will be possible. Once all samples have been identified, species accumulation curves, community dissimilarity metrics and non-metric multidimensional visualisations will be built. Such analysis will enable us to test whether a distinct community turnover is present between grasslands, open woodland, and close forests in the region. Understanding such community changes will have implications for the conservation of not only the ants in the region, but also the habitats themselves and the myriad of organisms which call them home.

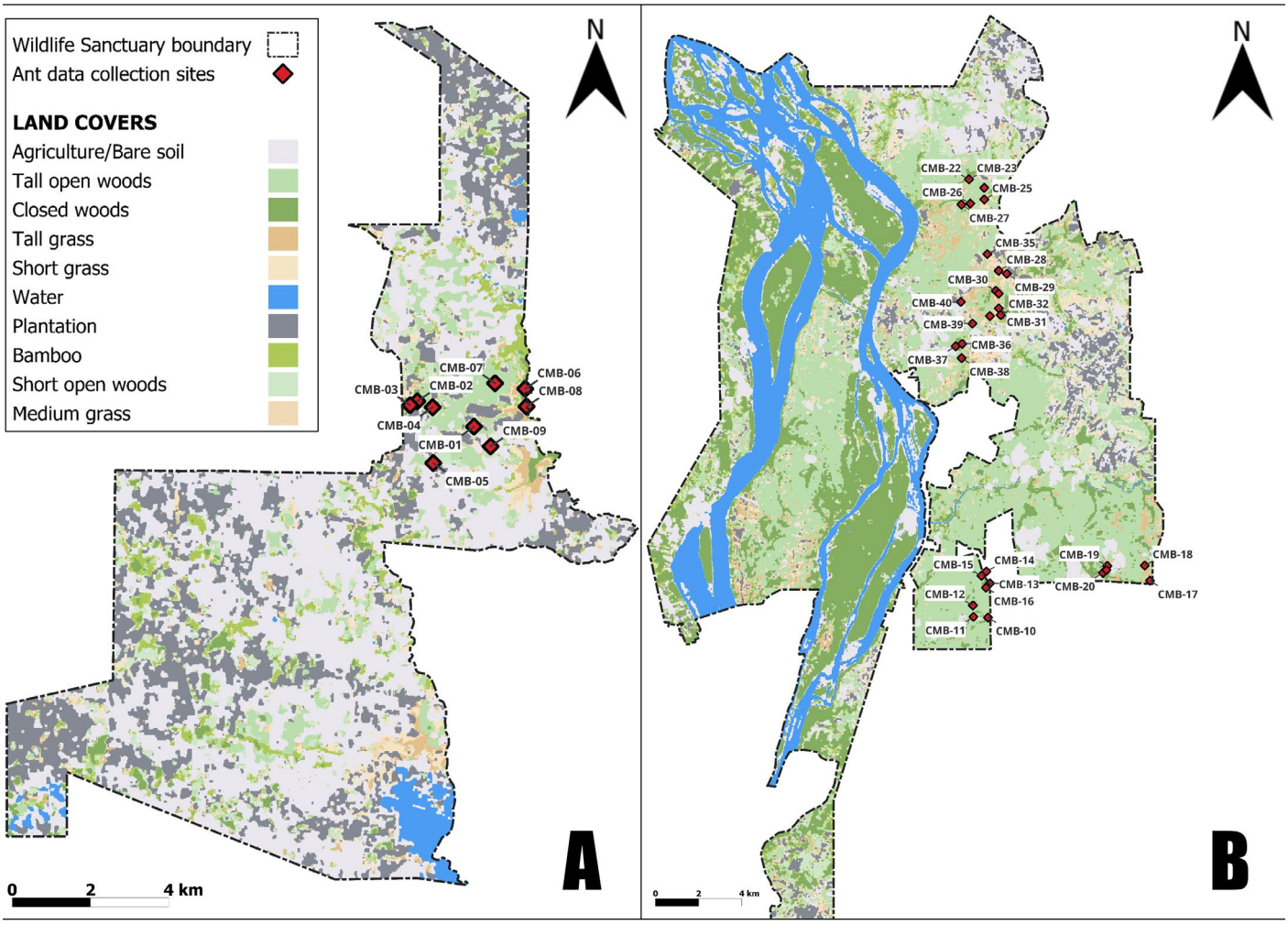

Figure 31. Distribution map of sites across both sanctuaries. **A.** Prek Prasab, **B.** Sambor.

4.4 Moths, butterflies, and other invertebrates

Jonas Merckx

4.4.1 Introduction

In recent years, there has been a surge in research focusing on invertebrates such as butterflies in Cambodia (Kosterin 2019, Phauk, 2019, Miles et al 2021). However, many invertebrate groups remain understudied due to their high diversity and the significant effort required for comprehensive documentation of their ecology. This knowledge gap poses a real threat, as undiscovered species face the risk of extinction under mounting environmental pressures on Cambodian wildlife.

Particularly in the central and northern regions of Cambodia, which have received less attention compared to southwestern Cambodia, there is a pressing need for further baseline inventories of invertebrates. In 2018, the BINCO expedition (BES 7) successfully published a checklist of tiger beetles in the studied area (Jocque et al. 2018), further contributing to our understanding of the invertebrate diversity in the region. While incomplete checklists exist for certain other invertebrate groups in Cambodia, including butterflies, dragonflies, damselflies and mites, no published inventories are available for the specific region under investigation.

As part of a biodiversity survey, we focused on selected invertebrate groups, including butterflies, moths, ants, arachnids, hoverflies, and beetles.

4.4.2 Methods

Invertebrates were collected using a range of methodologies tailored to different (micro-) habitats. This included both standardized methods and opportunistic sampling to cover as much diversity as possible.

4.4.2.1 Herpetologic pitfalls

Many invertebrates were collected from the herpetological pitfall series, mostly ants, ground beetles and spiders. These traps, primarily designed for herpetofaunal studies (see chapter Herpetofauna for survey effort in each camp), comprised deep buckets equipped with plastic drift fences. The content of the bucket was poured through a sieve and focus groups (beetles and spiders) were hand collected and stored in 70% ethanol. Collection was conducted on the final day of each basecamp.

4.4.2.2 Light trap

Nighttime surveys to sample flying and dispersing invertebrates was done via light traps comprising a HPL-160W E27 mixed Mercury Lamp affixed centrally above a white 6m2 sheet suspended approximately 1.5m above ground level (**Figure 32**). The lightbulb was fitted in a ceramic base to prevent overheating and was connected to a generator placed several meters away from the trap to avoid invertebrate disturbance. Additional sheeting was positioned on the ground beneath the primary trap to account for ground dwelling invertebrates. The setup was typically positioned in elevated, open spaces to optimize visibility. Light trapping surveys started shortly after sunset and ran for 2-3 hours. Locations and sampling times can be found in **Table 9**. Collection efforts targeted moths (mainly Sphingidae and Saturniidae), beetles, and ants, with other invertebrate taxa noted and occasionally collected. Moths were euthanized using a kill jar containing Ethyl

acetate (CH3COOCH2CH3) and subsequently preserved in glassine envelopes and later stored in a Tupperware box with netted silica beads to ensure the specimen remained dry. Each envelope was labeled with date, locality and time. All other invertebrates were collected by hand and stored in a jar with 70% ethanol. Variables such as temperature, humidity, date, time, wind speed, cloud cover, moon phase, location and location were all noted at the start of the trapping. Although no rain was present during our trapping, precautions should be taken to protect the electric connections.

4.4.2.3 Head-torching

Supplementary to light trapping, periodic nocturnal collections of spiders were conducted through head-torching, wherein light from head-mounted torches was employed to locate specimens, particularly ground-dwelling spiders within soil litter and lower vegetation. These spiders can be located by the reflection of torch light in their eyes and caught using tweezers. Collections were performed for 10 minutes once every hour while the light trap was running. Specimens were preserved in 70% ethanol.

Figure 32. Light trapping moths and other invertebrates with the local community members.

Table 9. Light trap setup.

Date	Camp	Grid code	Land cover	Latitude	Longitude	Start-End time
22/11/2023	1	O70	bare soil	105°57'36.167"	12°37'47.838"	19:30 - 22:30
23/11/2023	1	O70	short open woods	105°57'36.167"	12°37'47.838"	19:00 - 22:00
24/11/2023	1		short grass			19:00 - 21:30
25/11/2023	1	Q72	short grass	105°58'37.831"	12°36'32.976"	19:00 - 22:00
27/11/2023	2	AH28	rocky, next to pond	106°8'18.187"	13°0'30.601"	19:00 - 21:45
28/11/2023	2	AD29	plantation	106°6'4.01"	12°59'55.563"	18:44 - 21:45
29/11/2023	2	AF29	agricultural	106°7'0.721"	12°59'57.948"	18:40 - 20:40
30/11/2023	2	AD29	plantation	106°6'4.01"	12°59'55.563"	18:58 - 21:00
02/12/2023	3	AD14	plantation	106°6'6.956"	13°8'16.018"	19:30 - 21:30
03/12/2023	3	AD14	short open woods	106°6'6.956"	13°8'16.018"	18:30 - 20:30
04/12/2023	3	AD14	short open woods	106°6'6.956"	13°8'16.018"	19:00 - 21:00
05/12/2023	3	AE11	tall open woods	106°6'34.436"	13°9'35.635"	19:30 - 21:30
11/12/2023	5	AL14	short open woods	106°10'46.163"	13°8'20.143"	17:30 - 20:30
12/12/2023	5	AL14	agricultural	106°10'46.163"	13°8'20.143"	18:00 - 21:00

4.4.2.4 Butterfly surveys

Dedicated surveys were conducted to collect day-butterflies. Selection of survey sites was based on a predefined grid system (see chapter habitat mapping), with specific habitats targeted for sampling. We aimed to sample as many 1 km squares with different habitats as possible. Once arrived at the survey site, a mini base was defined and variables such as temperature, humidity, date, wind speed, cloud cover, location, land cover, start and end time of the survey were recorded. Collection was performed for 30 minutes using butterfly nets within approximately 300 meters of the mini base, staying within the grid square and the habitat type. Captured butterflies were euthanised by pinching the thorax and index finger to quickly stun the specimen and prevent it from damaging itself and immediately stored in glassine envelopes labelled with date, time, location and the butterfly family it belongs to. All surveys were done during optimal daylight hours (between 9:00 and 17:00), to coincide with butterfly activity. Environmental parameters such as temperature and wind speed were recorded. Uncaptured specimens were characterized based on general observations. Locations and sampling times can be found in **Table 10**. At the end of the day all envelopes were stored in a Tupperware box with netted silica beads to ensure the specimens remained dry.

Table 10. Location, time and temperatures for each butterfly survey. Each survey lasted 30 minutes.

Date	°C	Camp	Grid code	Land cover	Latitude	Longitude	Start time
23/11/2023	25	1	M70	closed woods	105°56'46.502"	12°37'57.339"	08:19
23/11/2023	28,6	1	M70	short open woods	105°56'52.094"	12°37'59.161"	09:00
23/11/2023	33,8	1	N70	short open woods	105°56'59.438"	12°38'5.352"	09:47
23/11/2023	32,4	1	M69	closed woods	105°56'53.849"	12°38'12.199"	10:38
23/11/2023	35,2	1	N71	short open woods	105°57'12.001"	12°37'45.722"	13:10

Date	°C	Camp	Grid code	Land cover	Latitude	Longitude	Start time
23/11/2023	33,6	1	N70	short open woods	105°57'0.553"	12°37'16.57"	12:50
23/11/2023	33	1	M72	agricultural	105°56'44.296"	12°36'43.447"	14:22
24/11/2023	30	1	P69	closed woods	105°58'26.472"	12°38'18.267"	09:10
24/11/2023	33	1	O69	short open woods	105°57'48.946"	12°38'12.507"	11:15
24/11/2023	32,3	1	P70	closed woods	105°58'34.477"	12°37'43.118"	13:25
24/11/2023	32,4	1	O71	Tall grass	105°57'42.383"	12°37'18.793"	15:25
25/11/2023	33,7	1	O67	bare soil	105°57'30.495"	12°39'12.897"	10:50
25/11/2023	33,6	1	N67	grassland	105°57'17.467"	12°39'16.702"	11:30
25/11/2023	33,4	1	N68	grassland	105°57'23.647"	12°39'5.615"	12:12
25/11/2023	33,4	1	O68	agricultural	105°57'51.663"	12°38'44.869"	01:05
25/11/2023	34,3	1	O70	Tall open woods	105°57'40.265"	12°37'43.655"	14:12
27/11/2023	31,6	2	AD31	grassland	106°6'2.359"	12°59'5.809"	09:35
27/11/2023	32,5	2	AD31	agricultural	106°5'44.105"	12°59'9.496"	10:40
27/11/2023	35,7	2	AC30	short open woods	106°5'42.465"	12°59'26.158"	11:30
27/11/2023	33,9	2	AD29	agricultural	106°6'9.668"	13°0'0.212"	14:00
28/11/2023	29,2	2	AD28	short open woods	106°5'54.1"	13°0'24.94"	09:30
28/11/2023	30,5	2	AC28	short open woods	106°5'41.759"	13°0'29.154"	10:15
28/11/2023	32,6	2	AC29	tall open woods	106°5'40.049"	13°0'6.356"	11:40
28/11/2023	31,9	2	AD30	short open woods	106°6'7.423"	12°59'38.594"	14:25
29/11/2023	30,9	2	AB32	short open woods	106°5'13.921"	12°59'19.357"	09:45
29/11/2023	32	2	AB31	Tall open woods	106°4'34.613"	12°59'9.37"	10:55
29/11/2023	34,7	2	AA31	Medium grass	106°4'38.948"	12°59'38.24"	11:40
29/11/2023	34,3	2	AA30	short grass	106°5'8.125"	13°0'12.114"	12:45
30/11/2023	32,1	2	AB29	Tall open woods	106°4'55.87"	13°0'40.81"	09:35
30/11/2023	33,2	2	AB28	short grass	106°4'24.979"	13°0'36.758"	10:47
30/11/2023	37	2	AA28	short open woods	106°4'34.776"	13°0'7.459"	11:55
30/11/2023	37,7	2	AA29	closed woods	106°5'40.378"	13°10'11.497"	13:40
02/12/2023	33,4	3	AC16	closed woods	106°6'2.421"	13°10'11.455"	11:45
02/12/2023	35,3	3	AD10	short grassland	106°6'3.057"	13°9'58.135"	13:30
02/12/2023	37,7	3	AD11	closed woods	106°6'3.16"	13°9'30.49"	14:15
02/12/2023	35	3	AD12	short grass	106°5'42.546"	13°9'35.687"	15:00
02/12/2023	33,9	3	AC11	short open woods	106°5'26.827"	13°9'31.772"	15:40
02/12/2023	34,2	3	AC12	bamboo	106°6'23.164"	13°7'52.197"	16:15
03/12/2023	26,5	3	AD15	short open woods	106°6'36.865"	13°7'48.253"	08:48
03/12/2023	27,3	3	AC15	Medium grass	106°6'20.444"	13°7'21.662"	09:26
03/12/2023	32,3	3	AD16	short open woods	106°6'27.832"	13°6'54.863"	10:16
03/12/2023	33,5	3	AE16	Tall open woods	106°6'27.304"	13°6'46.47"	11:00

Date	°C	Camp	Grid code	Land cover	Latitude	Longitude	Start time
03/12/2023	33,3	3	AE17	agricultural	106°6'10.134"	13°6'45.372"	11:40
03/12/2023	35,1	3	AD17	bamboo	106°6'29.111"	13°7'18.145"	12:45
03/12/2023	32,3	3	AE16	short open woods	106°6'40.867"	13°8'15.982"	13:45
04/12/2023	31,9	3	AE14	Tall open woods	106°7'12.8"	13°8'19.38"	09:30
04/12/2023	34,3	3	AF14	short open woods	106°7'33.183"	13°8'24.994"	10:33
04/12/2023	33,4	3	AG14	bamboo	106°7'33.492"	13°8'32.067"	11:30
04/12/2023	34,2	3	AG13	plantation	106°7'16.333"	13°8'43.168"	12:03
04/12/2023	35,2	3	AE13	plantation	106°6'57.372"	13°8'33.625"	13:45
05/12/2023	34,5	3	AC15	Tall open woods	106°5'38.948"	13°7'49.877"	09:15
05/12/2023	34,5	3	AB15	Tall open woods	106°5'7.768"	13°7'44.389"	09:45
05/12/2023	35,2	3	AA15	short open woods	106°4'40.05"	13°7'43.815"	10:25
05/12/2023	34,7	3	Z15	short open woods	106°4'8.715"	13°7'35.549"	11:10
05/12/2023	35,1	3	Y15	short open woods	106°3'37.888"	13°7'29.097"	11:50
05/12/2023	34,4	3	Y16	bamboo	106°3'35.997"	13°7'19.872"	12:20
07/12/2023	26,1	4	U18	closed woods	106°1'6.887"	13°5'29.845"	10:10
11/12/2023	33,9	5	AL14	Tall open woods	106°10'47.522"	13°8'18.687"	13:25
11/12/2023	34,2	5	AM14	closed woods	106°11'5.207"	13°8'13.562"	14:00
11/12/2023	35,9	5	AM13	Tall open woods	106°11'6.322"	13°8'29.022"	14:30
12/12/2023	31	5	AM14	Tall open woods	106°10'53.16"	13°8'20.803"	09:20
12/12/2023	34,8	5	AM14	Tall open woods	106°10'54.721"	13°8'24.261"	09:55
12/12/2023	33,1	5	AM14	closed woods	106°11'4.075"	13°8'18.978"	10:30

4.4.2.5 Opportunistic sampling (mites, spiders, beetles and hoverflies)

Opportunistic sampling occurred for certain focus groups: predatory mites (Phytoseiidae and Anystidae), spiders (ground-based spiders and Salticidae), beetles (Cerambycidae, Cicindelidae, Chrysomelidae, Staphylinidae, Carabidae) and hoverflies. Specimens were stored in jars or tubes with 70% ethanol.

4.4.3 Results

Processing of the invertebrates is in full progress. In total, about 700 butterflies, 1000 moths, and 80 invertebrate samples (multiple specimens) were collected. Due to medical reasons, the entomological surveys at basecamp 4 and 5 were limited. These are the locations with both most butterfly types and great abundance. As you can see they cover almost all of the land covers.

Of the 761 butterflies recorded **Table 12**, the Lycanidae make up the largest part of the collection with 419 records. These were quite abundant and often found together in groups of 2–8 individuals. Lycaenidae are known to associate with ant nests and as the butterfly surveys often went alongside the ant surveys it is not surprising to see this abundance. The Nymphalidae was the second most caught group of butterflies with 203 specimens collected, followed by the Pieridae with 106. These are both widespread and conspicuous families which made them easy to observe in contrast to

the Hesperiidae (13 specimens recorded). Butterflies of the Hesperiidae family are known to hide in shaded spots which make them hard to spot and accounts for the low number of records. The members of the Papilionidae family (20 specimens recorded) were hard to catch due to their fast and high-flying nature; nonetheless several other specimens were observed outside of the surveys and recorded separately to gain a better understanding of their distribution.

The light trap yielded a great number of micro-moths (about a 1000 specimens) but the focus-taxa, Sphingidae and Saturniidae were absent from the trap, although few sphingids were found during opportunistic sampling at night. There was little to no rainfall during the expedition, which might have influenced the moth abundance. Other taxa found at the light trap included spiders (Aranea), silverfish (Zygentoma), mayflies (Ephemeroptera), dragonflies & damselflies (Odonata), grasshoppers & crickets (Orthoptera), stick insects (Phasmatodea), earwigs (Dermaptera), mantids (Mantodea), cockroaches (Blattodea), true bugs (Hemiptera), net-winged insects (Neuroptera), wasps, bees & ants (Hymenoptera), flies (Diptera) and a great diversity of beetles (Coleoptera).

Butterfly abundance and diversity was high in a variety of habitats, particulary in the sampling locations listed in **Table 11** as shown on **Figure 33**.

Table 11. Coordinates of locations with both most butterfly types and great abundance.

Grid code	Land cover	n° on map	Latitude	Longitude
AB30	Dipterocarp forest	1	106°5'13.921"	12°59'19.357"
AC28	Dipterocarp forest	2	106°6'2.359"	12°59'5.809"
AA31	Medium height grass	3	106°4'38.948"	12°59'38.24"
AB28	short grass	4	106°4'24.979"	13°0'36.758"
AA29	riarian forest	5	106°5'40.378"	13°10'11.497"
AE14	shrub	6	106°7'12.8"	13°8'19.38"
AG14	riparian forests	7	106°7'33.492"	13°8'32.067"
AE13	shrub	8	106°6'57.372"	13°8'33.625"
U19	riparian forest	9	106°1'6.887"	13°5'29.845"
AL14	tall grass	10	106°10'47.522"	13°8'18.687"
AM13	riparian forest	11	106°11'6.322"	13°8'29.022"
AC12	bamboo	12	106°6'23.164"	13°7'52.197"

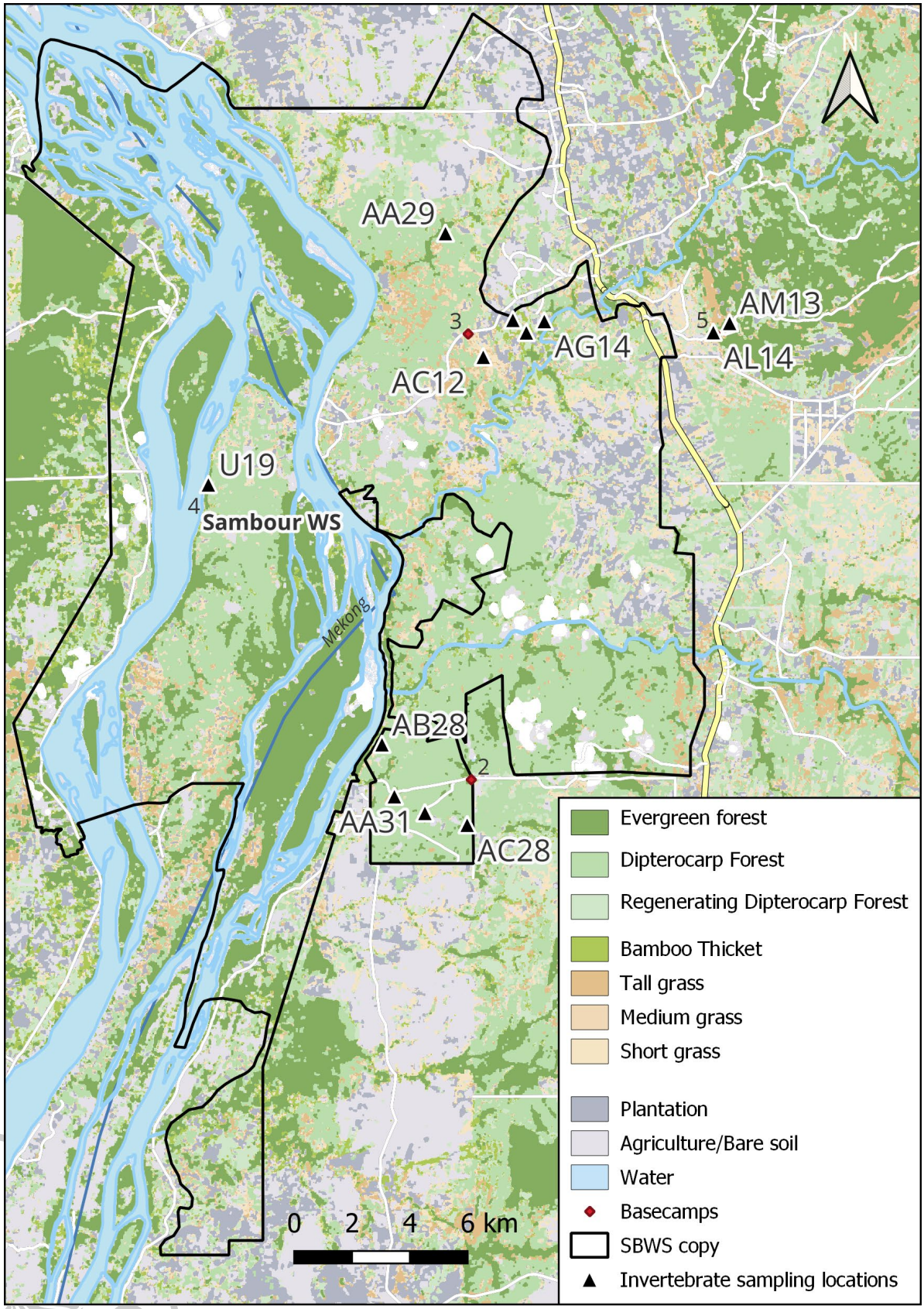

Figure 33. Locations of high butterfly abundance and diversity

Table 12. Butterfly specimen recorded for each family during each butterfly survey. Pap=Papilionidae, Hes=Hesperiidae, Nym=Nymphalidae, Lyc=Lycaenidae, Pie= Pieridae.

Date	Camp	Grid code	Land cover	Start time	Pap	Hes	Nym	Lyc	Pie
23/11/2023	1	M70	closed woods	08:19				2	
23/11/2023	1	M70	short open woods	09:00			1	7	
23/11/2023	1	N70	short open woods	09:47			2	6	
23/11/2023	1	M69	closed woods	10:38	2		2		1
23/11/2023	1	N71	short open woods	13:10			2	1	
23/11/2023	1	N70	short open woods	12:50			8		
23/11/2023	1	M72	agricultural	14:22	1		5	2	1
24/11/2023	1	P69	closed woods	09:10		1	1	1	
24/11/2023	1	O69	short open woods	11:15			1	5	1
24/11/2023	1	P70	closed woods	13:25			1		1
24/11/2023	1	O71	Tall grass	15:25		1	1	9	1
25/11/2023	1	O67	bare soil	10:50		1	2	33	1
25/11/2023	1	N67	grassland	11:30			2	21	4
25/11/2023	1	N68	grassland	12:12			3	27	4
25/11/2023	1	O68	agricultural	01:05		2	2	5	13
25/11/2023	1	O70	Tall open woods	14:12			2	14	1
27/11/2023	2	AD31	grassland	09:35			2	5	
27/11/2023	2	AD31	agricultural	10:40			1	12	1
27/11/2023	2	AC30	short open woods	11:30			3	6	2
27/11/2023	2	AD29	agricultural	14:00			1	9	
28/11/2023	2	AD28	short open woods	09:30			2	4	
28/11/2023	2	AC28	short open woods	10:15	1		11	6	1
28/11/2023	2	AC29	tall open woods	11:40		1	4	5	
28/11/2023	2	AD30	short open woods	14:25	1		9	7	
29/11/2023	2	AB32	short open woods	09:45	2		7	8	5
29/11/2023	2	AB31	Tall open woods	10:55			4	9	2
29/11/2023	2	AA31	Medium grass	11:40	1		6	6	3
29/11/2023	2	AA30	short grass	12:45			10	10	1
30/11/2023	2	AB29	Tall open woods	09:35	1		6	7	
30/11/2023	2	AB28	short grass	10:47	1		7	6	3
30/11/2023	2	AA28	short open woods	11:55	1		2	1	1
30/11/2023	2	AA29	closed woods	13:40	1		2	4	4
02/12/2023	3	AC16	closed woods	11:45			1	6	1
02/12/2023	3	AD10	short grassland	13:30	2			13	
02/12/2023	3	AD11	closed woods	14:15		1	2	3	1
02/12/2023	3	AD12	short grass	15:00			1	8	

Date	Camp	Grid code	Land cover	Start time	Pap	Hes	Nym	Lyc	Pie
02/12/2023	3	AC11	short open woods	15:40	2		1	1	1
02/12/2023	3	AC12	bamboo	16:15				2	1
03/12/2023	3	AD15	short open woods	08:48				12	
03/12/2023	3	AC15	medium grass	09:26			2	11	
03/12/2023	3	AD16	short open woods	10:16				3	
03/12/2023	3	AE16	tall open woods	11:00			1	7	6
03/12/2023	3	AE17	agricultural	11:40				5	2
03/12/2023	3	AD17	bamboo	12:45			2	1	2
03/12/2023	3	AE16	short open woods	13:45			1	6	
04/12/2023	3	AE14	tall open woods	09:30	1		4	5	4
04/12/2023	3	AF14	short open woods	10:33	1		4	2	2
04/12/2023	3	AG14	bamboo	11:30		1	3	3	4
04/12/2023	3	AG13	plantation	12:03			1	6	5
04/12/2023	3	AE13	plantation	13:45	1		6	10	1
05/12/2023	3	AC15	tall open woods	09:15	1		1	12	
05/12/2023	3	AB15	tall open woods	09:45			3	8	
05/12/2023	3	AA15	short open woods	10:25			6	2	3
05/12/2023	3	Z15	short open woods	11:10			4	5	4
05/12/2023	3	Y15	short open woods	11:50			4	7	1
05/12/2023	3	Y16	bamboo	12:20			2	3	2
07/12/2023	4	U18	closed woods	10:10		3	4	1	4
11/12/2023	5	AL14	tall open woods	13:25		1	4	5	3
11/12/2023	5	AM14	closed woods	14:00			6	5	
11/12/2023	5	AM13	tall open woods	14:30		1	5	7	3
12/12/2023	5	AM14	tall open woods	09:20			11	9	3
12/12/2023	5	AM14	tall open woods	09:55			5	8	1
12/12/2023	5	AM14	closed woods	10:30			7	5	1
				Total	20	13	203	419	106

4.4.4 Discussion

Because identification of specimens is still in progress, we can only provide preliminary results.

However, every location sampled for butterflies (**Table 12**) yielded a substantial number of specimens, highlighting the potential of each habitat type for supporting both species diversity and abundance. The predominant good quality dipterocarp forests stood out for supporting numerous butterfly populations, largely due to the habitat's heterogeneity, a finding which is aligned with the strong evidence in the literature for habitat heterogeneity being one of the greatest drivers of biodiversity. Patches of closed forest, shrubland, and grassland contributed significantly to enhancing biodiversity within the area. Notably, the bamboo habitats deserve special recognition, as they host distinct butterfly species not found in other habitats. Further taxonomic analysis will allow us to identify rare species and define species-habitat associations, which will aid in assessing the importance of each habitat type and understanding how the interlinkage of habitat types contribute to conserving butterfly species in a regional context.

4.5 Mammals

Tim van Berkel

Mammals (other than hog deer, publication in progress) were not surveyed. However, some opportunistic observations were recorded, including two species listed as Endangered on the IUCN Red List.

Long-tailed macaque (*Macaca fascicularis*)

Endangered (Hansen et al. 2022)

We observed four long-tailed macaques in PPWS (12.634964°N,105.947728°E) near Camp 1, in a patch of evergreen forest on 2 December 2024.

Indochinese silvered langur (*Trachypithecus germaini*)

Endangered (Duc et al. 2022)

We observed four individuals in dry dipterocarp habitat in SBWS (13.010639° N, 106.275444° E) on the 24th of November (**Fig. 8.1**).

Cambodian striped squirrel (*Tamiops rodolphii*)

We regularly observed Cambodian ground squirrels on dirt roads and on tree trunks in PPWS, especially during early mornings.

Shrews (Soricidae)

Three shrews were opportunistically collected in the pitfall traps. Identification of which is underway.

Figure 34. Indochinese silvered langur (*Trachypithecus germaini*, EN) observed in Sambour Wildlife Sanctuary. (Photo by Martin Suanjak)

5 Core and Conservation Zoning Recommendations for Sambour WS (Kratie, Cambodia)

Tim van Berkel, Jeremie Tranchant, Merlijn Jocque

Introduction

Protected areas play a pivotal role in safeguarding biodiversity, yet the effectiveness of these areas hinges on the identification and management of zones with varying conservation priorities. Zonation—the systematic division of protected areas into core, conservation, sustainable use, and community zones—is a critical tool for balancing biodiversity conservation with the needs of local communities. Ideally, by applying ecological and socio-economic criteria, zonation ensures that the most ecologically significant areas and species receive the highest levels of protection while allowing sustainable use in less sensitive areas.

Sambour Wildlife Sanctuary (SBWS) was established in 2018 with the principal aim to conserve several river-associated threatened birds, including their habitat and nesting sites. WWF has been working towards nature conservation in the area for years, including targeted protection programmes for the irrawaddy dolphin and several bird species such as the white-shouldered ibis and lesser adjutant. Now SBWS has been established, the next step is to develop a nature conservation management plan within the protected area that entails the delineation of zones to facilitate cooperation with people in the sanctuary. The primary goal of this rapid biodiversity assessment was to gather additional biodiversity data to support this effort. The information collected during the study, combined with existing biodiversity data, was utilized to propose preliminary recommendations for the zonation of SBWS. These recommendations are aligned with Cambodia's zoning guidelines for protected areas, as outlined in the document "Zoning Guidelines for the Protected Areas in Cambodia" (GDANCP, 2017). Our effort represents an initial attempt, and a more in-depth analysis is desirable, ideally utilizing higher-resolution biodiversity data. Our recommendations are limited to core and conservation zones. The zoning guidelines define these zones as follows:

Core Zones shall be managed to achieve maximum ecological integrity such as protecting the highest conservation value containing threatened, endangered, and critically endangered species, the most fragile ecosystems, and other natural resources.

Conservation Zones shall be managed to achieve high level of ecological integrity, safeguarding areas of high conservation value containing threatened, endangered, and critically endangered species, fragile ecosystems, natural resources, watershed areas, and natural landscapes, often located adjacent to a Core Zone while still generating revenues from ecotourism activities without or minimum impacts on fauna and flora in the zone.

For clarification and in line with IUCN terminology, we consider species listed as Vulnerable (VU), Endangered (EN) and Critically Endangered (CR) in the IUCN Red List of Threatened Species 2024-2 (IUCN, 2024) as threatened species.

Data and analysis

Data

As a basis for the zonation we used land cover and tree height data (Chapter 3) and superimposed observations collected in this study of birds (Chapter 4), amphibians and reptiles (Chapter 5) and mammals (Chapter 8). Additionally we included the following data in our analysis:

1. Bird observations from boat surveys, mainly from the main channel of the Mekong (2005-2018) by WWF and Bezuijen. Data from Bezuijen et al. (2008) and unpublished records from WWF.
2. WWF bird nest data (2023) - Collected by WWF Cambodia staff. Unpublished records obtained from WWF Cambodia.
3. WWF camera trap data of terrestrial mammals (2020, 2023) - From two short camera trap surveys focussed on Eld's deer in SBWS. Unpublished data from WWF Cambodia.
4. BINCO bird and herpetofauna data (2018) - Collected during a rapid biodiversity assessment in PPWS and SBWS the 2018 dry season. Available from Mittermeijer et al. (2019) and Jocque et al. (2018).

We included a total of 595 observations of 16 threatened species and 80 observations of 13 near threatened species in our analysis (**Table 13** and **Table 14**). The data is highly fragmentary and for instance the paucity of "Near Threatened" species records before 2018 is a reflection of survey effort rather than absence.

Table 13. Location records of IUCN Red listed species in Sambour Wildlife Sanctuary used for preliminary delineation of core and conservation zones including their status as Critically Endangered (CR), Endangered (EN), Vulnerable (VU) and Near threatened (NT). Multiple species/observations may have been made at each location but this data is not available.

English Name	Scientific Name	IUCN Status	Observations
Birds			
White-shouldered Ibis	*Pseudibis davisoni*	CR	293
Giant Ibis	*Pseudibis gigantea*	CR	2
Red-headed Vulture	*Sarcogyps calvus*	CR	4
White-rumped Vulture	*Gyps bengalensis*	CR	9
Masked Finfoot	*Heliopais personatus*	CR	1
Green peafowl	*Pavo muticus*	EN	16
Spotted Greenshank	*Tringa guttifer*	EN	1
River Tern	*Sterna aurantia*	VU	232
Lesser Adjutant	*Leptoptilos javanicus*	NT	51
Red-breasted Parakeet	*Psittacula alexandri*	NT	21
Blossom-headed Parakeet	*Psittacula roseata*	NT	25
White-rumped Falcon	*Neohierax insignis*	NT	9
River Lapwing	*Vanellus duvaucelii*	NT	8
Asian Woollyneck	*Ciconia episcopus*	NT	5
Gray-headed Fish-Eagle	*Icthyophaga ichthyaetus*	NT	73
Mekong Wagtail	*Motacilla samveasnae*	NT	11
Oriental Darter	*Anhinga melanogaster*	NT	3
Great thick-knee	*Esacus recurvirostris*	NT	1
Red-necked Stint	*Calidris ruficollis*	NT	1
Mammals			
Long-tailed macaque	*Macaca facsicularis*	EN	19
Eld's deer	*Rucervus eldii*	EN	4
Indochinese silvered langur	*Trachypithecus germaini*	EN	1
Smooth-coated otter	*Lutrogale perspicillata*	VU	13
Otter sp.	*Lutra (sumatrana/lutra)*	EN/NT	10
Herpetofauna			
Asian Giant Softshell Turtle	*Pelochelys cantorii*	CR	1
Siamese crocodile	*Crocodylus siamensis*	CR	14
Chinese water dragon	*Physignathus cocincinus*	VU	2
Indochinese spitting cobra	*Naja siamensis*	VU	2
Blunt-headed burrowing frog	*Glyphoglossus molossus*	NT	2

Table 14. An overview of the number of observations of threatened and near threatened (in between brackets) species used to identify high priority (core and conservation) nature protection zones in Sambour Wildlife Sanctuary.

Year	Birds	Mammals	Herpetofauna	Total
2003	0	0	2	2 (0)
2004	0	0	1	1 (0)
2005	44	0	4	48 (0)
2006	0	22	1	23 (0)
2007	30	19	1	135 (0)
2008	1	0	0	1 (0)
2009	7	0	0	7 (0)
2010	1	0	0	1 (0)
2011	35	0	0	35 (0)
2012	55	0	0	55 (0)
2013	35	0	0	35 (0)
2014	55	0	0	55 (0)
2015	42	0	0	42 (0)
2016	54	7	0	61 (0)
2017	73	0	0	73 (0)
2018	54 (7)	0	0	53 (7)
2019	0	0	0	0 (0)
2020	1	0	0	1 (0)
2021	2	0	0	2 (0)
2022	0	0	0	0 (0)
2023	35 (71)	8	6 (2)	49 (73)
Total	**524 (78)**	**56 (0)**	**15 (2)**	**595 (80)**

Species Accounts

Here, we provide a brief overview of the status of the most important IUCN Red Listed species of specific conservation concern in SBWS, which were considered for the delineation of core and conservation zones. These are primarily species with recent observation records (2020–2023) and those encountered in sufficient numbers to suggest the presence of viable populations in the area.

White-shouldered ibis (*Pseudibis davisoni*)

The white-shouldered ibis is internationally listed as Critically Endangered on the IUCN Red List (Birdlife International, 2018) and is one of the main species of concern in this area. It nests and roosts in trees, mainly on the main islands, but also in the surrounding dipterocarp forests. With an estimated global population of approximately 670 mature individuals, the wider Sambour area is one of the most critical sites for the species. Notably, 87–95% of the total population is found in Cambodia (BirdLife International, 2019d). Main threats are habitat destruction and the collection of eggs and chicks by local villagers. WWF actively monitors and guards its nests. WWF has a good monitoring system in place and recorded 52 nests in the 2022-2023 breeding season.

Green peafowl (*Pavo muticus*)

The green peafowl is internationally listed as Endangered on the IUCN Red List (Birdlife International, 2018).It is a forest bird which nests on the ground. Green peafowl still seem relatively common on the islands (for instance on Koh Khlab) based on observations in riverine habitat. Camera traps also recorded the species in multiple locations in the riparian and dipterocarp forests along the Mekong river. Hunting and deforestation are known threats, while the abundant free-roaming domestic dogs could be disadvantageous to this species in the region too.

River tern (*Sterna aurantia*)

The river tern is internationally listed as Vulnerable on the IUCN Red List (Birdlife International, 2022). While relatively widespread, the river tern is one of the most threatened birds in Cambodia. An 80% population decrease happened during the past 20 years, leaving only an estimated 54-62 mature individuals. North-east Cambodia supports the last breeding population in the Mekong basin (Timmins 2008), where it relies on sandbars on islands in the Mekong for nest sites. WWF actively guards nest sites against poaching, including the erection of wire mesh enclosures to protect against rats and other terrestrial predators. It is considered Critically Endangered in Cambodia. The remaining pairs are currently being guarded by residents as part of nest conservation efforts by WWF. The impact of egg predation by rats should be evaluated, with eradication programs on breeding and non-breeding islands to be considered to improve breeding success. The sandy beaches on the islands in the Mekong river are critical for its survival.

Spotted greenshank (*Tringa guttifer*)

The Spotted Greenshank is internationally listed as Endangered on the IUCN Red List (Birdlife International 2020b) and winters on coastal mudflats in South-East Asia and breeds in eastern Siberia. its movements between wintering and breeding grounds are poorly understood. We observed a single bird in winter plumage in company with a Common Greenshank (*Tringa nebularia*) on a sandbank at Khang Lok Krau on 7 May 2018. This record fits in the observation that the Mekong may be a north–south corridor for migratory species and that the riverine habitats may provide important stop-over points for migratory shorebirds (Schwilk & Claassen 2012).

Chinese water dragon (*Physignathus cocincinus*)

The Chinese water dragon is internationally listed as Vulnerable on the IUCN Red list (Stuart et al. 2019). This species inhabits evergreen forest, where it is always found in association with streams and rivers. The species was recorded three times, only on islands in the Mekong river. Good quality riverine forest is essential for the conservation of the species.

Eld's deer (*Rucervus eldii*)

Eld's deer is internationally listed as Endangered on the IUCN Red list (Gray et al. 2015) and was recorded in 2023 camera trap surveys by WWF (see data overview for analysis) in the dipterocarp forests in SBWS. The species appears to be widely distributed but at low densities. Further surveys are required to establish the population size and viability of the population. The Eld's deer is threatened by habitat conversion and hunting.

Fish-eagles (*Icthyophaga ichthyaetus* and *I. humilis*)

Both species are internationally listed as "Near Threatened" on the international IUCN Red list

(Birdlife International 2024) Both fish eagle species used to be common in Cambodia and the core zone until at least 2007 (Timmins 2008), but both this study and Mittermeier (2019) recorded only two grey-headed fish-eagles and no lesser fish-eagle. The reasons for their rapid declines remain unknown and need urgent attention, but the presence of an active grey-headed fish-eagle nest may indicate that with adequate measures, the region may provide opportunities as a breeding area.

Lesser adjutant (*Leptoptilos javanicus*)

Lesser adjutant breeding colonies require good quality and relatively undisturbed dipterocarp forest. The species is susceptible to human disturbance at nesting sites, causing very low breeding success, which may have led to a significant historic decline (BirdLife International 2019c). WWF actively monitors colonies, recording 39 nests in SBWS in 2023.

Mekong wagtail (*Motacilla samveasnae*)

The Mekong wagtail is internationally listed as Near threatened (Birdlife International 2020b). The central section of the Mekong River supports one of the largest populations and is therefore of global significance. This species was commonly observed in our study, particularly in fast-flowing stretches characterized by rocky islets with bushes along the Mekong River and hereby confirms the findings of previous surveys (Mittermeier et al., 2019; Timmins, 2008).

Great thick-knee (*Esacus recurvirostris*)

The great thick-knee is internationally listed as Near threatened (Birdlife International 2017). Great thick-knees favour riverbed shingle and rocks, stony banks, but along the Mekong River in Sambour WS occurs on extensive sandbars, a habitat under great human pressure (Goes, 2013; Timmins, 2008). No observations were made during this study because it was not targeted, but it was recorded widely and frequently in 2007 (Timmins, 2008) and eBird (eBird, 2024) data from 2018 suggests it still occurs here.

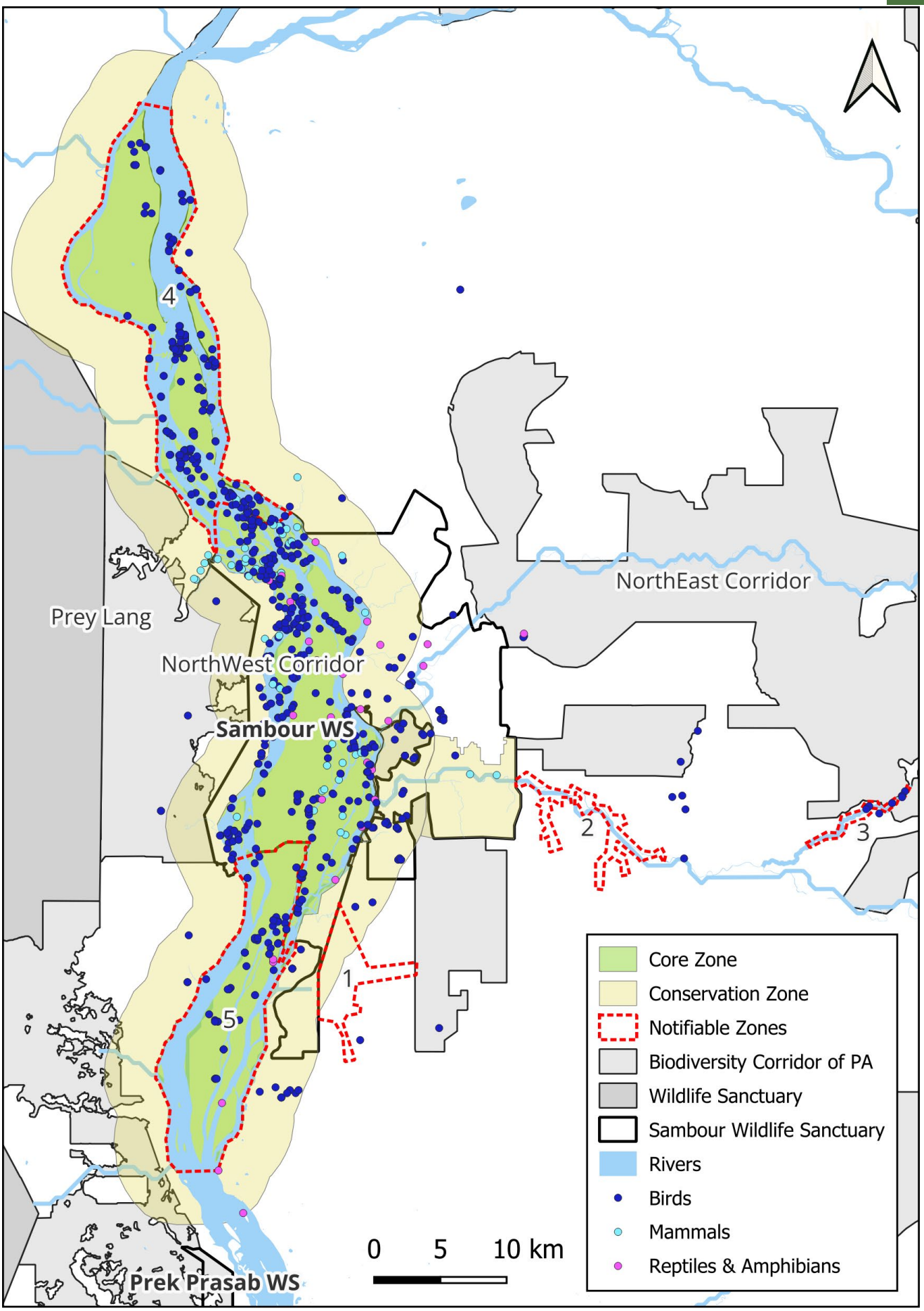

Figure 35. Suggestion for conservation management zones of Sambour Wildlife Sanctuary, with records of species of conservation concern (IUCN internationally Red listed species with a status of CR, EN, VU and NT). Three additional zones, (partly) located outside SBWS, were identified that are of high conservation importance. These are described in the below.

Tentative identification of core and conservation zones in Sambour WS

We used all the available data to create spatial layers in the GIS software QGIS (v3.28.14, QGIS project, 2023). All the available information was combined into a single map and was first visually inspected to identify clusterings of threatened wildlife species and assess habitat quality. Variance analysis of the species observations was used to further define specific boundaries of zones. This resulted in the tentative identification of one core and two conservation zones (**Figure 35**). The core zone includes all the islands in the main Mekong river channel. The adjacent conservation zone surrounds the core zone and extends 4 km either side of the core zone and extends further inland in the South East corner of SBWS.

Suggested core zone in Sambour WS

A visual analysis of the distribution of species of conservation concern (IUCN internationally Red listed species with a status of CE, EN, VU and NT) shows that the majority of these observations are on the islands in the Mekong river. The islands are important for the globally threatened white-shouldered ibis (CR) and green peafowl (EN) and for the threatened river tern (VU). The islands are also important for at least eight Near Threatened bird species: lesser adjutant, Asian woollyneck, grey-headed fish-eagle, lesser fish-eagle, white-bellied sea-eagle, Mekong wagtail, river lapwing, and great thick-knee. They also contain a population of the Chinese water dragon (VU). The core zone falls within BirdLife's 'Mekong River from Kratie to Lao PDR' Important Bird and Biodiversity Area (BirdLife International 2024). Surveys carried out in the core zone between 2005 and 2007 also recorded otters (*Lutra* sp. and *Lutrogale* sp., VU/NT), long-tailed macaque (EN), Indochinese silvered langur (EN), Asian giant softshell turtle (CR), and Siamese crocodile (*Crocodylus siamensis*). The current status of most of these threatened species needs reassessing though, as we expect that these species are now either extremely rare or locally extinct. Based on this information we suggest delineating the islands in the main channel of the Mekong River in SBWS as nature conservation "core zone" (**Figure 35**).

Suggested conservation zones in Sambour WS

On the mainland, there have been a good number of observations of species of conservation concern across SBWS. To define the most effective priority zones, a more detailed species-specific analysis, incorporating high-resolution habitat mapping, is required. The information available for this preliminary analysis indicated that many observations of species of conservation concern in SBWS are closely associated with forested habitats, including several bird species that specifically rely on tall trees for nesting. Consequently, we explored the potential of establishing a riparian buffer zone along the Mekong River to encompass these critical habitats including good quality riverine and dry dipterocarp forest. These support threatened species including Eld's deer (EN), long-tailed macaque (EN), green peafowl (EN) and nest locations of white-shouldered ibis (CR). It also contains nesting colonies of lesser adjutants (NT), while white-rumped falcon (NT) remains common.

By plotting all observations of threatened bird species, we analyzed the data for potential breakpoints in the series using the PELT (Pruned Exact Linear Time) algorithm from the changepoint package in R. This approach helped identify a breakpoint that would encompass the majority of the observations

(**Figure 36**). A clear cutoff point was identified at just under 4 km from the Mekong River. Based on this analysis, we propose defining a conservation zone as a 4 km buffer from the river's edge. This zone would encompass the majority of nesting sites for threatened bird species and include critical forest habitats for species conservation. Special attention here should be devoted to safeguarding the riparian/riverine forest and any tall trees as these are crucial nesting places for many river-associated birds.

Based on the high quality and extent of riverine and dipterocarp forests, combined with observations of Eld's deer, green peafowl and long-tailed macaque, we further suggest the conservation zone to extend to the Eastern edge of SBWS in the south, to include the O'Krieng River. With more surveys, areas of particular importance may be identified, warranting the establishment of additional core zones.

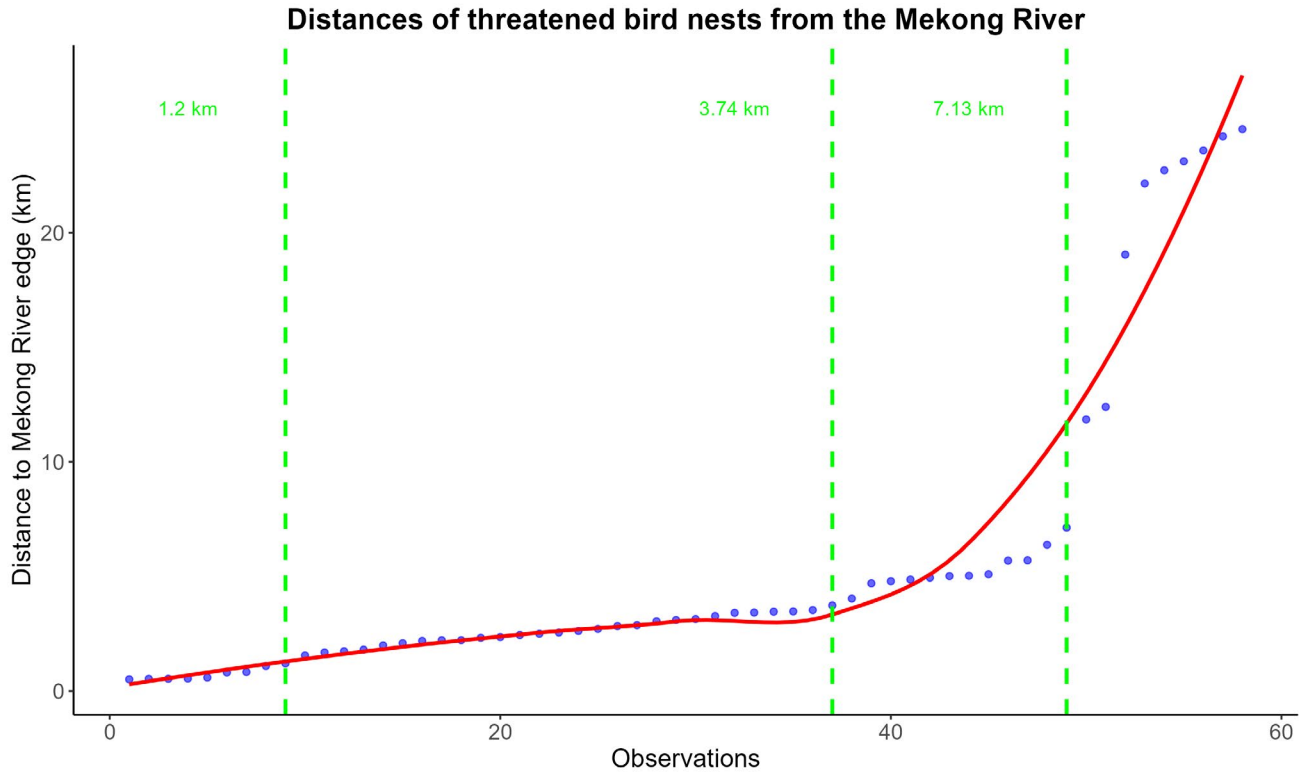

Figure 36. Recorded distance of nest sites for threatened bird species from the edge of the Mekong River (the core zone). The X-axis provides the numbered individual observations.

Regions with high conservation value and good ecological potential outside Sambour WS

Based on land cover analysis and species occurrence we identified some areas located outside SBWS that are either of known high conservation importance (**Figure 35**, corresponding numbers 1–3) and ideally should be included in Sambour WS.

1. **Forested area located in the south of SBWS.** Analysis of satellite imagery indicates that this area still contains high quality evergreen forest. Little data is available from this region. We recommend surveying this area to assess its conservation value before the habitat disappears or is degraded. Results may warrant the area to receive formal protection, and inclusion in SBWS.

2. **O'Krieng River section, bordering SBWS in the southeast.** Satellite image analysis indicates that the river banks still contain riverine forest, which is of high importance for reptiles and amphibians, and which might disappear without adequate protection. Otters have been recorded in the O'Krieng river section that is part of SBWS. The adjacent area would provide a buffer for the protection of these species. We recommend surveying this section to assess its conservation value.

3. **River section approximately 25 km East of SBWS.** Multiple nests of white-rumped and red-headed vultures were recorded here between 2015 and 2017. There are few observations of nesting sites for these threatened species and this well defined cluster with permanent nest sites of vultures would benefit from formal protection to reduce disturbance and enhance breeding success and monitoring of the site.

4,5. **The islands in the Mekong River outside SBWS.** These are a vital habitat for many threatened species. However, there are several islands in the areas that are not, or only partly, included in SBWS, but whose habitats (nesting trees, sandbars) are of significant conservation concern, particularly for threatened birds. To ensure effective protection of these habitats and the species they support, it is of utmost importance to extend the protected area and its core zone to include the remainder of islands outside of the SBWS. Additionally, delineation of the boundaries of SBWS, rather than leaving them partially included, could facilitate better communication and collaboration with local communities. This approach would help avoid confusion about the exact location of borders and ensure more streamlined management and conservation efforts.

Limitations, next steps and conclusions

A tentative delineation of core and conservation zones is presented, based on available observations of species of conservation concern from the past 10 years. However, this information is highly fragmentary and incomplete. Comprehensive up-to-date distribution data exists for a number of threatened species (mainly birds), which would meet the definitions of the establishment of a core and conservation zone. However, this data is lacking for many others in SBWS (e.g. Eld's deer, otters, primates, tortoises). It is important to understand their distribution status and assess the need to extend conservation actions here as well such as the cause for the disappearance of both fish eagle species and the status and distribution of green peafowl. The aim here was to initiate the zonation

process and provide a preliminary baseline delineation as a starting point, with the intention of improving and refining it over time.

For a more thorough analysis, detailed habitat classification is essential. Higher resolution satellite data allows better analysis of land cover, and will help provide a more detailed picture of land cover types. This will help improve delineation of conservation zones, including zones that have not been included in this study. Additionally, more comprehensive data on non-avian groups—including plants, large mammals, amphibians, and reptiles—as well as other taxa such as bats, small mammals, fish, and selected invertebrates (e.g., butterflies, dragonflies) are crucial for a reliable and balanced identification of priority core zones for nature conservation. Further surveys looking at these particular groups, including the start up of standardised monitoring for other taxonomic groups such as reptiles would be most valuable.

The available observations clearly highlight the islands in the Mekong River as priority conservation areas. We propose including these islands in the core zone of Sambour Wildlife Sanctuary (SBWS). However, several of these islands are only partially included in the current SBWS boundary, and their full inclusion would significantly enhance conservation efforts and provide greater ecological value.

6 Conclusions

Our surveys are part of a continuous effort to map the biodiversity of two wildlife sanctuaries (Prek Prasab and Sambour Wildlife Sanctuaries) in Kratie, Cambodia, and identify high conservation value areas in Sambour WS to aid in the production of an adequate zoning strategy.

The area is of specific importance for the bird community, showing a great diversity and density of species. During our surveys we recorded 192 bird species, bringing the total recorded species (including our 2018 surveys) to an impressive 252. Threatened species included: white-shouldered ibis (*Pseudibis davisoni*), green peafowl (*Pavo muticus*), river tern (*Sterna aurantia*) and great slaty woodpecker (*Mulleripicus pulverulentus*). A further eight species are classified as Near Threatened.

We tentatively recorded 36 species of reptiles and 24 species of amphibians, including nine species that were not directly recorded during previous surveys within the sanctuaries. These included 22 frog, two toad, 17 lizard and 19 snake species. No turtles were recorded despite targeting suitable habitat. We recorded 1 species categorized as Near Threatened (NT), 2 as Vulnerable (VU), and 1 as Data Deficient (DD). All other species are categorized as Least Concern (LC). Some of the identified genera however, comprise threatened species (e.g. *Sylvirana* spp.), but are not yet reported here because identification is still ongoing.

We collected at least eight subfamilies and 40 ant genera, including at least three new genera records for Cambodia (*Paratopula* Wheeler, 1919, *Bothroponera* Mayr, 1862, *Vollenhovia* Mayr, 1865 and *Platythyrea* Roger, 1863). We also collected 700 butterflies, 1000 moths, and 80 invertebrate samples (multiple specimens).

We recorded the highest biodiversity and most specialist species in the larger, least disturbed, habitats. Closed forest bordering water bodies such as streams are of high conservation value for reptiles, amphibians, and ants while the Mekong River and its islands harbour most threatened bird species. However, surrounding good-quality dry dipterocarp forest has also a great value for woodpeckers and other rare specialists, and provides nesting trees for storks and large raptors.

Surveys in SBWS did not focus on mammals, while they form an important part of the wildlife community as seed dispersers and predators, landscape designers and fertilisers. Despite large mammals not being included in our survey effort in SWBS, these were still observed and recorded, either directly or through tracks, during other surveys. The lack of large mammal activity reported during our time in the field indicates that mammal density and diversity in SBWS is low. This is consistent with previous findings from PPWS, from which we also reported very low large mammal diversity and density. Camera trap surveys targeting terrestrial species and thermal drone or transect surveys targeting arboreal species will improve our understanding of the large mammal community in SBWS.

Both wildlife sanctuaries have experienced, and continue to experience, different threats including livestock grazing, hunting and conversion to agriculture. In SBWS we observed areas of degraded and converted habitat including riverine and dipterocarp forests, but large stretches of good quality dipterocarp forest remain, with a seemingly high density and diversity of bird species, making the

area potentially suitable for ecotourism. Even so, species that are traditionally hunted (deer, tortoises, turtles, primates) and that could still be expected to survive here, were either rare or not recorded.

The conservation situation in PPWS is worse. Very little good quality habitat is left, with only small patches of floodplain grassland, essential for hog deer conservation, remaining. Details are covered in a separate report. These grasslands are under imminent threat. We observed new agricultural fields being created in grasslands, with livestock grazing in existing grasslands occurring throughout the hog deer conservation zones. The dipterocarp forests here have been either selectively logged or clear cut for livestock grazing, cashew or rice production. Some of these pastures have been abandoned and in places the forest is regrowing. However, bird diversity remains high, including records of lesser adjutant, great slaty woodpecker and white-rumped falcon.

Despite these human pressures, both Sambour and Prek Prasab Wildlife Sanctuaries remain of great biodiversity value, holding some moderately good habitat. They contain a large number of species of conservation concern, making them part of one of the global biodiversity hotspots (Myers et al., 2000). Although some species appear to have become either locally extinct or extremely rare, both areas hold significant potential for these (threatened) species to return and or increase in abundance, providing the necessary habitat is available.

With proper management, requiring local community involvement, a lot of this biodiversity can be protected. This is evidenced by WWF's excellent work on hog deer in PPWS and threatened bird species in SBWS, and may in the future include reintroductions of (near) extinct species such as tortoises and turtles.

We provided an initial zoning outline for SBWS, with the central section of the Mekong River in and around SBWS designated as a core zone, and a surrounding buffer as conservation zone. Some of the islands that we included in the core zone, however, are not part of SBWS or other protected areas, and have a lower, or no, conservation status, leaving a significant proportion of threatened species populations vulnerable to extinction. Their inclusion in SBWS would greatly benefit a great proportion of threatened species.

The Greater Mekong is a remarkable and diverse region, with the Mekong River the jewel in the crown. We have a duty to preserve its unique and rich biodiversity as it provides a lifeline for plants, wildlife and humans alike.

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