



THE  
WILDERNESS  
PROJECT

RIVER REPORT

AN IN-DEPTH SURVEY  
OF THE KAFUE RIVER

2024-2025

## ABOUT THE WILDERNESS PROJECT

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The Wilderness Project (TWP) is a non-profit organisation dedicated to advancing the research and conservation of Africa's major freshwater basins by establishing detailed hydrological and ecological baselines.

In 2022, TWP launched the Great Spine of Africa series of expeditions to document, explore and protect over 1.2 million km<sup>2</sup> of largely understudied headwaters and watersheds across the Zambezi, Okavango, Congo and Nile Basins. To date, and in close collaboration with partners, TWP has completed 75 expeditions, conducting vital research along more than 30,000 km of rivers, lakes, and wetlands — including often-overlooked systems such as the Cassai, Chambeshi, Kabompo, Ruvubu, Akanyaru, and Cuito.

Through these expeditions, TWP generates critical baseline data to inform long-term freshwater management and conservation. The organisation's overarching goals are to: i) Assess the status of Africa's freshwater ecosystems; ii) Identify areas of critical concern or conservation significance; iii) Support the efforts of governments and NGOs working in the freshwater conservation space; iv) Develop local scientific and storytelling capacity; and v) Generate interest and catalyse funding for the conservation of freshwater ecosystems in Africa.



*Above: The expedition team travels through the Kafue Flats.*

*Cover page: water abstraction, ferry boats and the expedition team on the banks of the Kafue River.*

## EXECUTIVE SUMMARY

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The Kafue River is amongst the most vital yet imperilled waterways in Zambia. It originates on the Katanga Plateau near the border with the Democratic Republic of Congo, before flowing for over 1,620 km through Zambia, meeting the Zambezi River downstream of Lake Kariba. On this journey, the Kafue traverses several areas of natural, cultural and economic importance. The river is vital to the biodiversity of 17 national parks, game management areas and conservancies, which together form the Greater Kafue Ecosystem.

The Kafue remains understudied, particularly in its upper reaches. There are no known cases of contiguous data along the entire river, and as a result, there is no established baseline for the river. This makes it difficult to monitor changes over time, with baselines shifting as the river slowly degrades. Additionally, a lack of open-access, high quality data has left catchment management authorities underprepared to address mounting environmental challenges — especially those related to contamination, invasive species and habitat loss.

With the aim of addressing this knowledge gap, The Wilderness Project conducted a comprehensive research expedition along the Kafue River in March–June 2024. The team travelled from the source of the Kafue to its confluence with the Zambezi, assessing the river’s biodiversity, water quality and flow. The team also collected visual survey data to understand how people interact with the river. Using a 360-degree camera, and a series of drone photographs, the team mapped the river, collecting footage that serves as a virtual library for future generations. This effort, which took place over the course of 82 days, represents the most comprehensive survey of the full length of the Kafue River to date.

The Wilderness Project returned in June 2025 to re-sample strategic sites within the Kafue National Park and upstream. This effort aimed to further develop the baseline dataset, accounting for interannual changes in water quality and biodiversity. The key findings, methodologies, and recommendations are presented herein, representing a knowledge contribution that will support the management and conservation of the Kafue River for generations to come. Select data are viewable via an interactive Esri WebMap, accessible here: [Kafue River Experience](#).



# 1620 km



Traversed by foot, kayak  
and canoe

## 2024 Expedition

March - June

175

Research Sites Established

82

Days on expedition

## 2025 Expedition

June

42

Research Sites

21

Days on expedition

## KEY FINDINGS

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### ***Fishing Pressure Is the Highest Recorded by TWP in the Zambezi Basin***

A total of 2,126 active fishers were recorded — nearly one fisher per km of river. This is three times the average density along the Zambezi River. Findings suggest that up to 95% of fishing gear in use is non-compliant with national regulations.

### ***Protected Areas Function as Critical Biodiversity Refugia***

A total of 5,119 animals from 18 species were recorded along the river. Wildlife density within Kafue National Park and Mushingashi Conservancy was five times higher than unprotected areas. The spatial inversion between wildlife and people confirms that protected landscapes are the primary refuges along the river corridor.

### ***Hippos Are Increasingly Concentrated in a Single Area***

The survey recorded 2,413 hippos — substantially fewer than reported in 2007. The vast majority were concentrated between Mushingashi Conservancy and Itezhi-Tezhi, indicating spatial contraction and growing reliance on protected river stretches.

### ***Drought Intensifies Ecological Compression***

Within Kafue National Park, wetland bird abundance declined from 2,235 individuals (54 species) in 2024 to 1,051 individuals (45 species) in 2025 — a 53% reduction. Severe drought conditions likely concentrated wildlife in the main channel during 2024, highlighting the river's importance as a dry-season refuge.

### ***Sediment Contamination Confirms Persistent Mining Influence***

Geochemical analyses revealed clear enrichment of cobalt, copper, arsenic, cadmium and lead in river sediments, particularly near the Mwambashi and Kitwe reaches. While dissolved metals in the water column were less pronounced, sediments are acting as long-term contaminant reservoirs with potential for remobilisation during floods and chemical shifts.

### ***Ecological Health Declines Through the Copperbelt***

Macroinvertebrate assessments across 26 sites produced an average ZISS score of 68.2 ( $\pm 17$ ), with 13.8 taxa per site. Scores were consistently lower where sediments are known to be contaminated, and improved only with distance from the Copperbelt, suggesting persistent ecological stress aligned with upstream industrial and land-use pressures.

### ***Wetlands Buffer the River***

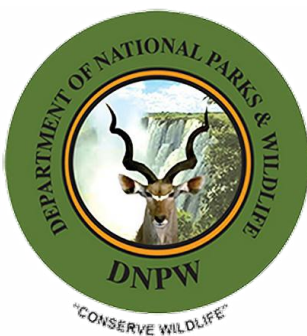
Improvements in water chemistry downstream of major wetland systems — including the Kwesa Floodplain, Lukanga Swamp and Kafue Flats — confirm their role as natural biofilters. However, increasing upstream contamination, altered flow regimes, and climate variability raise concerns about the long-term resilience of these systems.

### ***Improved Monitoring and Enforcement Systems are Urgently Needed***

Existing national monitoring infrastructure lacks the capacity to detect short-term contamination events, cumulative sediment loading, or widespread fisheries non-compliance in real time. Without strengthened enforcement and repeated, standardised basin-wide surveys, the degradation of the Kafue River may become irreversible.

## ACKNOWLEDGEMENTS

The successful implementation of our research transects is made possible through the commitment and collaboration of our institutional partners, whose support provides essential river access, research permissions, logistical facilitation, and critical local expertise. We express our sincere appreciation to: Zambia Environmental Management Agency (ZEMA), Department of National Parks and Wildlife (DNPW), Ministry of Fisheries and Livestock (MFL), Copperbelt University (CU), African Parks (AP), the Water Resources Management Authority (WARMA), the International Crane Foundation (ICF), the University of Zambia (UZ), and the Wild Bird Trust (WBT). Finally, to the traditional custodians of the river, who granted us permission to navigate the waters and lands of the Kafue — *natotela*.



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## 1. INTRODUCTION

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### 1.1 Study Site Description

#### Geographical Overview

The Kafue River originates on the Katanga Plateau in the North-Western Province, on the border between Zambia and the Democratic Republic of Congo (Figure 1). From its source, it flows over 1,620 km through the Copperbelt, Central, and Southern provinces, skirting the border of Lusaka Province, before contributing ~9% to the total flow of the Zambezi River below Lake Kariba. The Kafue is one of Zambia's most important rivers, draining nearly 20% of the country's land surface and supporting half of Zambia's population<sup>1</sup>.



Figure 1. The Kafue River basin covers an approximate area of 155,000 km<sup>2</sup>. It represents roughly 20% of Zambia's total land area and is a major tributary of the Zambezi River.

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<sup>1</sup> Lower Kafue River Basin Report Card: Methodology Report. 2020. WWF Zambia.

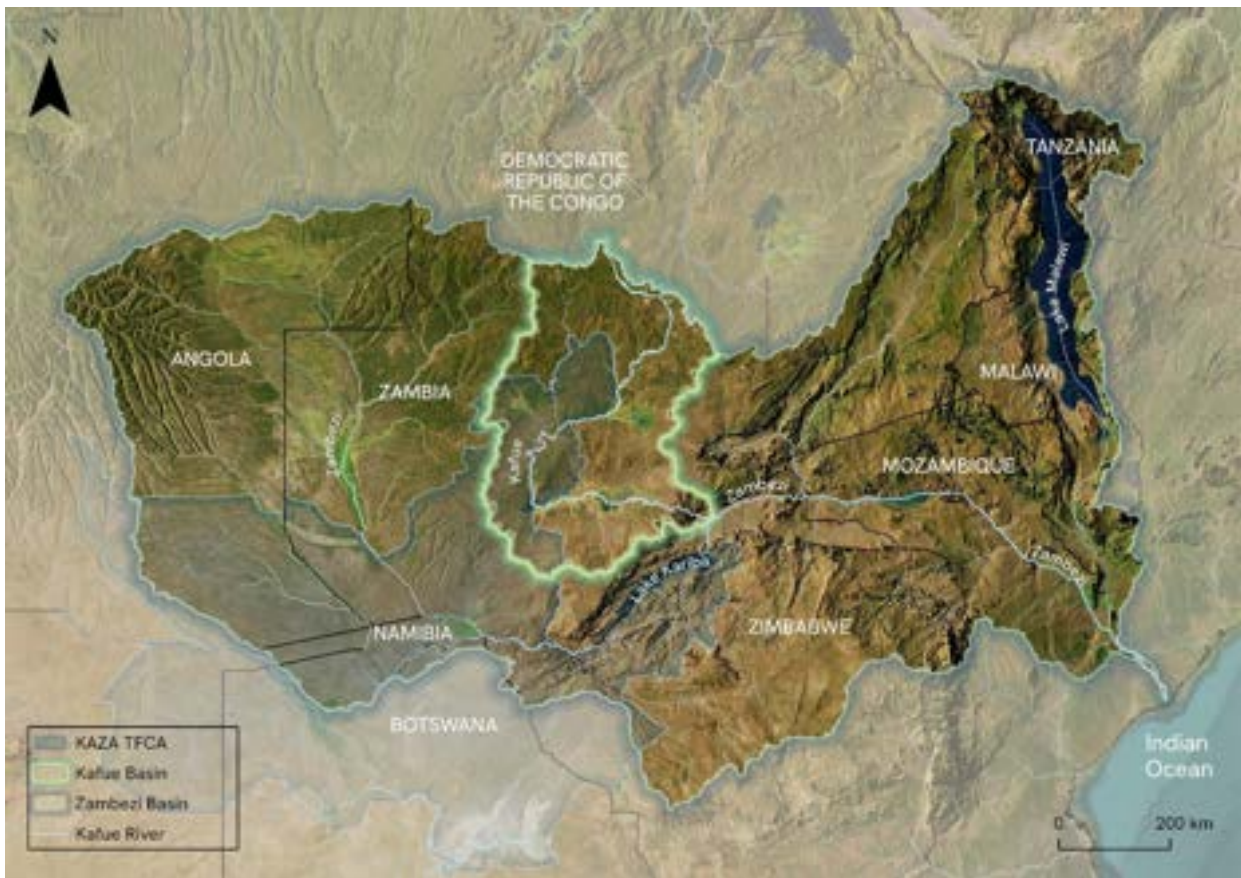


Figure 2. The relative position of the Kafue Basin within the Zambezi Basin.

### River Sections

The Kafue River changes substantially along its course, with several unique biogeographical features (Figure 3, Table 1). The river can loosely be divided in 15 sections, each of which has: i) varying degrees of human settlement; ii) unique hydrological characteristics, including flow and depth; and iii) different floodplain widths. In most cases, biodiversity is also likely to vary between these sections.

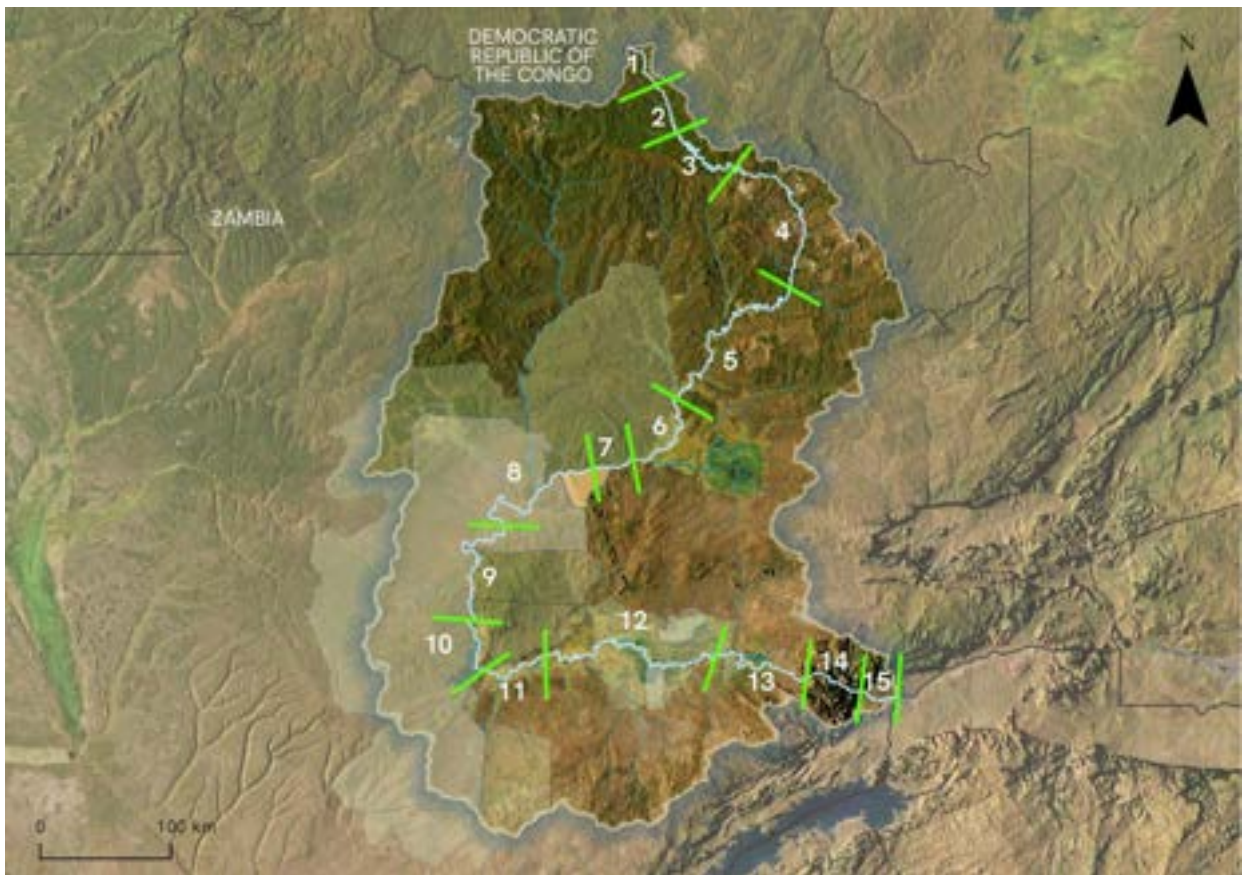












Figure 3: Unique sections of the Kafue River. The numbers in the figure correspond to the descriptions in Table 1 below.

Table 1: Distinct sections of the Kafue River based on hydrological and biogeographical characteristics.

River Section	Description	Photograph
<p><b>1. Kafue Source</b></p>	<p>The source area is characterised by an expanse of dambo wetlands that are fed by a network of small tributaries. These are bordered by mixed miombo woodlands, interspersed by open savannah.</p>	
<p><b>2. Kwesa Floodplain</b></p>	<p>A permanent floodplain, up to 5 km wide and ~50 km long. There is no defined river channel within the floodplain. Surrounding vegetation is dominated by Phragmites reeds.</p>	
<p><b>3. Seasonal Floodplain</b></p>	<p>A seasonal floodplain, with permanent stands of Phragmites reeds along the river channel, interspersed with riparian forest. Protected by the Chimfunshi Wildlife Sanctuary.</p>	
<p><b>4. Copperbelt/Kitwe</b></p>	<p>An area that is strongly influenced by human activity, particularly mining and urban settlement. The river channel is shallow, with several rapids.</p>	
<p><b>5. Luanshya / Mpongwe</b></p>	<p>Near Luanshya/Mpongwe, water turbulence reduces, and the river returns to a well-defined main river channel. Agriculture is common, with some evidence of mining activities.</p>	

<p><b>6.Lukanga Confluence</b></p>	<p>Near the Lukanga River confluence, the Kafue River opens into a seasonal floodplain, where fishing is common. The western bank of the river falls within the Lunga Luswishi Game Management Area (GMA).</p>	
<p><b>7.Kaindu</b></p>	<p>Kaiundu has a markedly higher human footprint than many other areas of the Kafue River. Most of this activity is centred around fishing, agriculture and livestock grazing.</p>	
<p><b>8.Mushingashi / Kafue NP</b></p>	<p>Along the Mushingashi Conservancy and Kafue National Park, the Lunga and Lufupa Rivers merge with the Kafue. The river is predominantly bordered by riparian forests, with a narrow floodplain relative to the Kaindu section above.</p>	
<p><b>9.Kafwala Rapids</b></p>	<p>The Kafwala Rapids are the second major rapids on the Kafue River and are located within the Kafue National Park. Here, bands of rock create islands within the river that are commonly inhabited by crocodiles.</p>	
<p><b>10.Itezhi Tezhi</b></p>	<p>Below the Kafwala Rapids, the Kafue River drains into a 390 km<sup>2</sup> man-made reservoir formed by the Itezhi Tezhi Hydroelectric Dam. This reservoir supports a multi-species artisanal fishery and a smaller commercial fishery for introduced kapenta<sup>2</sup>.</p>	

<sup>2</sup> The term 'kapenta' usually describes the Lake Tanganyika sardine, *Limnothrissa miodon* and Lake Tanganyika sprat, *Stolothrissa tanganyicae*, found in many large waterbodies throughout Africa.

<p><b>11.Namwala</b></p>	<p>Below Itezhi Tezhi, there is intense grazing pressure along the historical floodplain. As a result, riparian vegetation is not as dense as upstream and woodland cover is reduced.</p>	
<p><b>12.Kafue Flats</b></p>	<p>The Kafue Flats is a 6,500 km<sup>2</sup> Ramsar Wetland of International Importance<sup>3</sup>. Papyrus is the dominant marginal vegetation within this wetland.</p>	
<p><b>13.Mazabuka/Kafue Town</b></p>	<p>Towards the end of the Kafue Flats, the floodplain constricts and there is an increase in human activity, particularly agriculture and tourism.</p>	
<p><b>14.Kafue Gorge</b></p>	<p>The steep topography of the lower Kafue River makes the Kafue Gorge well-suited to hydropower production. As a result, the Upper and Lower Kafue Gorge hydropower stations are located here. There are several dry stretches where the entire river is re-routed through tunnels.</p>	
<p><b>15.Lower Kafue</b></p>	<p>Below the Kafue Gorge, the river reaches its confluence with the Middle Zambezi River — just upstream of the Mana Pools UNESCO World Heritage Area. Here, water from the Kafue is used for commercial agriculture, mining and domestic supply.</p>	

<sup>3</sup> Zambia Wildlife Authority. 2006. Ramsar Information Sheet: Kafue Flats. Available: <https://rsis.ramsar.org/RISapp/files/RISrep/ZM530RIS.pdf>.

## Economic Importance

The Kafue River basin is home to nearly eight million people, constituting almost half of Zambia's population. Of these, ~65% reside in urban centres, while 35% live in rural areas. Major cities within the basin include Lusaka (3,324,000 people), Kitwe (792,000 people), Ndola (627,000 people) and Kabwe (288,000 people) (Figure 4).



Figure 4: Urban areas, provincial boundaries, and major reservoirs along the Kafue River. Reservoirs along the Kafue River include the Itezhi Tezhi, Kafue Gorge Upper (KGU) and Kafue Gorge Lower (KGL).

As much as 44% of the water used in Lusaka is drawn from the Kafue sub-basin<sup>4</sup>. The Kafue Gorge Dam on the Lower Kafue River produces an estimated 50% of Zambia's national hydroelectricity supply<sup>5</sup>. As a result, the annual gross domestic profit (GDP) from economic activities associated with the Lower Kafue River was 48 billion Kwacha (1.78 billion USD) in 2018, however this has likely grown substantially in recent years<sup>6</sup>.

Mining is a major economic driver in Zambia. Copper and cobalt alone represent approximately 12% of the country's GDP, while the entire mining sector accounts for over 17%<sup>7</sup>. The Zambian Copperbelt, located almost entirely within the Kafue Basin, holds some of the highest known concentrations of sedimentary-hosted copper deposits on the planet. Mining these sediments is the cornerstone of the country's economic development strategy, and as a result the Kafue Basin has over 680 active mining

<sup>4</sup> Water Resources Management Authority (WARMA), Zambia. 2022. *Kafue Catchment*. Available at: [www.warma.org.zm](http://www.warma.org.zm).

<sup>5</sup> Water Resources Management Authority (WARMA), Zambia. 2022. *Kafue Catchment*. Available at: [www.warma.org.zm](http://www.warma.org.zm).

<sup>6</sup> WWF. 2018. *Water Situational Analysis of the Lower Kafue Basin. Socio-Economic Development and Climate Change: Risks and Opportunities*.

<sup>7</sup> Zambian Ministry of Finance and National Planning. 2024. *Annual Economic Report*.

licenses, of which 85 are for large-scale operations<sup>8</sup>. These large-scale operations constitute almost 90% of the total mining area within the basin, much of which is located near the towns of Kitwe, Chililabombwe, Chingola and Ndola.

The Kafue River is also a critical source of hydropower for Zambia. There are three hydropower dams along its mainstem: Itezhi Tezhi, Kafue Gorge Upper (KGU) and Kafue Gorge Lower (KGL) (Figure 5). The KGU Dam, completed in 1973, has a generation capacity of 990 MW but a relatively small water storage volume. To address this limitation, the Itezhi Tezhi Dam was completed upstream in 1977, increasing storage capacity crucially and supporting hydropower generation. Itezhi Tezhi has an installed capacity of 120 MW. In 2023, the KGL Power Station became operational, adding an additional 750 MW to the national grid. Collectively, these facilities on the Kafue River account for over 55% of Zambia's total power generation.



Figure 5. Some of the river infrastructure along the Kafue River. 1) a weir in the upper section of the river; 2) Itezhi-tezhi Dam and hydropower station; 3) and 4) Kafue Gorge Lower Dam and hydropower station.

Approximately 20% of Zambia's cattle graze within the Kafue Flats, with Namwala, Itezhi-Tezhi, and Mumbwa districts forming the core of the country's largest livestock production area. Cattle farming is deeply embedded in local economies and cultures through the traditional *kuwila* transhumance system, which enables seasonal access to nutrient-rich pastures and supports herd productivity<sup>9</sup>. Beyond its cultural value, *kuwila* contributes to food security, employment, and income generation. However, hydrological alteration from dam operations and increasing climate variability have reduced grazing areas, disrupted seasonal movements, and intensified competition for land and water, threatening the long-term economic viability of pastoral livelihoods.

<sup>8</sup> Zambia Mining Cadastre Map Portal. *Zambian Ministry of Mines, Energy and Water Development and Spatial Dimension*. Accessed on 30th July 2025. Available at: <https://portals.landfolio.com/zambia/>.

<sup>9</sup> Manford, M. 2025. *The Symbolic Concepts of Transhumance [Kuwila] in The Kafue Flats Among the Tonga People of Mwanachingwala, Hamusonde and Mungaila in Southern Province, Zambia*. *British Journal of Multidisciplinary and Advanced Studies*. 6(1):23–36. DOI: 10.37745/bjmas.2022.04213..

## Climate and Hydrology

Most of the Kafue River Basin lies within a humid subtropical climate, with the north-western headwaters classified as subtropical highland<sup>10</sup>. Temperatures are warm year-round, averaging approximately 21°C. Rainfall is spatially variable, with northern areas receiving up to 1,400 mm annually, compared to around 700 mm in the drier southern basin. Strong seasonality drives pronounced fluctuations in river discharge, as most precipitation occurs during the wet season (October–April), followed by a prolonged dry period from May to September.

The Kafue Expedition was conducted between March and June 2024, during the transition from the wet to the dry season. However, the 2023–2024 wet season was marked by exceptionally low rainfall, with some regions receiving half or less of average precipitation, prompting a national state of emergency in November 2023. During the survey, the basin was experiencing one of the most severe droughts on record, resulting in widespread crop failure, reduced river flows, and a contraction of riparian and floodplain habitats (Figure 6).

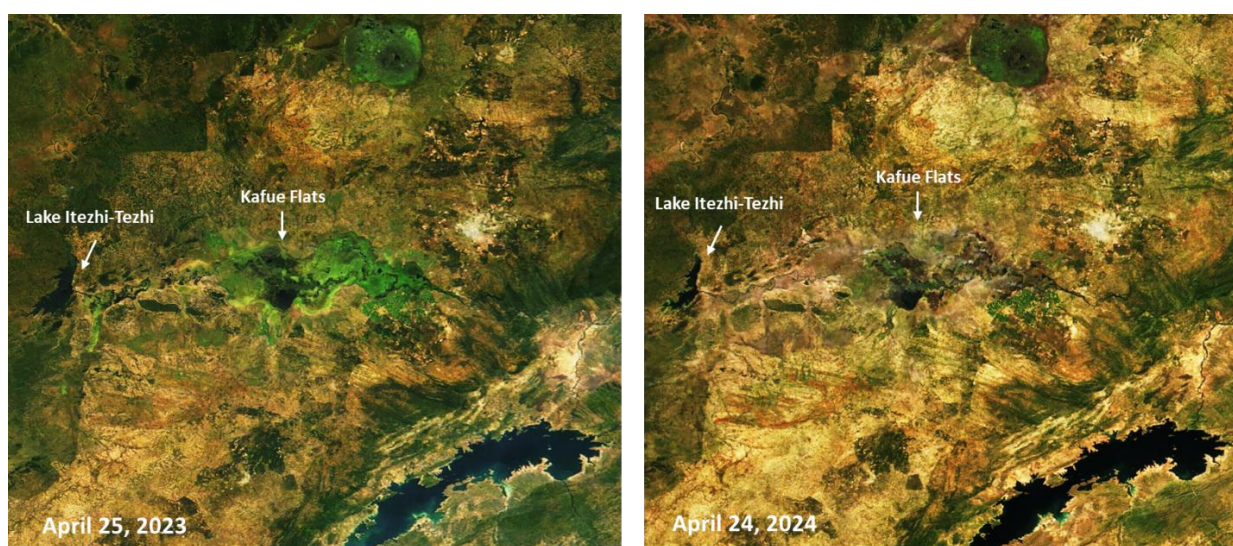


Figure 6. Satellite images from NASA Earth Observatory<sup>11</sup> show how exceptionally low rainfall in the 2023–2024 wet season influenced the landscape of the Kafue River. On April 24, 2024, when the bottom image was taken, the team was on the river.

## Important Conservation Areas

Much of the Kafue River Basin lies within the Kavango-Zambezi Transfrontier Conservation Area (KAZA TFCA) (Figure 7), the world’s largest transboundary conservation initiative. Covering 519,912 km<sup>2</sup> across Angola, Zambia, Namibia, Botswana, and Zimbabwe, KAZA TFCA connects national parks, game reserves, and conservation zones, allowing wildlife to move freely across international borders. It promotes cross-border conservation, biodiversity protection, and sustainable land use, while supporting ecotourism and local economies.

Within KAZA TFCA, the Greater Kafue Ecosystem (GKE) spans 66,000 km<sup>2</sup>. At its core is Kafue National Park

<sup>10</sup> Peel, M.C. et al. 2007. Updated world map of the Köppen-Geiger climate classification. *Hydrology and Earth System Sciences*. 11(5):1633–1644. DOI: 10.5194/hess-11-1633-2007.

<sup>11</sup> NASA Earth Observatory. 2025. Parched Kafue Flats. Available at: <https://earthobservatory.nasa.gov/images/152746/parched-kafue-flats>

(KNP), Zambia's largest national park at 22,400 km<sup>2</sup>. Surrounding KNP are nine Game Management Areas (GMAs) and two conservancies, which serve as buffer zones that support wildlife movement and habitat conservation. The GKE also includes Busanga Swamp, one of three Ramsar Wetlands of International Importance in the basin.

Further downstream, the Kafue Flats Complex forms a critical wetland system along the river. This 6,000 km<sup>2</sup> floodplain includes Lochinvar National Park (428 km<sup>2</sup>), Blue Lagoon National Park (500 km<sup>2</sup>), and the Kafue Flats GMA. Recognized as a Ramsar Wetland of International Importance, the Kafue Flats support seasonal wildlife migrations, sustain key fisheries, and provide vital water resources for local communities and Zambia's economy. Further north, the Lukanga Swamp, another Ramsar-designated wetland, plays a key role in regulating water flow into the Kafue River while supporting fisheries and wildlife.

National parks cover ~23,330 km<sup>2</sup> of the basin, and prohibit human settlement, except for personnel involved in park management and tourism. Game management areas (GMAs) span ~52,000 km<sup>2</sup> and typically allow for some level of human settlement and wildlife use. As a result, biodiversity and human activity typically vary substantially between national parks and GMAs.

Game management areas are typically managed through traditional land tenure systems, with support and oversight from the Zambian government. These areas play an important role as buffer zones around critical wildlife habitats, providing massive conservation benefits to the GKE. Unlike national parks, GMAs typically allow for trophy and subsistence hunting, and need to be carefully managed to ensure that resource-use remains sustainable — particularly in the face of rapid human settlement growth in the Kafue Basin.

In July 2022, African Parks entered a 20-year management partnership with the Zambian Government to oversee Kafue National Park. Similarly, in 2023, the International Crane Foundation (ICF) signed a similar 20-year collaborative agreement to support the restoration and management of Lochinvar and Blue Lagoon National Parks. This partnership includes key stakeholders such as the Zambian Department of National Parks & Wildlife (DNPW), the World Wide Fund for Nature (WWF), and the Endangered Wildlife Trust (EWT).

Together, the GKE and Kafue Flats Complex represent the most significant conservation clusters within the Kafue River Basin, encompassing a diverse mix of national parks, GMAs, wetlands, conservancies, and wildlife reserves. For more information on past and ongoing conservation initiatives in the Kafue Basin, see Appendix 1.



Figure 7: Nearly one-third of the Kafue River Basin is encompassed by the Kavango–Zambezi Transfrontier Conservation Area (KAZA TFCA), underscoring the basin’s ecological significance within southern Africa’s largest transboundary conservation initiative.

## 1.2 Research Design

### Research Approach

#### 2024 Baseline Methodology

Along the 1,620 km transect, survey data and 360° imagery were collected continually, with other data at fixed points (Table 2, Figure 8). Survey data was divided into the following categories: i) human activity; ii) agriculture; iii) infrastructure; iv) biodiversity; v) and fire. In addition, every ~10 km, water quality was analysed, and aerial fixed-point images were recorded. At ~50–75 km intervals, eDNA samples were collected and a benthic macroinvertebrate survey was conducted. An acoustic bat recorder was deployed overnight at campsites, along with several traps for freshwater fish and crustaceans. Finally, where suitable sites were identified, river flow was measured using acoustic doppler current profiler (ADCP).

#### 2025 Resurvey Methodology

In June 2025, a 300 km stretch of the Kafue River alongside the Kafue National Park was resurveyed using the same baseline methodology. Additionally, several of the 2024 research sites within the Copperbelt were revisited in 2025 to collect eDNA, macroinvertebrate, water quality, and sediment samples. Importantly, the Copperbelt research effort did not include a boat-based survey, so visual survey data was not collected. These resurveys aimed to: i) better-understand the interannual variability of the Kafue River; and ii) confirm the hippo count within the Kafue National Park.

Table 2: Summary of the data collected along the Kafue River transect. Data collection is arranged according to collection frequency.

Data Collection Frequency	Data Category
Continuous	GPS track 360° video Survey forms relating to human activity, agriculture, infrastructure, biodiversity and fires
Every 10 km	Water quality analysis Fixed point aerial drone surveys
Every ~50–75 km	Benthic macroinvertebrate sampling using the Zambian Invertebrate Scoring System (ZISS) Environmental DNA (eDNA) sampling
Every Night	Acoustic bat recording Trap and net deployments for fish and invasive crayfish
Opportunistic	Fish sampling Discharge measurement

TWP expeditions are typically conducted on self-propelled vessels, including canoes, kayaks, and inflatable rafts. These are chosen according to river conditions. In addition, some sections are walked, including areas that are impassable by boat — for example, the river source, dam walls or dangerous rapids. On the Kafue River, there were three areas that were traversed on foot rather than in a vessel: i) the initial 60 km, where the river was too small and overgrown to paddle; ii) a 20 km stretch in the Kafue National Park, where the river disappeared through a boulder field; and iii) ~15 km in two stretches between the Upper and Lower Kafue Gorge Dams.

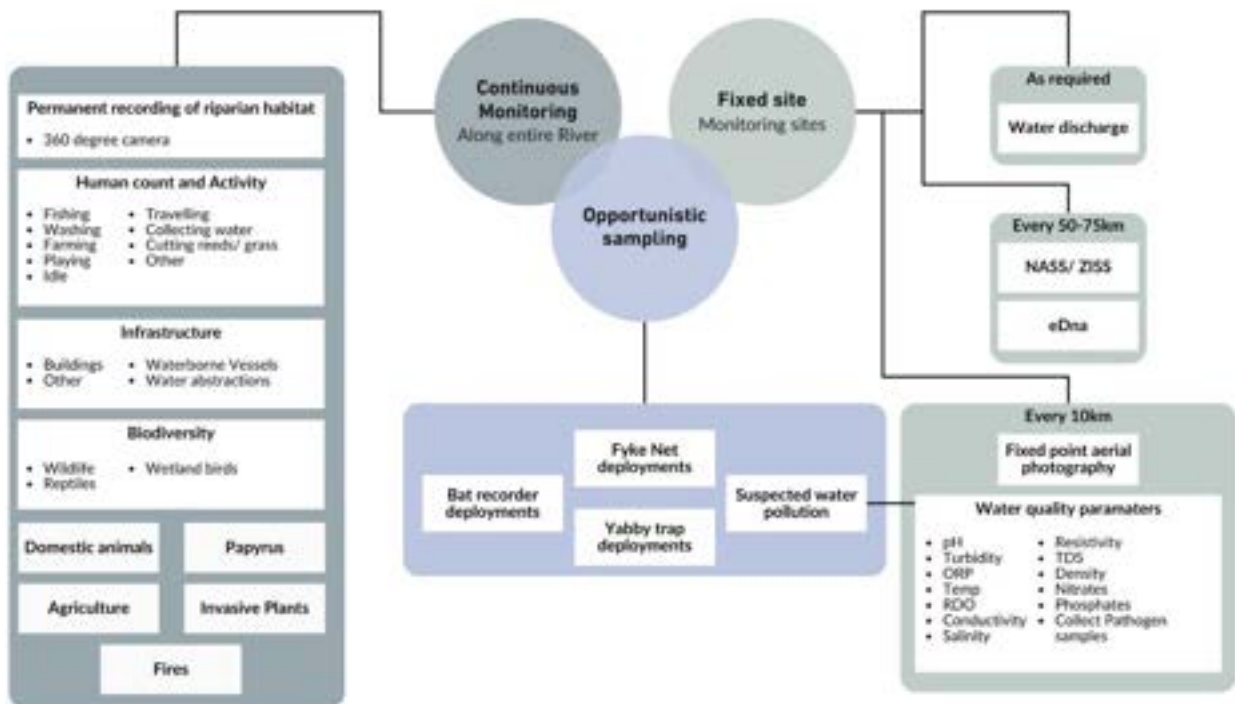


Figure 8: Summary of the data collected on the Kafue River.



Figure 9. Canoe-based river surveys during the Lungwevungu expedition, illustrating the use of self-propelled vessels for continuous transect sampling in navigable sections of the river.

## Survey Limitations and Potential Data Bias

It is important to note that there are several limitations and potential biases involved with data collection on rivers. These can limit the statistical confidence of data analysis and should be considered when interpreting data. In addition, data limitations and potential biases require due consideration when making management decisions or using data for scientific purposes. Survey limitations and potential data biases that are specific to the Kafue River expedition include:

- Our expeditions follow the main river channel. As such, oxbow lakes, backwaters and lagoons are excluded from our surveys.
- Observers only count what is visible from their vessels.
- Vegetation density and riverbank height, prevailing weather, team health, rapids, sharp corners in the river, sand banks and other uncontrollable variables can obscure observations or introduce observer bias.
- Survey time is restricted to daytime hours between 08:30 and 16:00. Some days are longer or shorter than others, depending on field conditions and other logistical variables.
- Fish sampling techniques vary and sampling effort is not consistent between sites.
- The presence or absence of people along rivers is influenced by the time of day, as people may spend more time by the river in the mornings and evenings when collecting water, bathing or washing clothes. Additionally, human activity is generally higher along rivers on weekends. As a result, human activity densities should be combined with supplementary census information to ensure that they are fully representative of people along the river.
- This data does not represent the permanent state of the river. It offers a snapshot of the river against which future data can be compared.
- It is important to note that in Zambia, regulations require a 50 m buffer of riparian vegetation, meaning that commercial crops are typically planted farther from the water's edge, reducing their visibility from the river. However, small-scale farmers are less likely to adhere to these regulations, as they often lack irrigation infrastructure and must plant closer to the water. As a result, most of the agriculture detected in this survey is small-scale subsistence agriculture.

## 2. VISUAL SURVEY RESULTS

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The process of collecting survey data on the transect involved two parties: the observer and the recorder. The observer visually scanned the river and its banks for relevant observations within 100 m from the water's edge. Sightings of relevance were then relayed to the recorder who used a smartphone to input the data into Survey123 (ESRI). Information obtained for each sighting included the : i) count; ii) side of the river; and iii) other important notes. From Survey123, data were uploaded to a cloud database for safekeeping. Survey123 forms were created beforehand and set to automatically assign geolocation, date, and time to each entry.



Figure 10: The expedition team paddling through the Kafue National Park.

### 2.1 Human Activity

#### Methods: Human Counts and Activity

The distribution of people along the Kafue River provides an important indicator of river-dependent livelihoods and resource-use dynamics within the riparian zone. Accordingly, all individuals interacting with the Kafue River were counted, regardless of age, sex, or ethnicity. Their activities, categorised below, are quantified and discussed throughout this section to understand the various ways in they rely on the Kafue River.

- Those present within the riparian zone, but not obviously engaged in any identifiable activity, were categorised as **inactive**.
- Some people were **collecting water** from the river.
- Many people were **farming**, including those who were tilling, sowing, harvesting, watering, building enclosures around their farms or other related activities.
- People using nets, traps, hook and line or other means to catch fish were considered to be **fishing**. Those involved in the cleaning or repairing of fishing nets were included in this category.

- **Herding**, logged separately to the *farming* category, included those controlling, feeding, gathering, moving, and tending to their livestock.
- Many people were **travelling** on foot, by motorbike or in a waterborne vessel.
- Those in the process of cleaning their bodies or clothes were **washing**.
- **Other activities:** Other activities on the Kafue River were recorded and categorised. Some specific activities which may have disproportionately large impacts on river health are discussed below.

#### Results and Discussion: Human counts and activity

The Kafue River has a moderate density of people along its banks, with an average of 49 people/10 km. This is slightly higher than the Zambezi Basin average of 41 people/10 km, calculated by TWP across over 6,000 km of surveys within the basin. However, it is lower than the Zambezi River mainstem (65 people/10 km), which has a particularly high population density in Mozambique.

People are distributed unevenly along the Kafue River, which is more densely populated in its lower sections. This is likely because of the productive fisheries in the area. Similarly, the Lunga Luswishi/Machiya Fungulwe GMA and adjacent riverbank also has a high population density (Figure 11). Urban centres within the Copperbelt are hotspots of river-related activities, including fishing.

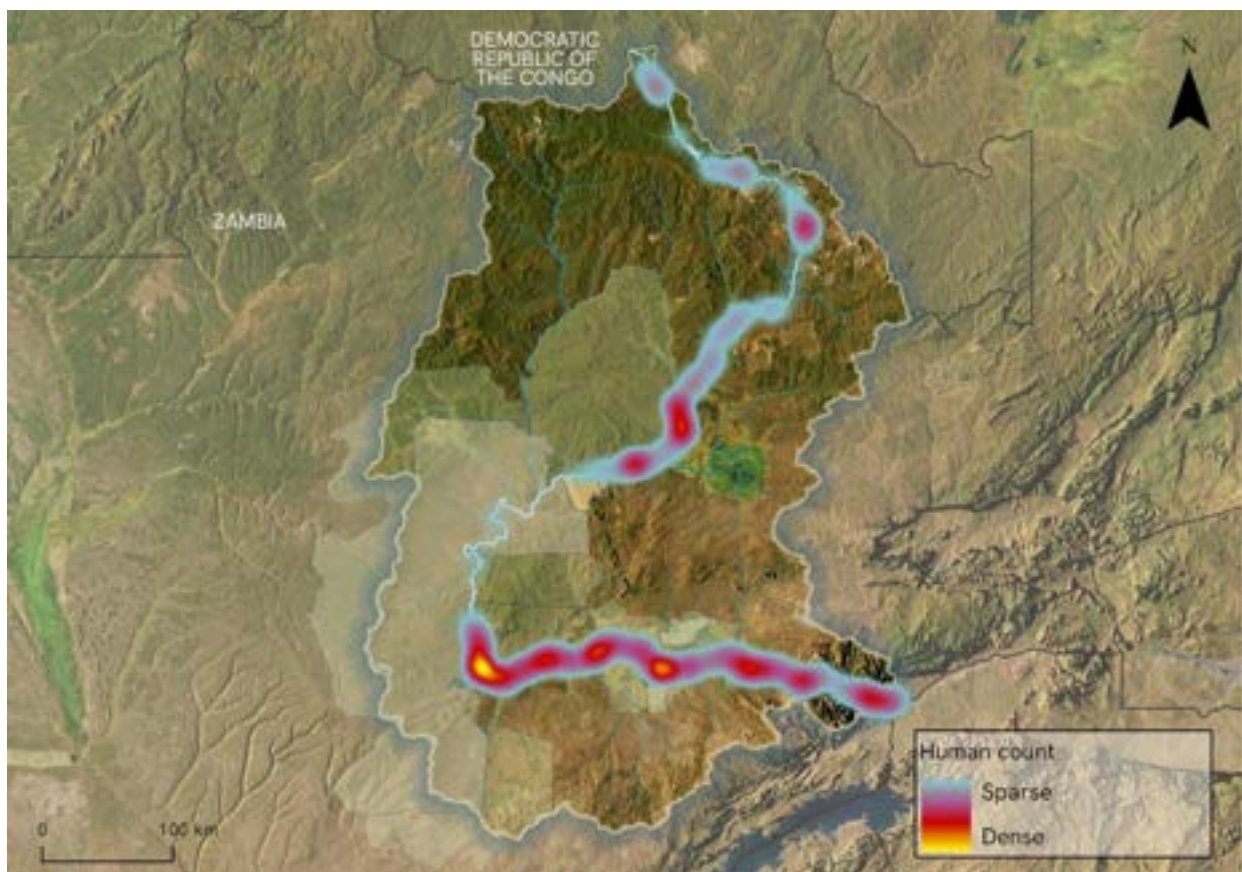


Figure 11: Distribution of human activity along the Kafue River.

Most people along the Kafue River were inactive (N=3,118), fishing (N=2,126) or travelling (N=1,231) (Table 3). In addition, a further 512 people were indirectly involved with fishing by either cleaning nets or processing fish. Cumulatively, these four categories accounted for almost 90% of activity, with fishing and fishing-related activities accounting for over 30%.

Table 3: Counts of human activities observed along the Kafue River.

Activity	Human count	Percentage of total count
Inactive People	3,118	39.6
Fishing	2,126	27.0
Travelling	1,231	15.6
Indirectly involved in fishing <sup>1</sup>	512	6.5
Collecting Water	205	2.6
Washing	198	2.5
Farming	176	2.2
Construction	121	1.5
Herding Livestock	58	0.7
Other Activities	129	1.6
<b>TOTAL</b>	<b>7,874</b>	<b>100</b>

<sup>1</sup>Processing fish, cleaning nets and repairing nets

### Fishing

There are at least 15,000 fishers that rely directly on the Kafue River, collectively supporting approximately 160 fishing villages and over 70,000 people<sup>12</sup>. Approximately 70% of these live within the Kafue Flats, which contributes over 20% of Zambia’s inland fish production (valued at ZMW 714 million/US\$30 million)<sup>13</sup>. Fishers use various methods, including gillnets, basket traps, longlines, hook and line, and *kutumpula* — where fish are driven into nets by beating the water<sup>14</sup>. Once harvested, fish are sun-dried, smoked, or salted before reaching markets, such as Chunga, Nakambala, Kalukulu, and Namwala. These markets handle an estimated 1,177 tonnes of fish annually (dry and wet weight), valued at approximately USD 1.4 million.

Despite its value, the Kafue fishery faces growing pressures. A WWF situational analysis of the Kafue Flats found that unregulated fishing has contributed to overexploitation and growing ecological stress<sup>15</sup>. For example, 30% of fishers do not adhere to the December–February fishing ban, which is designed to protect breeding cycles. Additionally, while fishers are required to obtain licenses, the authorities impose no limits on the number issued, leading to excessive fishing effort. Compliance monitoring is also minimal, further exacerbating stock depletion. These regulatory gaps are not unique to the Kafue River but reflect a broader challenge across the Zambezi River Basin, where enforcement struggles to control illegal fishing<sup>16</sup>.

In addition to overfishing, other pressures such as invasive species and damming have also led to changes in species composition and catches. Nile tilapia (*Oreochromis niloticus*) and redclaw crayfish (*Cherax quadricarinatus*) outcompete native fish, alter food webs, and degrade habitat quality, reducing fish diversity and productivity. Meanwhile, altered water flows disrupt the natural flood pulse downstream, lowering nutrient availability and diminishing individual catch rates. Reviewing the current water release plan and implementing an invasive species management plan could help to restore some ecological

<sup>12</sup> *Zambian Ministry of Fisheries and Livestock. 2024. Capture Fisheries Frame Survey: Summary Report.*

<sup>13</sup> *Aquatic Ecosystem Services and WWF. 2020. Situational Analysis of Fish and Fisheries of the Kafue Flats Wetland Ecosystem. WWF Summary Report. (August 2020):1–20.*

<sup>14</sup> *Aquatic Ecosystem Services and WWF. 2020. Situational Analysis of Fish and Fisheries of the Kafue Flats Wetland Ecosystem. WWF Summary Report. (August 2020):1–20.*

<sup>15</sup> *Aquatic Ecosystem Services and WWF. 2020. Situational Analysis of Fish and Fisheries of the Kafue Flats Wetland Ecosystem. WWF Summary Report. (August 2020):1–20.*

<sup>16</sup> *Tweddle, D. 2010. Overview of the Zambezi river system: Its history, fish fauna, fisheries, and conservation. Aquatic Ecosystem Health and Management. 13(3):224–240. DOI: 10.1080/14634988.2010.507035.*

balance and support the fishery's long-term sustainability.



*Figure 12: A dugout canoe filled with small fish in the Kafue Flats.*

The TWP survey recorded 2,126 active fishers along the Kafue River, with a density of almost one fisher every km (Figure 13). This is the highest recorded by TWP in the Zambezi Basin to date — 3X higher than the Zambezi River average. Importantly, this survey does not provide an indication of total fishing effort, which is estimated over 4,500 fishers in the Kafue Flats alone<sup>17</sup>.

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<sup>17</sup> Aquatic Ecosystem Services and WWF. 2020. *Situational Analysis of Fish and Fisheries of the Kafue Flats Wetland Ecosystem*. WWF Summary Report. (August 2020):1–20.

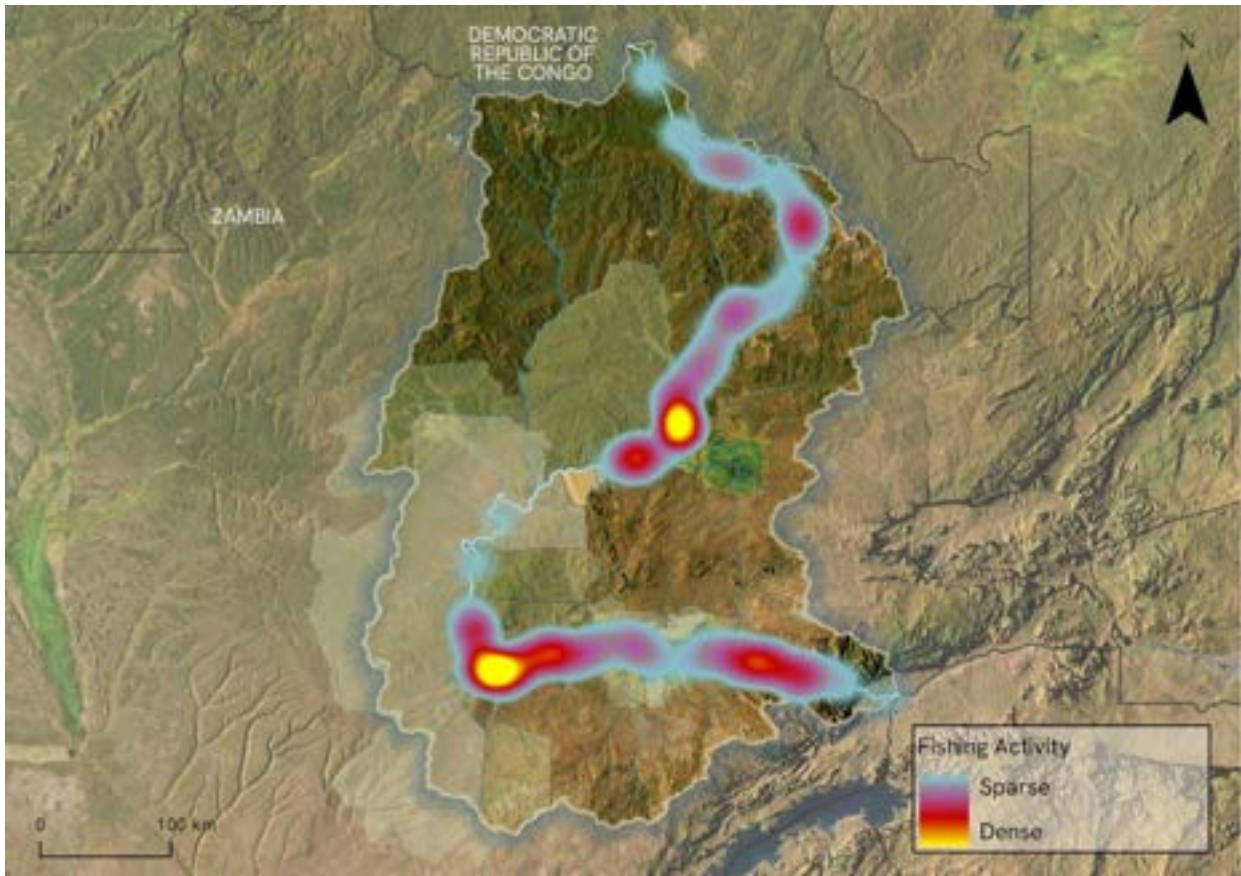


Figure 13. The distribution of people actively fishing along the Kafue River.

*Fishing Gear*

Fishing gear is generally present within the riparian zone throughout the day — either deployed, in-use or along the banks of the river — even when people are not actively fishing. As a result, the count and distribution of fishing gear can indicate the intensity of fishing pressure. Along the 2024 survey, the distribution of fishing gear broadly mirrored that of fishing activity, with clear hotspots in areas such as Lunga Luswishi GMA and Itezhi-Tezhi Reservoir (Figure 14). Additionally, fishing gear was present continuously along the entire length of the Kafue Flats, indicating sustained fishing activity even in the

absence of fishers during the survey.

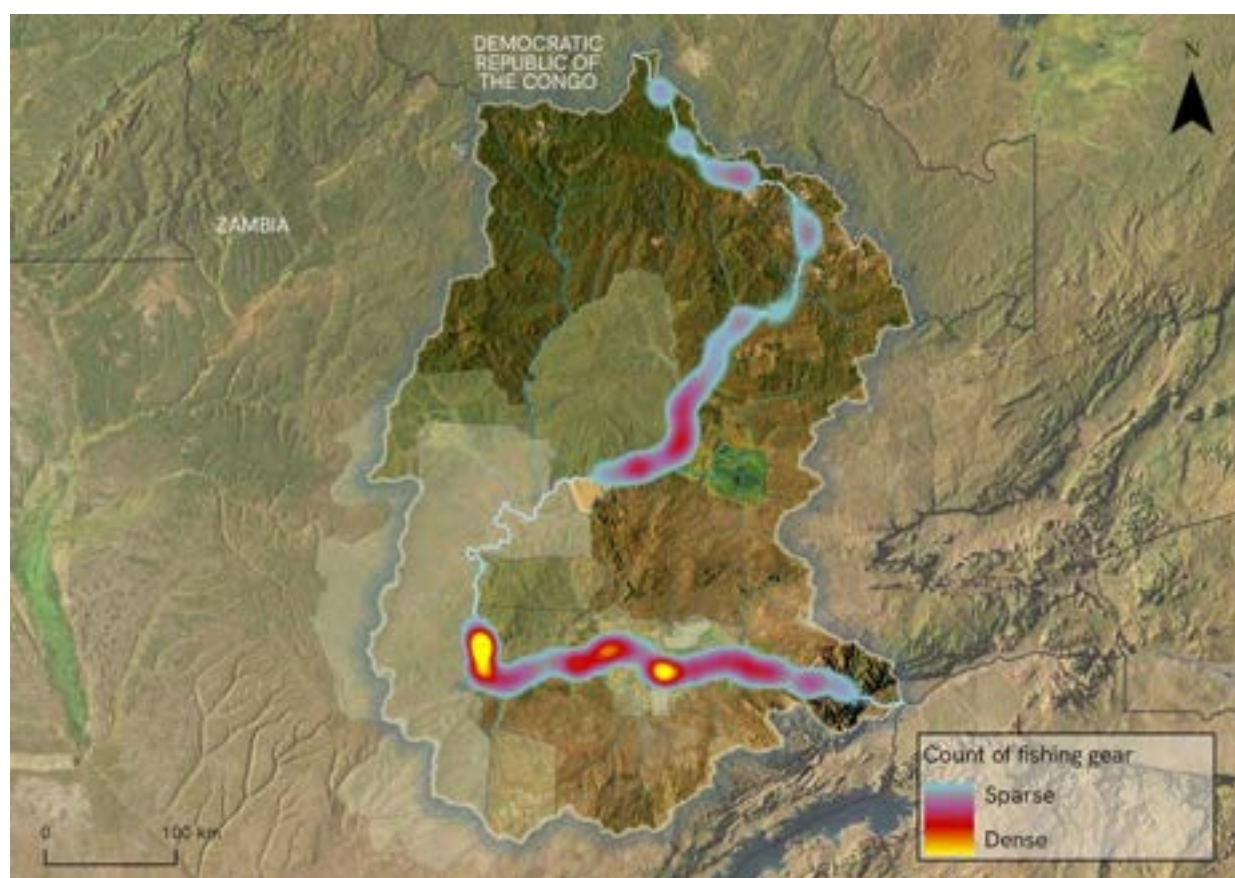


Figure 14. Distribution of fishing gear along the Kafue River.

Eight types and 7,156 items of fishing gear were present along the Kafue River. This includes set nets (N = 4,836), drag nets (N = 673), fishing lines (N = 777) and fishing traps (N = 676) (Table 4). The density of fishing gear along the Kafue (44 items/10 km) is notably higher than regional rivers such as the Zambezi River (7 items/10 km) and Chambeshi River (12 items/ 10km).

Table 4: Counts of fishing gear along the Kafue River

Fishing gear	Count
Gill nets	4,836
Drag nets	673
Fishing lines	777
Fishing traps	676
Other fishing apparatus <sup>1</sup>	78
<b>Total</b>	<b>7,156</b>

<sup>1</sup>Includes weirs (N=55), dip nets (N=12), trotlines (N=5), cast nets (N=2) and unknown fishing techniques (N=4).

#### Gill nets

Gillnets are used to catch fish in tropical and sub-tropical freshwater ecosystems across Africa. They are cheap, accessible, and often favoured for their high catch-per-unit-effort and ability to target a range of fishes. They are primarily distributed in floodplain environments (Figure 15), where they are effective for

catching cichlids, catfishes, and mormyrids — key targets of local fisheries<sup>18</sup>. However, the high effectiveness of gillnets can intensify overfishing. As a result, gillnets of 2.5 inch and above are the only legal gear on the river according to the fisheries act, except for Itezhi Tezhi where purse seines set for kapenta are also legal.

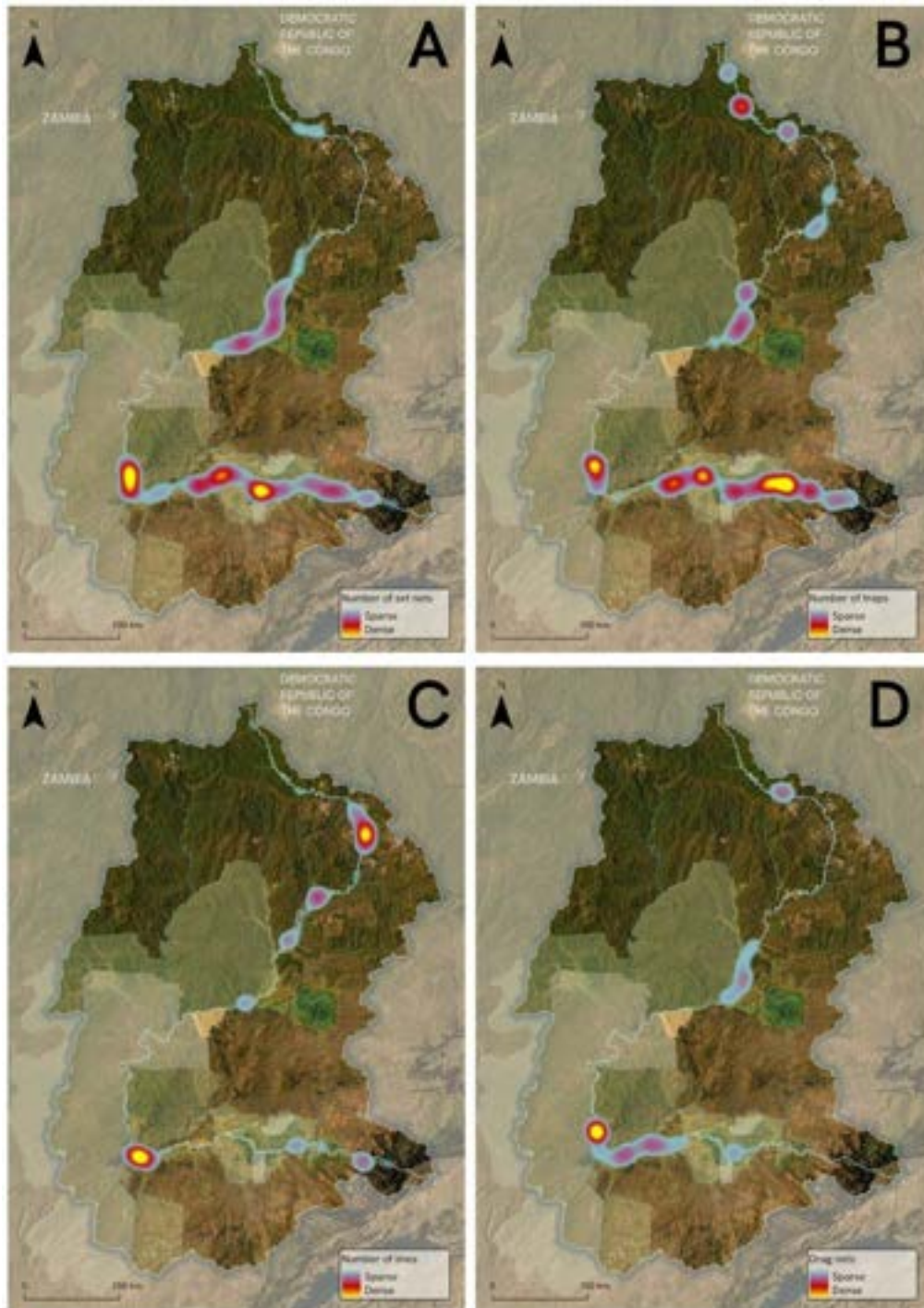


Figure 15. Fishing Gear along the Kafue River transect. A = Gill nets; B = Drag nets; C = Lines; D = Traps.

#### Mosquito and Shade-cloth Nets

The use of mosquito and shade-cloth nets for fishing in Zambia is under-recorded and poorly documented

<sup>18</sup> Status of the Kafue Flats Fishery. 2019. WWF-Zambia.

in the literature<sup>19</sup>. This practice has proliferated with increased access to mosquito nets, particularly through initiatives aimed at reducing the prevalence of malaria in the region. These nets are commonly used as seine nets by creating a wide arc around a target area to entrap large quantities of fish at a time. This is the preferred method for targeting kasepa<sup>20</sup> — a term for several species of small fish, including the *Procatopodidae* (topminnows), *Pseudocrenilabrus* (dwarf cichlids) and *Smilogastrini* (cyprinid barbs), which are dried and sold in bulk.

While this method is effective for capturing large quantities of fish, it is also indiscriminate, often catching non-target species and juveniles. In the Kafue Flats and other Zambian wetlands, dragnets have become increasingly common as fishers shift from passive gears like gillnets, to active techniques, in an effort to sustain catch rates in light of declining stocks (Figure 16)<sup>21</sup>.



Figure 16. A drag/seine net in the Bangweulu Wetlands, northern Zambia.

#### *Fish Traps and Weirs*

Fish traps are traditional fishing instruments commonly used in the Kafue River's floodplains (Figure 15). Fishers construct these traps within weir structures made of reeds and wood, altering the natural flow of river margins and wetlands to improve fishing efficiency. These structures serve two main purposes: i) damming sections of the river to create optimal conditions for net and trap placement, and ii) guiding and concentrating migrating fish to enhance catch rates.

#### *Illegal Fishing Gear*

A significant portion of the fishing gear used on the Kafue River does not comply with regulations (Figure 17). Zambia's fisheries are governed by the Fisheries Act (Act No. 22 of 2011), which prohibits monofilament gillnets, gillnets below a certain mesh size (ranging between 2 and 2.5 inches depending on the province), all drag nets, fishing weirs that obstruct the entire river, and mosquito netting. While the

<sup>19</sup> Short R. et al. 2018. *The use of mosquito nets in fisheries: A global perspective. PLoS ONE 13(1)*.

<sup>20</sup> Kapenta is a similar term that usually describes the Lake Tanganyika sardine, *Limnothrissa miodon* and Lake Tanganyika sprat, *Stolothrissa tanganicae*, found in many large waterbodies.

<sup>21</sup> *Status of the Kafue Flats Fishery. 2019. WWF-Zambia.*

exact proportion of non-compliant gear on the Kafue River is unknown, our observations suggest that at least 95% of the fishing equipment in use fails to meet legal standards. Previous studies indicate that at least 47% of gillnets in the Kafue Flats have mesh sizes below the legal limit, and dragnet use remains widespread<sup>22</sup>.

To address non-compliant fishing practices, a comprehensive Fisheries Management Plan for the Kafue Fishery was developed in 2011; however, it has yet to be implemented. Strengthening fisheries management requires greater support for enforcement efforts and the activation of this plan. Providing resources, enhancing capacity-building initiatives, and fostering community engagement could improve compliance and promote sustainable fishing practices.

The Mushingashi Conservancy fish breeding area stands as a successful intervention, demonstrating how well-managed protected zones can restore fish stocks and support local fisheries. Established in collaboration with local fishers, the breeding area has already led to measurable improvements. Data shows a 58% increase in the average catch rate of angling species between 2018 (when the breeding area was established) and 2022. Local fishers also report improved catches outside the protected zone, reinforcing the effectiveness of the 'spill-over' effect. A comprehensive fisheries assessment is needed to identify other areas where this model can be replicated successfully along the Kafue River.



Figure 17: Illegal fishing gear and methods were prevalent throughout the system. Extremely long, monofilament gillnets, with a mesh size smaller than the legal limit (left) and a fishing weir blocking the entire river, preventing fish movement (right).

#### Travel

Travel along the Kafue River was almost evenly divided between land-based (N = 544, 44%) and water-based modes (N = 683, 56%). The most common mode of travel was on foot (N = 483), followed by dugout canoes (N = 468) and other paddle vessels (N = 105). Dugout canoes are fashioned from large trees and are used predominantly for fishing and travelling (Figure 18).

<sup>22</sup> Tweddle, D. 2010. Overview of the Zambezi river system: Its history, fish fauna, fisheries, and conservation. *Aquatic Ecosystem Health and Management*. 13(3):224–240. DOI: 10.1080/14634988.2010.507035.



Figure 18: Traditional dugout canoes on the banks of the Zambezi River.

Wooden dugout canoes are commonly an indicator of fishing activity, however they are also used for general transport. Over 90% of the vessels on the river were dugout canoes, with 76% of them not in use at the time of the survey (Table 5). The high proportion of inactive vessels suggests significant human activity along the river that was not captured during the survey.

The use of dugout canoes and other types of vessels for fishing and transport is more common on the Kafue River than elsewhere in Zambia. For example, the densities of vessels on the Chambeshi River (10 vessels/10 km) and the Zambezi River within Zambia (24 vessels/ 10 km) are lower than the Kafue (33 vessels/10 km). Given that most vessels are used for fishing, this provides further evidence that the Kafue River fisheries are heavily utilised.

Table 5: Parked and in-use vessels along the Kafue River.

Type of vessel	Vessel Count
<b>Dugout canoe</b>	
In Use	1,147
Parked	3,544
Sub-Total	4,691
<b>Other Paddle Boat</b>	
In Use	52
Parked	442
Sub-Total	494
<b>Motorised Boat</b>	
In Use	27
Parked	151
Sub-Total	178
<b>Other Vessels</b>	
In Use	1
Parked	7
Sub-Total	8
<b>Grand Total</b>	<b>5,371</b>

### Charcoal Production

Charcoal production, transportation and household-use are widespread along the Kafue River (Figure 19). The process of charcoal production typically involves felling several trees and burying them underground in *chibili chamalasha* (earthen charcoal ovens). Within these ovens, the wood gradually smoulders in the absence of oxygen, resulting in a hardy, slow-burning fuel that can be used for cooking, boiling water or household heating. In Zambia, it is estimated that 70% of households rely on charcoal to meet their energy needs<sup>23</sup>.

Whilst charcoal is an essential fuel for livelihoods, charcoal production is a direct driver of deforestation. For example, to supply Lusaka alone, it is estimated that at least 197.4 km<sup>2</sup> of miombo woodlands are cleared annually<sup>24</sup>. In many cases, this deforestation drives habitat loss, reduces biodiversity, and encourages soil erosion — directly resulting in the degradation of nearby waterbodies. However, for communities living in remote areas, charcoal is often the only fuel option available. This is because alternative fuels such as diesel, petrol or paraffin are expensive and in short supply. Moreover, the national electricity grid seldom reaches rural villages. Without alternatives, deforestation for charcoal production in the Kafue Basin is likely to continue — despite ongoing efforts to counteract this practice<sup>25,26</sup>.



Figure 19: A charcoal kiln in operation (left) and transportation of charcoal (right).

## 2.2 Infrastructure

### Methods: Infrastructure

The type, quantity and distribution of infrastructure along the Kafue River offers insights about the level

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<sup>23</sup> Zambia report urges local controls over charcoal, timber trades - CIFOR-ICRAF Knowledge. 2025. CIFOR-ICRAF.

<sup>24</sup> Sedano, F. et al. 2022. Influence of charcoal production on forest degradation in Zambia: A remote sensing perspective. *Remote Sensing*. 14:3352.

<sup>25</sup> Zambia National Strategy to Reduce Emissions from Deforestation and Forest Degradation (REDD+, 2015-2030) | Wood Energy Info Portal | Food and Agriculture Organization of the United Nations. 2015. FAO.

<sup>26</sup> Charcoal: a burning issue. 2019. UNEP.

of development in the riparian zone. In addition, when combined with information about human activity, the presence of infrastructure can indicate resource utilisation patterns. For example, the presence of high numbers of seasonal fishing camps within the riparian zone of a river often indicates that fishing activities have a seasonal dimension — important information for the design of fisheries management plans.

It is important to note that permanent dwellings were not included in the visual survey. Rather, these were examined using remote satellite tools, as summarised in the **Google Open Buildings Analysis** section. However, all other infrastructure along the Kafue River was counted in the survey, including geolocations for each sighting.

## Results and Discussion: Infrastructure

### *Seasonal Camps*

Outside of towns and villages, seasonal camps were the most common type of infrastructure along the Kafue River. In total, there were 588 of these, most of which were located along the floodplain near the Lukanga River confluence and Kafue Flats. The distribution of seasonal camps followed the general pattern of human activity — indicating hotspots where local livelihoods intersect with natural resources, including fisheries, forests, wildlife, grazing lands and riparian vegetation (Figure 20).

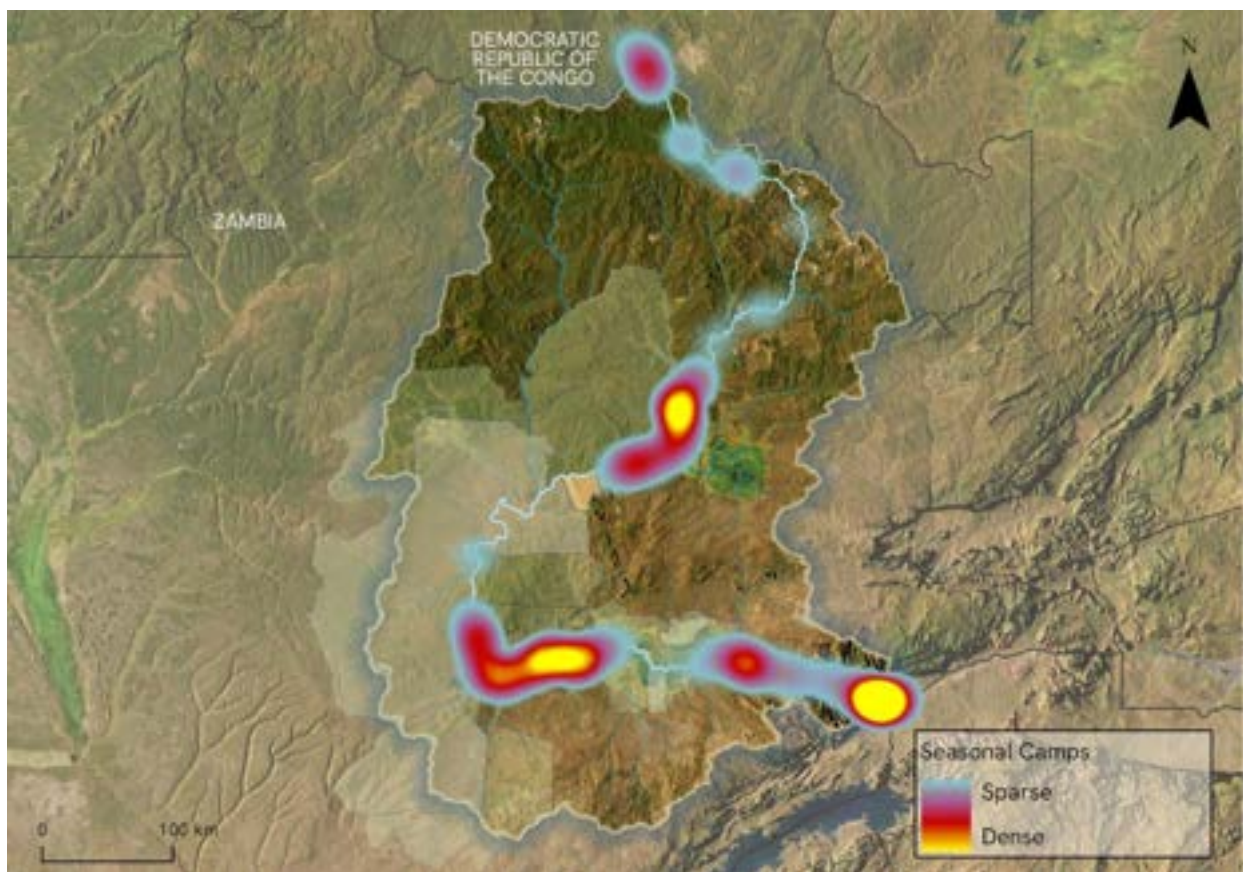


Figure 20: Distribution of seasonal camps along the Kafue River.

### *Bridges*

There were 34 bridges across the Kafue River, most of which were built from wood (N=20), followed by concrete (N=7) and metal (N=7) (Figure 22). Small bridges made from wood for pedestrians and motorcycles were common in the first 60 km of the river, before the Kwesa Floodplain. In addition, there

was one concrete bridge in this section, which spanned the entire Kafue River on the N37 between Yowela and Kipushi. For the following 1,560 kms of river, there were only 13 bridges, including nine vehicular bridges, three railroad bridges and one pedestrian bridge.



*Figure 21. A motor vehicle bridge crossing the Kafue River.*

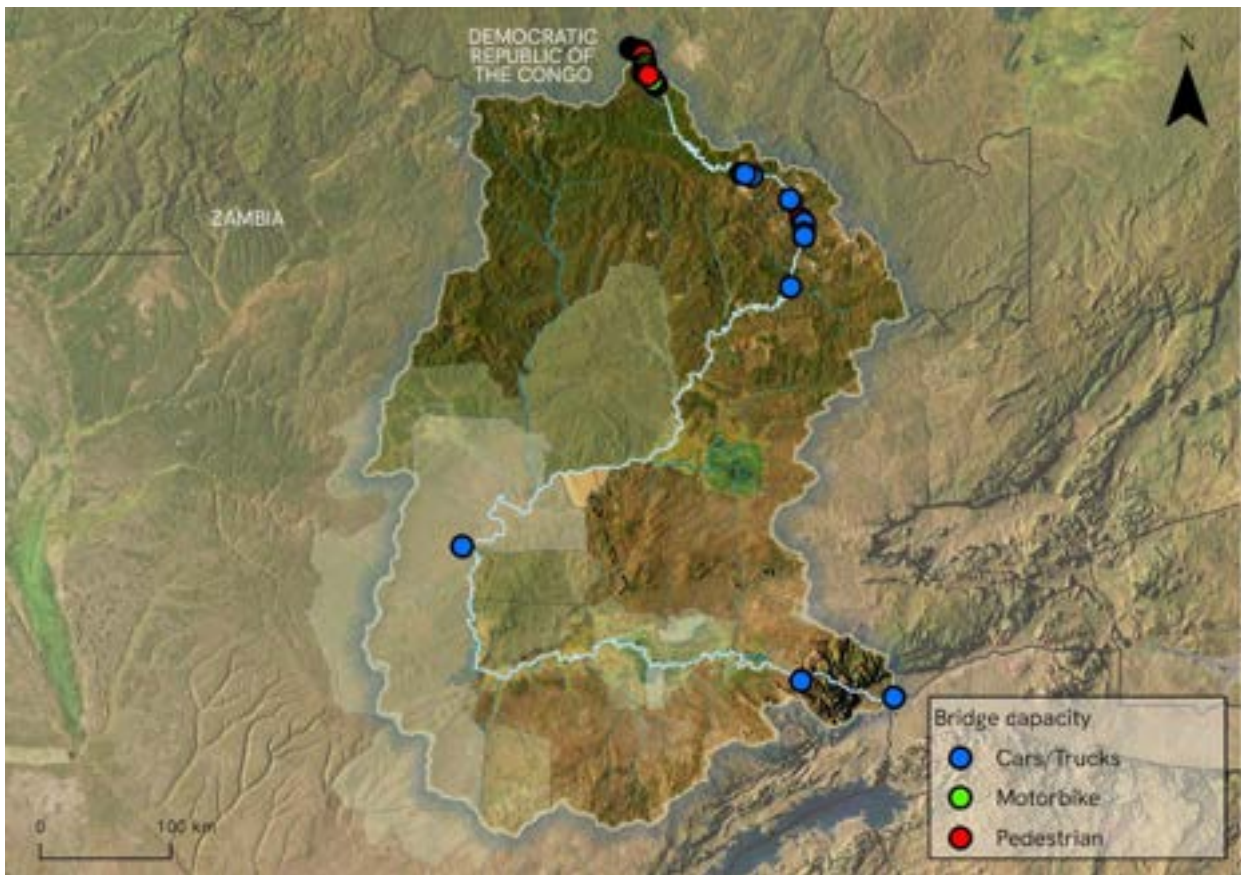


Figure 22: Type and distribution of bridges along the Kafue River. Pedestrian bridges are shown in red, motorbike bridges in green and car/truck/train bridges in blue.

#### Water abstractions

Water offtake from the Kafue River is legally permitted and supports agriculture, industry and domestic water needs. While most abstractions are for small-scale agriculture, several larger withdrawals supply municipal, industrial and commercial agriculture demands (Figure 23 and Figure 24). Collectively, abstractions along the Kafue River remove approximately 1.11 billion m<sup>3</sup>/year<sup>27</sup>. It is likely that water allocation in the lower Kafue Basin already at or above sustainable limits, and further abstraction will exacerbate pressure on the system, potentially threatening the long-term water security of local communities<sup>28</sup>.

<sup>27</sup> Water situational analysis of the Lower Kafue Basin. 2018. WWF Report Summary.

<sup>28</sup> Water situational analysis of the Lower Kafue Basin. 2018. WWF Report Summary.

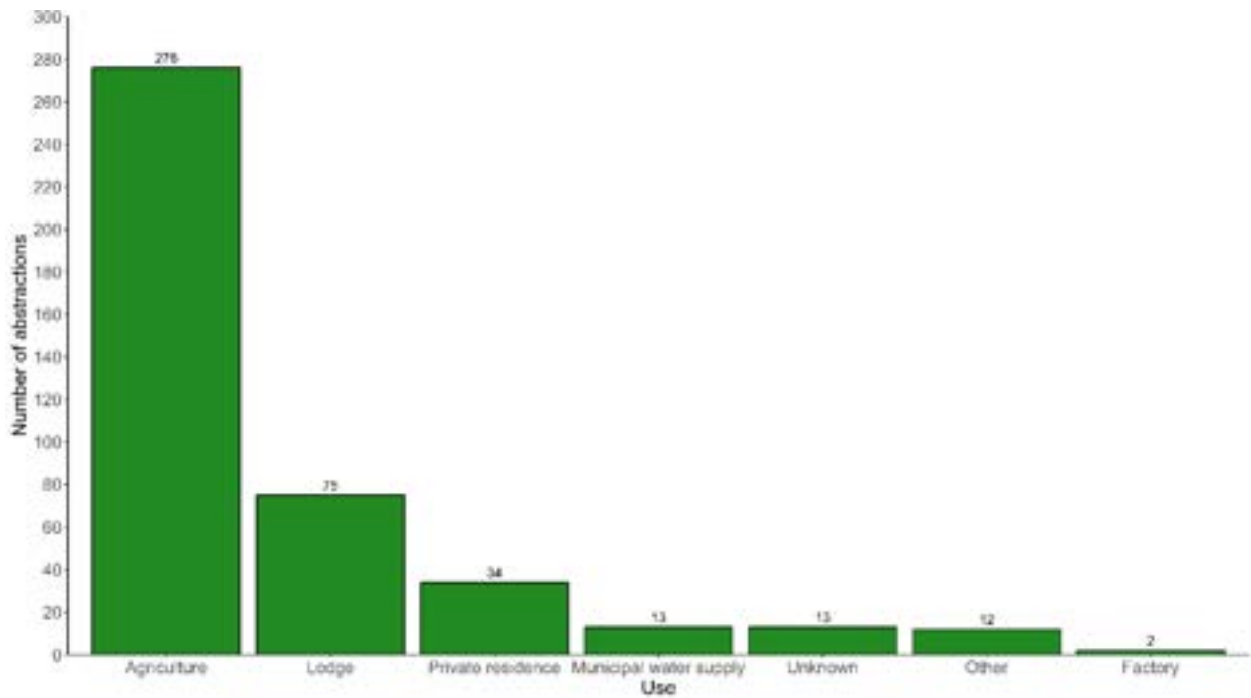


Figure 23: Water abstraction function.



Figure 24: A large water abstraction for commercial agriculture.

Over 400 abstraction points were noted along the transect, with the highest concentrations in densely populated areas including the Copperbelt and below the Lower Kafue Gorge Dam (Figure 25). In contrast, abstractions were sparse within Kafue National Park, the surrounding GMAs, and the Kafue Flats. This suggests a water resource-use disparity between agriculture, industry and urban abstraction, and local herding/fishing communities.

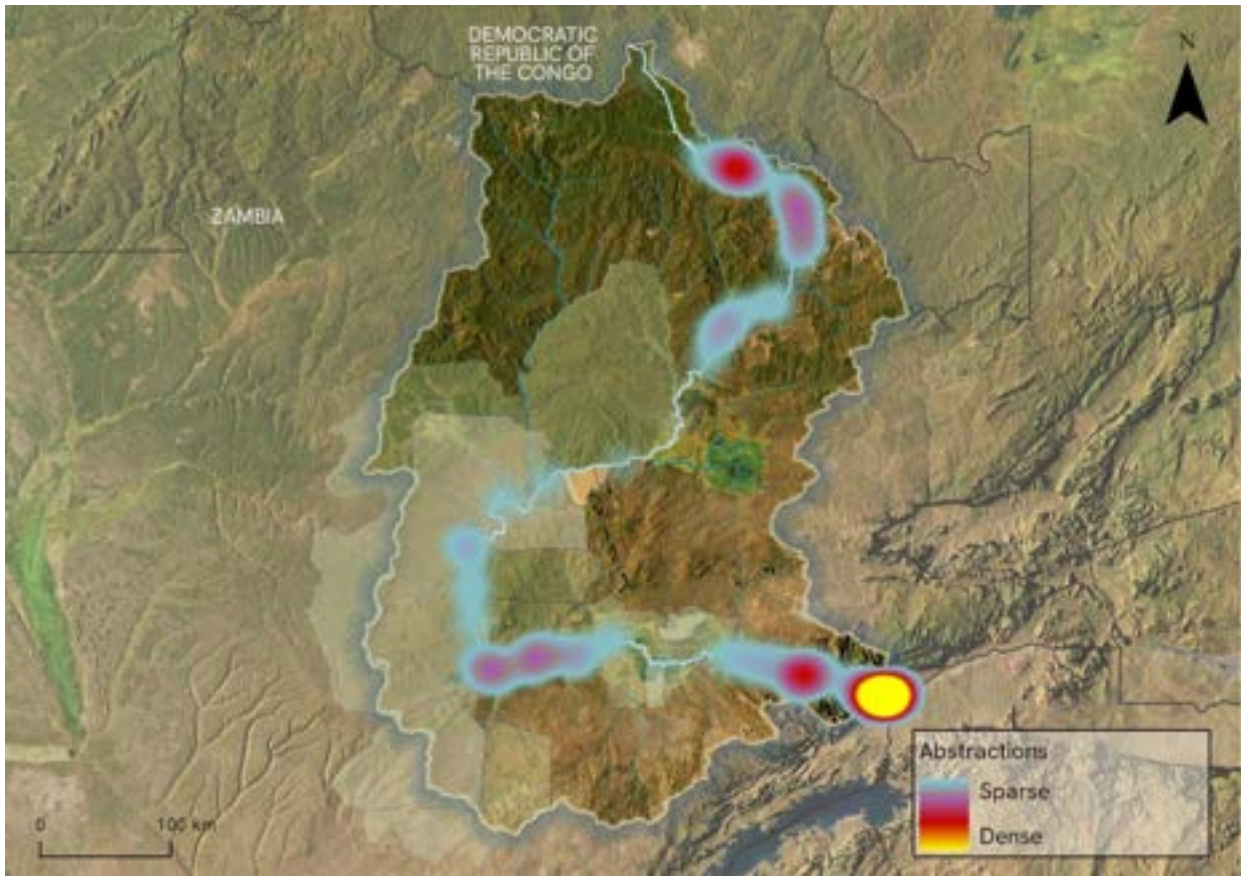


Figure 25: Distribution of water abstractions along the Kafue River.

*Dams and diversions*

Flow obstructions, including dams, weirs, diversions and sluices, have a significant influence over the hydrology of the Kafue River, particularly in its lower sections (Figure 26). The largest of these are Itezhi-tezhi, Kafue Gorge Upper and Kafue Gorge Lower. These dams are linked with hydroelectric power generation, which requires substantial flow to produce electricity, even in the dry season. As a result, dams along the Kafue River drive variable and unseasonal river flow that has significantly altered the biodiversity, morphology and floodplain extent of the river<sup>29</sup>.

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<sup>29</sup> Mumba M. and Thompson J. 2005. *Hydrological and ecological impacts of dams on the Kafue Flats floodplain system, southern Zambia. Physics and Chemistry of the Earth, 30.*



Figure 26. The locations of major dams and diversions along the Kafue River.

## 2.3 Agriculture

### Methods: Agriculture

All agricultural activity within the riparian zone (<100 m from the riverbank) was recorded, including the scale of the activity and the side of the river on which it was taking place. Crop cover was recorded as distance along the river. For a detailed analysis of crop cover within the Kafue Basin, see the **WorldCereal Cropland Analysis** below.

Farms were categorised as commercial-scale or subsistence-scale based on the size of the plots and/or the presence of commercial farming equipment (e.g., tractors or centre-pivot irrigation systems). It was assumed that farmers of large agricultural plots were selling their produce, and as a result these operations were categorised as commercial farms.

### Results and Discussion: Agriculture

#### Crops

61 km of the Kafue's riparian zone was under cultivation at the time of the survey. Almost all of this was for small-scale subsistence agriculture (~99%) (Table 6). However, as mentioned previously, regulations require a 50 m buffer of riparian vegetation, meaning that commercial crops are typically planted farther from the water's edge. As a result, commercial agriculture is under-represented in this survey. The most common crops recorded in the survey include maize (37% of crop cover), mangos (24% of crop cover) and bananas (21% of crop cover).

Table 6: Type of crop and its distance along the bank as recorded during the Kafue River expedition. Note that only crops within the riparian zone (<100m from the riverbank) were counted.

<b>Crop</b>	<b>Distance along bank (m)</b>
Maize	22,560
Mangos	14,620
Bananas	12,735
Mixed Vegetables	5,895
Pawpaw	2,732
Beans	1,245
Sugarcane	683
Cassava	310
Ground nuts	80
Soybeans	70
Wheat	50
Citrus	50
Sunflower	50
Sorghum	45
Avocado	10
Rice	5
<b>Total</b>	<b>61,140</b>

There are two notable hotspots of crop cover: i) near the river’s source; and ii) downstream of the Lower Kafue Gorge Hydropower Dam (Figure 27). The concentration of crop cover near the source is likely because of the fertile, seasonally inundated soils that are suitable for agriculture directly adjacent the river. Whilst these soils exist elsewhere — for example, along the margins of the Kafue Flats — they are not visible from the main river channel and are therefore not included in this survey.

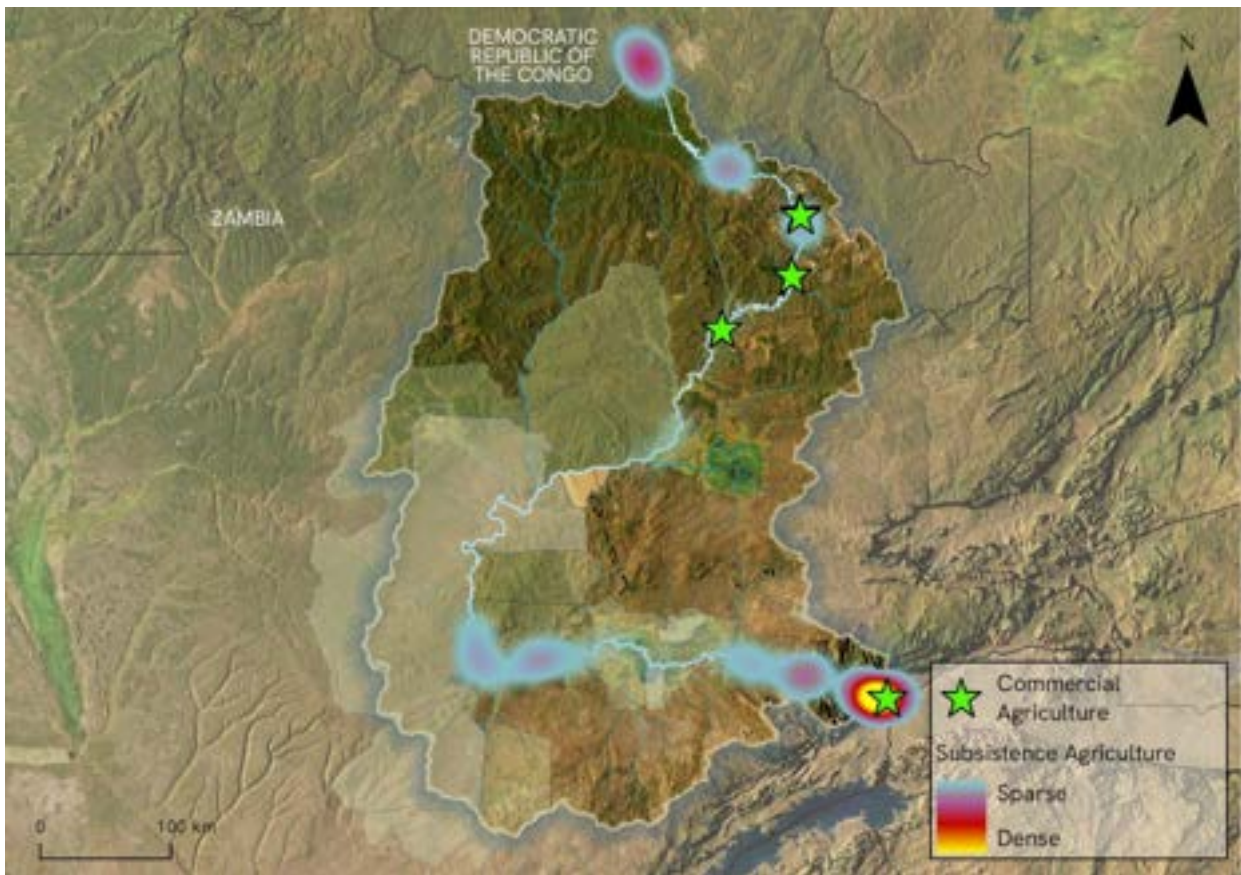


Figure 27: Distribution of subsistence agriculture (heatmap) and commercial agriculture (green stars) within the riparian zone (<100 m from the riverbank).

The Kafue Basin supports a large commercial agriculture industry, much of which uses the Kafue River for irrigation (Figure 28). As the closest major agricultural region to Lusaka, it is a key supplier of food to the city<sup>30</sup>. Mazabuka Town accounts for 89% of Zambia’s sugar production, entirely dependent on the Kafue River for irrigation. The basin also produces 25% of the country’s maize<sup>31</sup>.

While commercial agriculture is a vital contributor to the economy and food production, it can significantly impact water quality. Runoff from agricultural activities can cause eutrophication, pesticide and herbicide contamination, siltation, and salinization<sup>32</sup>. Although our study did not directly confirm these effects, their potential influence on the Kafue River warrants consideration, particularly given the scale of agricultural activity in the region.

<sup>30</sup> *Water in the Zambian economy: Exploring shared risks and opportunities in the Kafue Flats*. 2016. WWF Report.

<sup>31</sup> *Water in the Zambian economy: Exploring shared risks and opportunities in the Kafue Flats*. 2016. WWF Report.

<sup>32</sup> Cooper, C.M. 1993. Biological effects of agriculturally derived surface water pollutants on aquatic systems – a review. *Journal of Environmental Quality*. 22:402-408.



Figure 28: Commercial agriculture located just outside of the riparian zone of the Kafue River.

#### *Domestic animals*

The Kafue Flats supports approximately 20% of Zambia's cattle (~290,000), with most concentrated on the western side near Namwala<sup>33</sup>. Along the 2024 transect there were 8,239 domestic animals recorded, with cattle making up the majority (85%), followed by goats (12%) (Table 7). Domestic animals were concentrated in and around GMAs, particularly in Lunga Luswishi and Kafue Flats (Figure 29). While GMAs permit livestock, it is concerning that some of the highest densities recorded along the river occur within these semi-protected areas.

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<sup>33</sup> *Water in the Zambian economy: Exploring shared risks and opportunities in the Kafue Flats. 2016. WWF Report.*

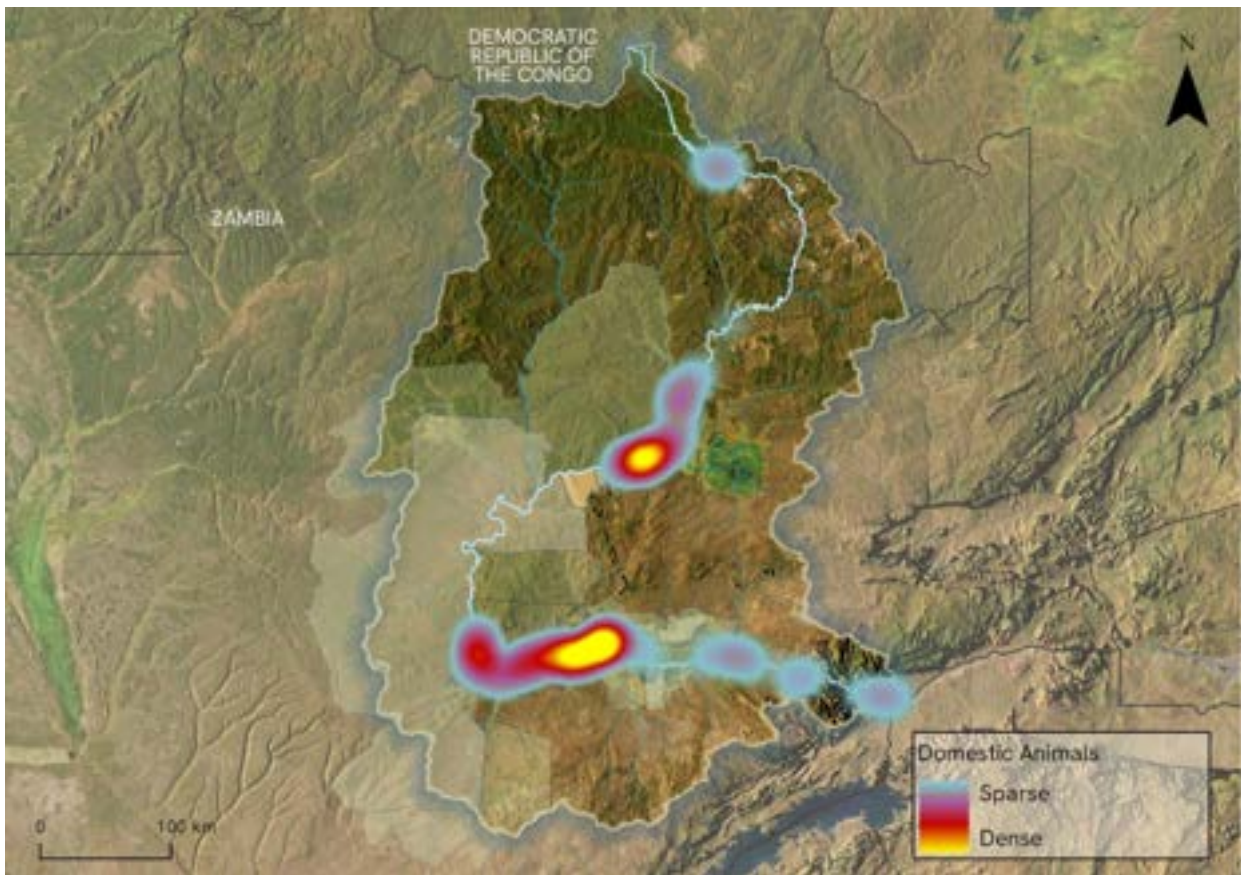


Figure 29: Distribution of domestic animals along the Kafue River.

Table 7: Counts of domestic animals along the Kafue River.

Animal	Count
Cattle	6,996
Goats	972
Pigs	132
Dogs	98
Donkeys	26
Sheep	10
Ostrich	5
<b>Total</b>	<b>8,239</b>

Livestock density on the Kafue River is comparable to the mainstem Zambezi, with 50 livestock/10 km on the Kafue versus 52 livestock/10 km on the Zambezi. However, livestock on the Kafue are concentrated within a smaller area between Itezhi Tezhi and the Kafue Flats (~263 km), where are 4,763 animals — a density of over 180 livestock/10 km. This herd has grown rapidly over recent years, leading to overgrazing in some areas — particularly during severe droughts when vegetation cover is already reduced. As a result, the cattle stocking density of the Kafue Flats is considered unsustainable, threatening the endemic Kafue lechwe population through competition for grazing land<sup>34</sup>. Furthermore, bovine diseases, including tuberculosis, may contribute to lechwe mortality<sup>35</sup>.

<sup>34</sup> Shanungu G.K., Kaumba C.H. and Beilfuss R. 2015. Current population status and distribution of large herbivores and floodplain birds of the Kafue Flats Wetlands, Zambia: Results of the 2015 wet season aerial survey. *Zambian Wildlife Authority, Chilanga, Zambia.*

<sup>35</sup> Stafford, K.J. 1991. A review of diseases of parasites of the Kafue lechwe (*Kobus leche kafuensis*). *Journal of Wildlife Diseases.* 27(4):661-667.

## 2.4 Wetland-Associated Birds

### Methods: Wetland-associated birds

Long-term biodiversity monitoring provides important insights into river health, eco-tourism opportunities and the potential for human-wildlife conflict. Birds in particular serve as reliable indicators of disturbance and ecosystem health<sup>36,37</sup>, often reflecting changes in habitat availability. To this end, continuous monitoring of birds over time allows for detection of threats to riverine ecosystems. In addition, the identification of important nesting sites and foraging grounds informs proactive and effective conservation management.

### Results and Discussion: Wetland-associated birds

The 2024 survey counted 24,353 wetland-associated birds and raptors from 109 species along the Kafue River (Table 8). The most common species were reed cormorants (N=5,272), followed by western cattle egrets (N=4,290) and white-faced whistling-ducks (N=1,550). Multiple species were only recorded once including, *inter alia*, the Abdim's stork, African crane, black stork, lizard buzzard, wood sandpiper and yellow-billed kite, likely because of seasonality effects. A full count of wetland birds is available in Appendix Appendix 2.

*Table 8: Total bird count along the Kafue River transect.*

<b>Guild</b>	<b>Count</b>	<b>% of Total Count</b>
Diving Birds <sup>1</sup>	6,186	25.40
Hérons and Egrets	5,973	24.53
Ducks, Geese and Teals	2,374	9.75
Lapwings and Thick-knees	1,492	6.13
Gulls and Terns	1,409	5.79
Bee-eaters	1,355	5.56
Small Shorebirds	1,197	4.92
Kingfishers	1,194	4.90
Storks	1,173	4.82
Ibises and Spoonbills	568	2.33
Raptors	530	2.18
Vultures	228	0.94
African Skimmer	159	0.65
Crakes and Moorhens	151	0.62
Hamerkop	140	0.57
Coucals	117	0.48
Finfoots	51	0.21
Cranes	39	0.16
Owls	12	0.05
Pelicans	5	0.02
<b>TOTAL</b>	<b>24,353</b>	<b>100</b>

<sup>1</sup>Cormorants and darters.

Overall abundance of birds was highest in the stretch between Itezhi Tezhi dam wall and the start of the Kafue Flats, around Namwala town (Figure 30). This stretch falls largely outside of protected areas, except for a short segment within the Kafue Flats GMA. Western cattle egrets accounted for approximately 26% of all bird observations within this stretch, compared to 18% along the whole river. Cattle are a key host

<sup>36</sup> Fraixedas, S. et al. 2020. A state-of-the-art review on birds as indicators of biodiversity: Advances, challenges, and future directions. *Ecological Indicators*. 118:106728.

<sup>37</sup> Mugatha, S.M. 2024. Bird species richness and diversity responses to land use change in the Lake Victoria Basin, Kenya. *Scientific Reports*. 14:1711.

of western cattle egrets, and their high abundance within this stretch closely matches the distribution of cattle, explaining the hotspot (Figure 31).

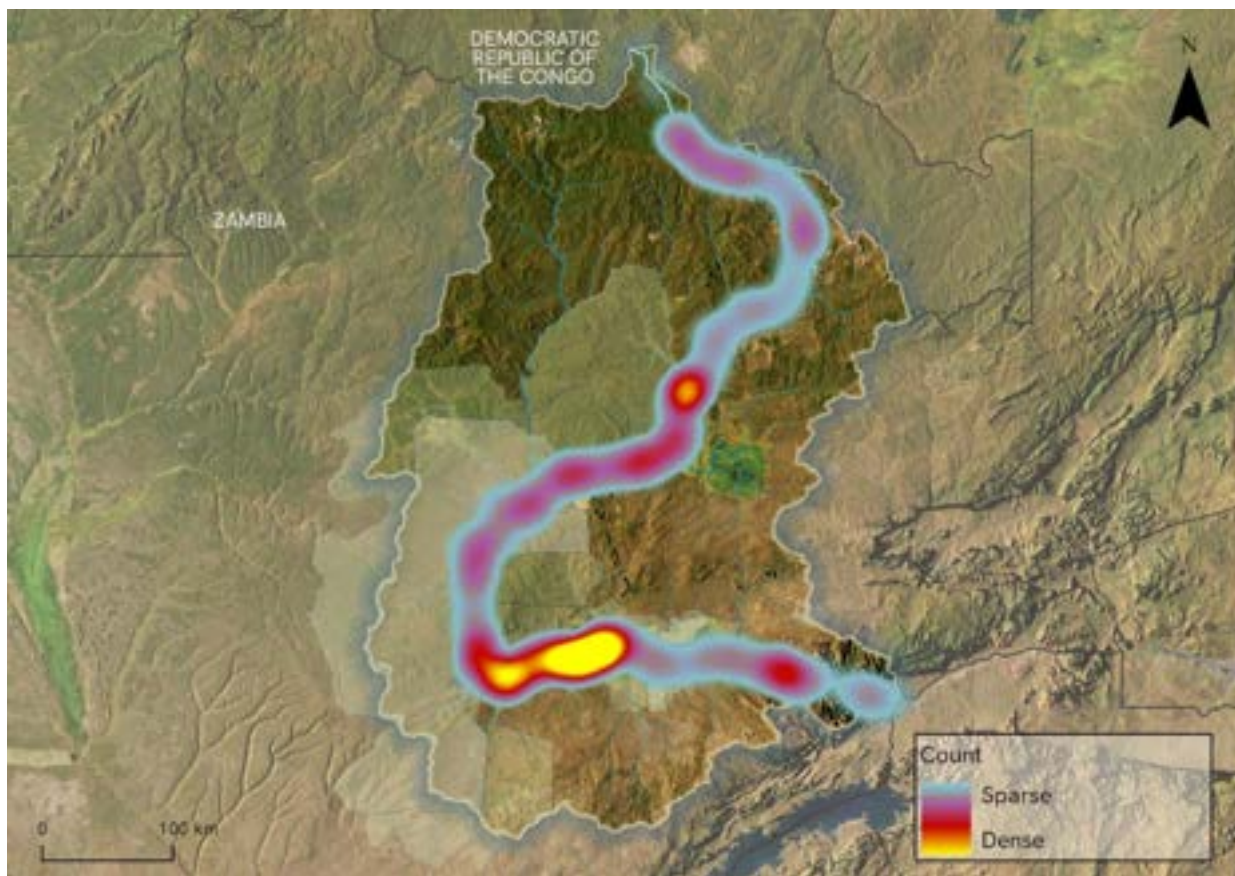


Figure 30: Distribution of wetland birds along the Kafue River.

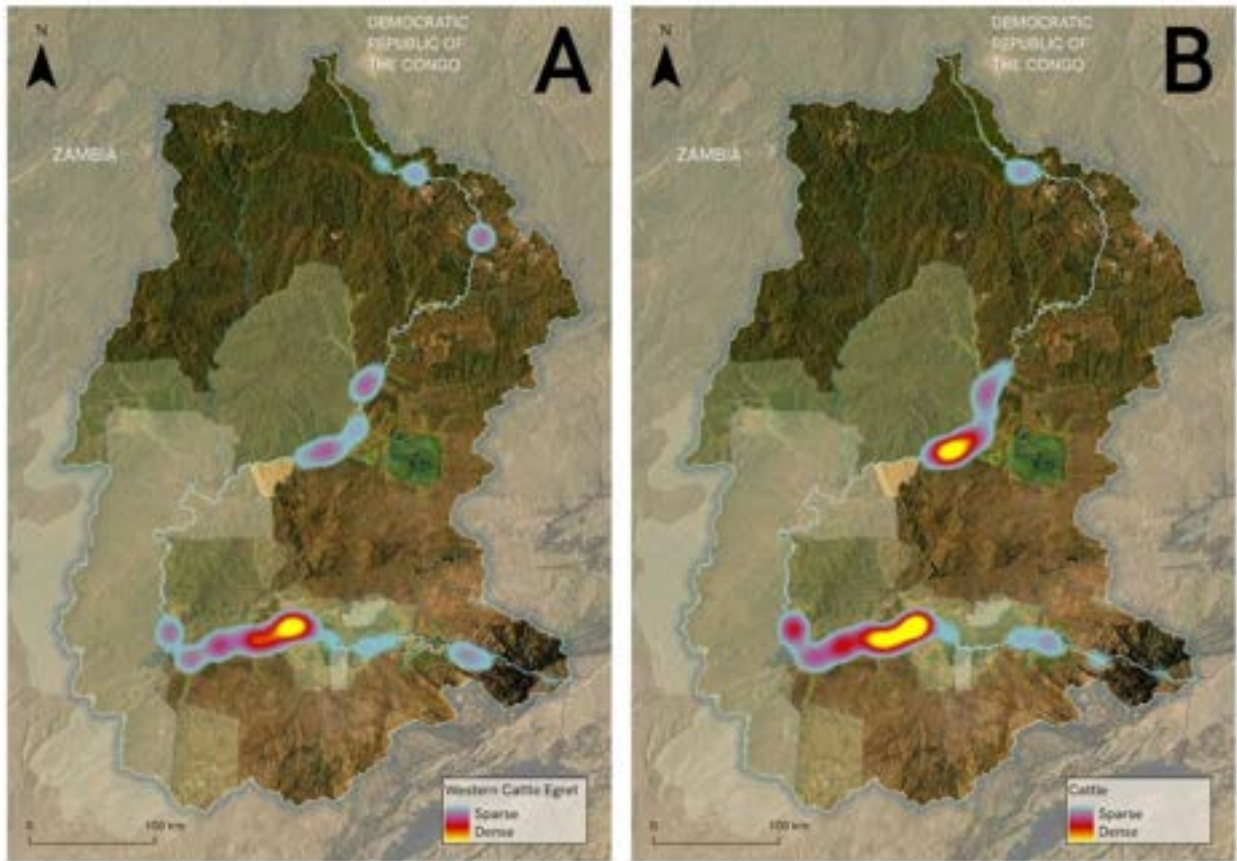


Figure 31: Distribution of western cattle egrets (A) and domestic cattle (B).

273 birds from nine threatened species were recorded along the Kafue River (Table 9). Three species, namely the white-backed vulture, hooded vulture and white-headed vulture, are classified as *Critically Endangered*, according to the IUCN Red List of Threatened Species. Threatened birds occurred almost exclusively within protected areas (N=241), and most (N=169) were in the Kafue National Park.

Table 9: IUCN Red Listed bird species observed along the Kafue River transect.

Species	Count	Threat Status
White-backed Vulture	133	Critically Endangered
Hooded Vulture	43	Critically Endangered
Bateleur	37	Endangered
Grey Crowned Crane	30	Endangered
Wattled Crane	9	Vulnerable
White-headed Vulture	9	Critically Endangered
Lappet-faced Vulture	6	Endangered
Martial Eagle	4	Endangered
Tawny Eagle	2	Vulnerable
<b>TOTAL</b>	<b>273</b>	

Protected areas play a crucial role in supporting bird populations, providing safe habitats with abundant food and minimal disturbance. In the 2024 survey, diving birds, including cormorants and darters, were more common within protected areas (Figure 32). The KNP covered just 19% of the expedition route, but accounted for 70% of African darter and white-breasted cormorant sightings. This highlights the success of conservation efforts within in the park, where the Kafue River is carefully managed to sustain fish populations and protect riparian vegetation.

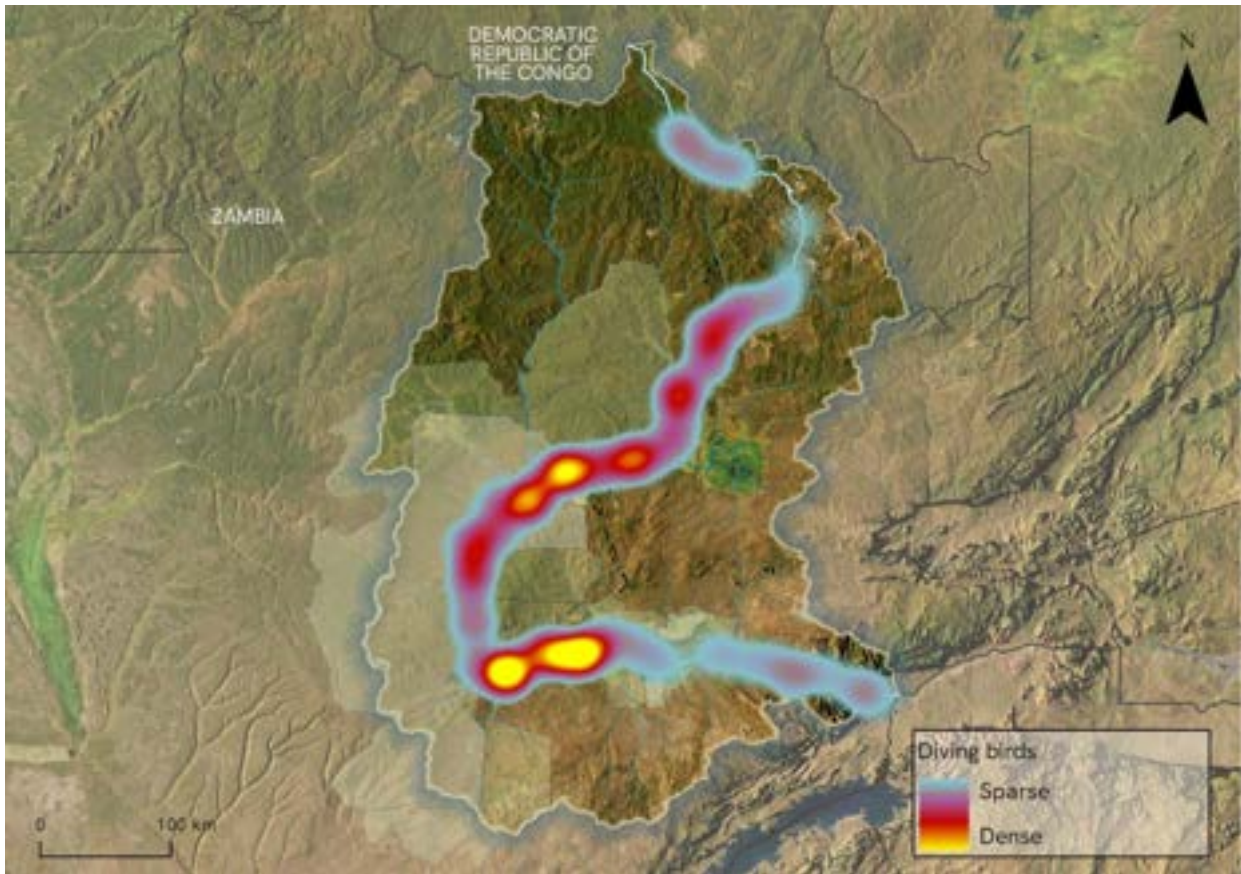


Figure 32: Distribution of diving birds along the Kafue River.

The wetland bird distribution within the KNP was unchanged between 2024–2025. However, there was a marked change in the abundance and biodiversity of wetland birds. In 2024, TWP recorded 2,235 birds from 54 species. In contrast, there were just 1,051 birds from 45 species in 2025. This represents a 53% decline in abundance, alongside a 16% decline in the number of species counted.

The most common wetland birds in 2024 were the piscivorous diving birds, particularly reed cormorant (N = 668), white-breasted cormorant (N = 302), and African darter (N = 227). While these species remained the most common in 2025, their count was 72% lower than the previous year (338 in 2025 vs 1197 in 2024). Several previously abundant species were also absent from the 2025 count, including the little bee-eater, yellow-billed duck, and malachite kingfisher, as well as several large waterbirds like the African spoonbill and both the rufous-bellied and black-headed heron.

The 2024 survey was conducted during a period of extreme drought, leaving many of the inland waterbodies completely dried out. This likely concentrated birds in the main channel of the Kafue River, enhancing visibility on the boat-based survey. With the higher rainfall in 2025, these birds were likely able to disperse to floodplains and seasonal pans, which provide much safer and more productive foraging grounds than the river corridor.

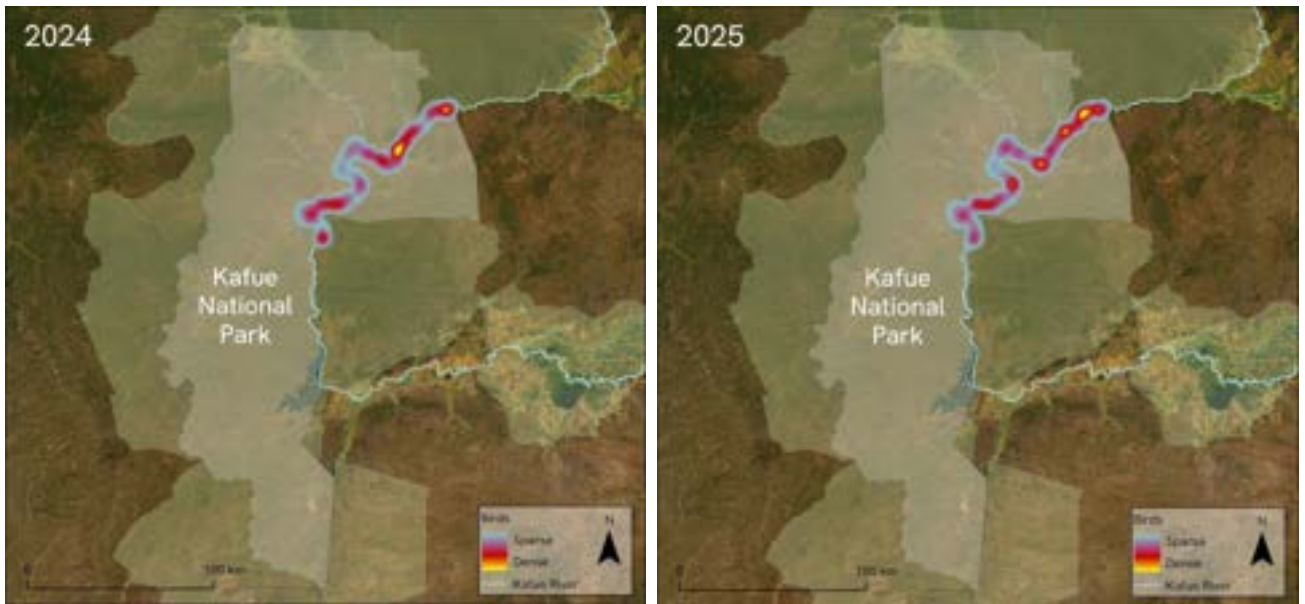


Figure 33. Distribution of bird observations along the repeated survey section of the Kafue River in Kafue National Park in 2024 (left) and 2025 (right).

Although further research is needed to confirm this pattern, these early findings highlight the immense importance of the Kafue National Park as a haven for piscivorous diving birds, particularly during drought times. With rising average and extreme temperatures, coupled with increasingly variable precipitation, droughts are projected to increase in both intensity and frequency within the Kafue Basin<sup>38</sup>. This will render the flow regime, water quality, and habitat integrity of the Kafue River within KNP vitally important for biodiversity conservation in Zambia.

<sup>38</sup> The World Bank Group. 2026. *Climate Knowledge Portal Country Profile: Zambia*. Available at: [Zambia - Trends & Variability \(CMIP6\) | Climate Change Knowledge Portal](#)



Figure 34: A selection of birds seen on the Kafue expedition. Clockwise from top left: a malachite kingfisher, a half-collared kingfisher and grey crowned cranes.

## 2.5 Wildlife

Wildlife monitoring in the Kafue landscape began in earnest with the establishment of Kafue National Park in the 1950s, initially relying on ranger patrols and opportunistic observations to track large mammals. From the 1970s onward, aerial surveys and ground counts were introduced to assess population trends, particularly for key species such as elephants and antelope. More recently, monitoring has expanded to include community-based reporting, targeted species surveys, and the use of technologies such as GPS tracking and camera traps.

### Methods: Wildlife

Long-term biodiversity monitoring provides critical insights into river health, eco-tourism potential, and

the risk of human–wildlife conflict. Consistent monitoring over time enables the early detection of emerging threats to riverine ecosystems and associated wildlife populations. For this survey, all non-avian wildlife observed within the Kafue River and its riparian vegetation were systematically recorded.

### Results and Discussion: Wildlife

5,119 animals from 18 species were recorded along the Kafue River (Figure 35). As expected, the most common animals were river-associated, including hippopotamus (N=2,394), puku (N=1,579) and crocodile (N=278). In addition, several uncommon animals were recorded, including the first observation of leopard on a TWP expedition to date. Other notable sightings included Lichtenstein’s hartebeest and lion.

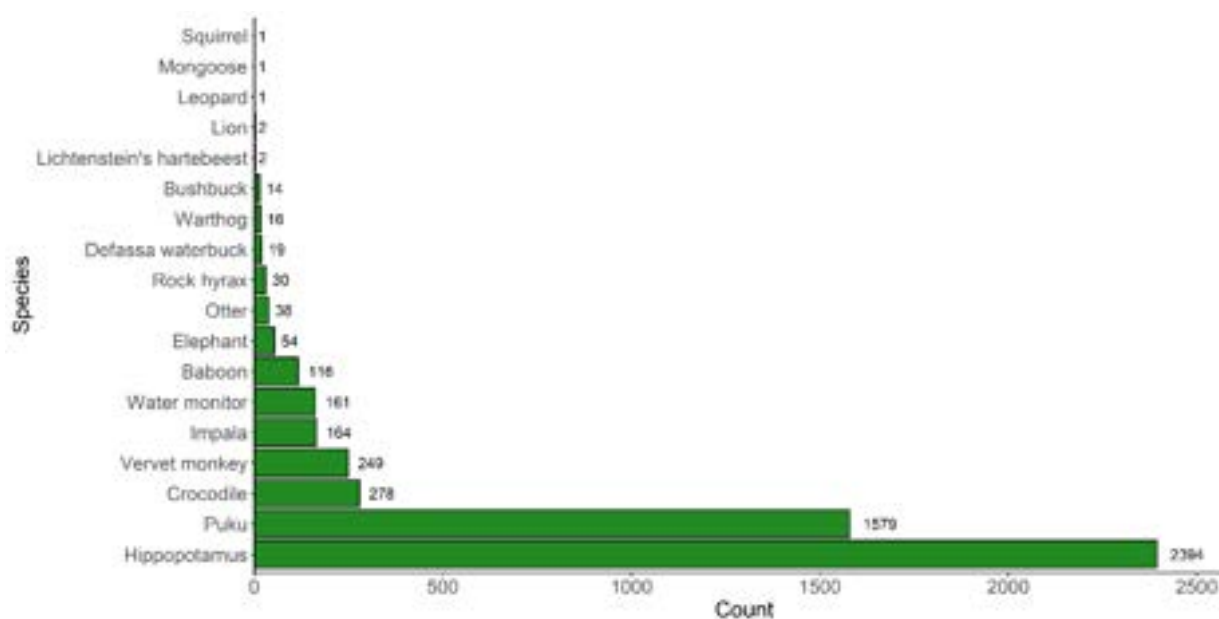


Figure 35: Wildlife species observed along the Kafue River.

The 2024 survey recorded 32 animals/10 km along the entire Kafue River. This is comparable to the Zambezi River average of 31 animals/10 km. The combined density of wildlife within the Kafue National Park and Mushingashi Conservancy was much higher than unprotected areas (88 animals/10 km vs 17 animals/10 km, respectively). Similarly, the distribution of wildlife was opposite to that of people, highlighting the impact of conflicting resource-use, hunting and deforestation on the biodiversity within the Kafue Basin (Figure 36).

The highest wildlife density along the river lies within the Mushingashi Conservancy, a private game ranch spanning ~527 km<sup>2</sup>. The ranch has benefited from significant investments in conservation infrastructure, including the construction of a game fence enclosing both Mushingashi and the adjacent Kaindu Conservancy. Whilst not necessarily feasible elsewhere in the basin, the conservation measures of the Mushingashi Conservancy successfully protect local wildlife, including a substantial population of puku (at least 1,370 animals along the 47 km stretch of river).

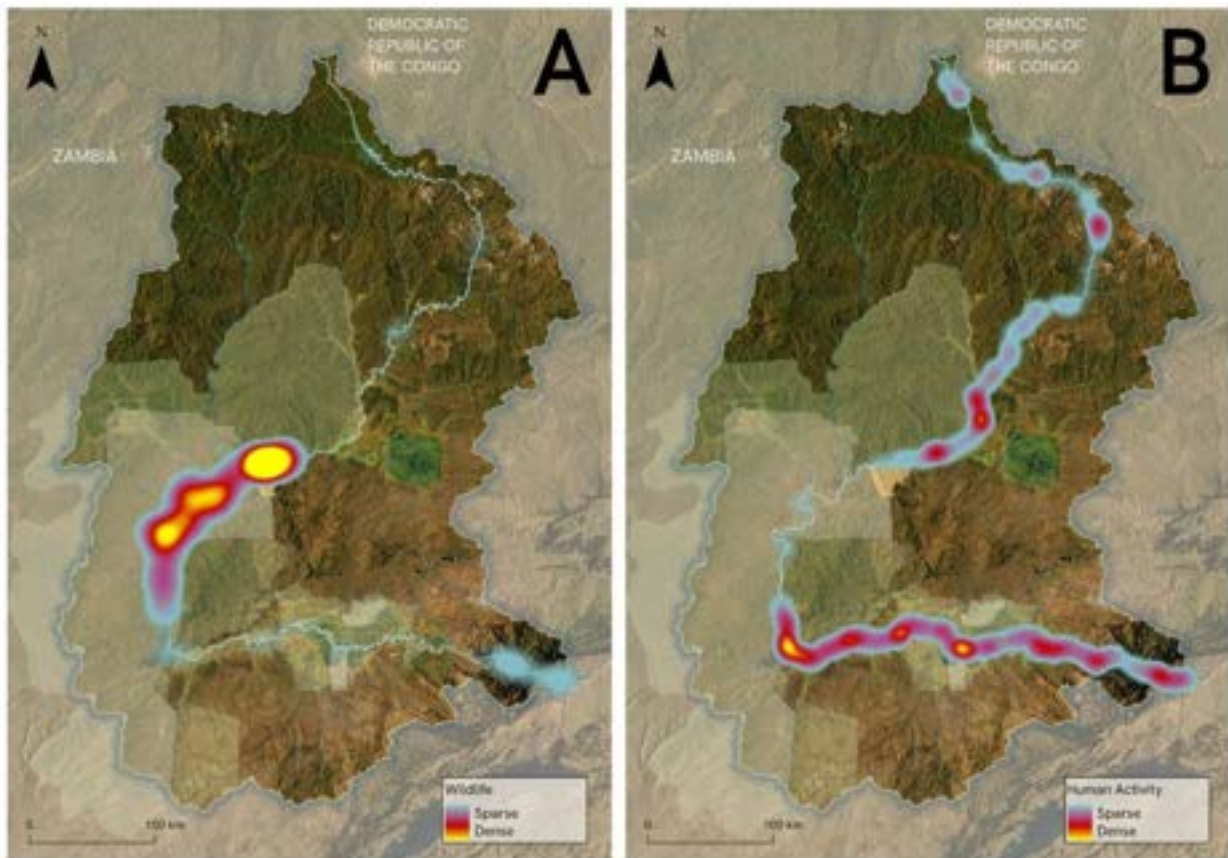


Figure 36: Distribution of wildlife (left) and distribution of people (right) along the Kafue River.

Game Management Areas (GMAs) are intended as buffers around national parks, although our findings suggests that these are not equally balancing biodiversity and development within the Kafue Basin. Reviews of the GMA portfolio in Zambia indicate that target communities often do not benefit sufficiently from these landscapes, and that illegal poaching is common<sup>39,40</sup>. Ongoing biodiversity conservation along the Kafue River will rely heavily on the improved management of the GMA portfolio.

### Hippos

The Kafue River supports one of Zambia’s largest hippopotamus populations, with a 2007 boat-based survey recording 4,000 individuals<sup>41</sup>. Our count is substantially lower (N=2,413), despite similar sampling techniques. While we did not survey the entirety of Itezhi Tezhi reservoir, which hosted 250 hippos in 2007, our count still suggests a substantial decline in the hippopotamus population of the Kafue River between 2007–2024.

Notably, 98% of hippopotamus recorded in the 2024 survey were concentrated between the beginning of Mushingashi Conservancy and Itezhi-Tezhi. In 2025, the repeat survey recorded 1,810 hippos, representing 489 fewer individuals than in 2024 (N = 2,413). Abrupt interannual changes are more plausibly explained by redistribution of animals and changes in water availability, rather than true population decline. This should be confirmed by an aerial survey to accurately explore back-waters,

<sup>39</sup> Becker, M. et al. 2013. Evaluating wire-snare poaching trends and the impacts of by-catch on elephants and large carnivores. *Biological Conservation*. 158:26-36.

<sup>40</sup> Lindsey, P. et al. 2013. *Zambian game management areas: The reasons why they are not functioning as ecologically or economically productive buffer zones and what needs to change for them to fulfil that role.* Wildlife Producers Association of Zambia.

<sup>41</sup> Chomba, C. et al. 2013. Does shore length influence population size and density distribution of hippopotamus? *Journal of Ecology and the Natural Environment*. 4(5):56-63.

wetland margins and braided river sections. Importantly, future aerial surveys should focus their efforts adjacent the Kafue National Park and Mushingashi Conservancy, where almost all hippos (97%) are found (Figure 37).

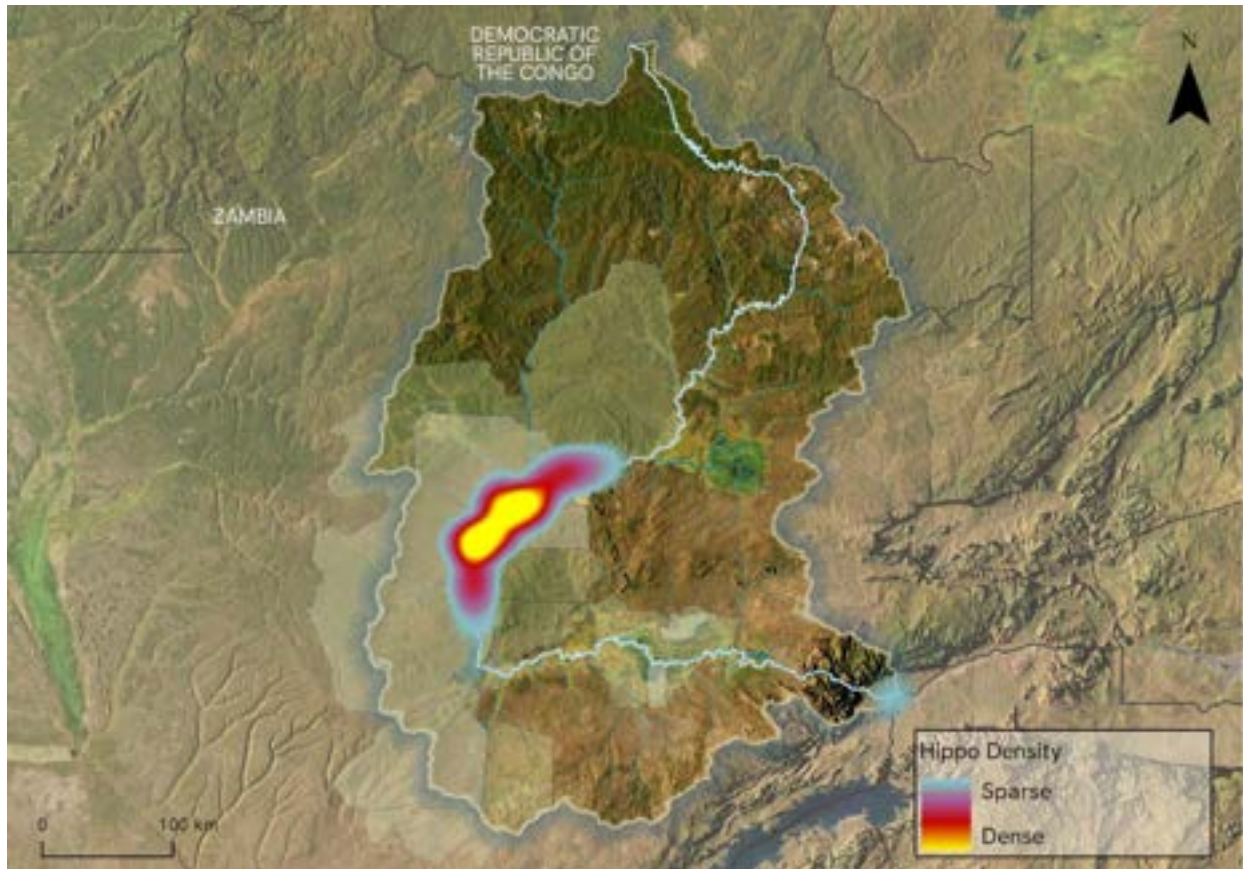


Figure 37. Distribution of hippos along the Kafue River. Note the high density in Kafue National Park, which is the last remaining refuge along the Kafue River.

## 2.6 Alien Invasive Plants

### Methods: Alien invasive plants

Alien invasive plants (AIPs) are known to have several impacts on river systems in Africa. These include the displacement of native vegetation and changes in nutrient cycling, which have detrimental impacts on native plant communities and local biodiversity. In addition, alien plant invasions alter the fire regimes of invaded areas by changing the size, distribution and plant chemistry of the biomass available for fuel<sup>42</sup>. AIPs also reduce water quality by increasing evaporation rates and reducing stream flow and dilution capacity<sup>43</sup>. The continuous monitoring of alien invasive plants allows for early detection of threats to riverine ecosystems.

All alien invasive plant species within the Kafue River and riparian zone were identified and their extent was recorded. In general, sightings included an estimate of the patch size of an AIP cluster. However, in cases where invasions were widespread, we estimated their distance along the riverbank. Combined,

<sup>42</sup> Vilà, M. 2011. Ecological impacts of invasive alien plants: a meta-analysis of their effects on species, communities and ecosystems. *Ecological Letters*. 14:702-708.

<sup>43</sup> Chamier, J. 2012. Impacts of invasive alien plants on water quality, with particular emphasis on South Africa. *Water SA*. 38(2):345-356.

these measures provided unique insights to the distribution and extent of invasive alien plant species along the Kafue River.

### Results and Discussion: Alien invasive plants

We detected nine species of AIPs along the Kafue River (Table 10). Four species (*Limnobium laevigatum*, *Mimosa pigra*, *Salvinia molesta* and *Azolla filiculoides*) were so abundant that we transitioned from recording individual patches to quantifying the distance along the riverbank. The most widely distributed AIP was *S. molesta*, although *L. laevigatum* covered a larger area. In addition, we noted only one patch of *Calotropis sp.* and two small patches of *Hydrilla verticillate* (Figure 39).

Table 10: Alien invasive species detected along the Kafue River.

Scientific name	Common name	Cumulative patch size (m <sup>2</sup> ) <sup>1</sup>	Distance along bank (m)	Number of kilometres of presence
<i>Limnobium laevigatum</i>	Spongeplant	940	26,440	328
<i>Mimosa pigra</i>	Giant sensitive plant	169	24,280	341
<i>Salvinia molesta</i>	Kariba weed	110	10,880	445
<i>Azolla filiculoides</i>	Red water fern	148	3,920	132
<i>Eichhornia crassipes</i>	Water hyacinth	2,702	NA	151
<i>Tithonia diversifolia</i>	Mexican sunflower	1,455	NA	53
<i>Ricinus communis</i>	Castor oil bush	676	NA	47
<i>Calotropis sp.</i>	Milkweed	20	NA	1
<i>Hydrilla verticillata</i>	Waterthyme	2	NA	2

<sup>1</sup>For four species (*L. laevigatum*, *M. pigra*, *S. molesta* and *A. filiculoides*) we initially recorded the area of individual patches. These species became near continuous at times, so we switched to recording their distance along the bank. The cumulative patch size therefore represents initial patches, while the distance along the bank and the number of kilometres of presence gives a better idea of their prevalence in the system.

*Salvinia molesta* is the most widely distributed AIP along the Kafue River, with the highest densities observed from Matabula to the border of Kafue National Park. This free-floating aquatic fern forms dense mats on the water surface, particularly in slow-moving sections and backwaters. Its rapid vegetative reproduction and ability to double in biomass within a few days allow it to spread extensively. The thick mats reduce light penetration, negatively impacting submerged native vegetation and altering oxygen levels. Additionally, *S. molesta* impedes water flow and poses a challenge to fishing activities and water transport. It is also common from the middle of the Kafue Flats to the Upper Gorge power station, where it disrupts aquatic ecosystems and water usage.

*Limnobium laevigatum*, commonly known as South American spongeplant, covers the largest surface area along the river, forming continuous floating mats in calm waters and sheltered inlets. It first appears just downstream of Itezhi Tezhi Dam but is common thereafter until the confluence with the Zambezi. It thrives in nutrient-rich environments and spreads quickly due to its buoyant, interconnected root system. Its presence contributes to habitat degradation by blocking sunlight, reducing dissolved oxygen levels, and facilitating the accumulation of organic matter. The plant's rapid expansion has the potential to displace native aquatic vegetation and disrupt ecological balance.

*Mimosa pigra*, the giant sensitive plant, is highly problematic in the Kafue Flats<sup>44</sup>. It grows quickly, forming dense, thorny thickets that outcompete native vegetation, reduce biodiversity, and alter wetland habitats. Unpalatable to both wildlife and livestock, it limits available forage and further disrupts grazing areas. It is

<sup>44</sup> Witt, A.B.R. 2020. *Mimosa pigra* in eastern and southern Africa: Distribution and socio-ecological impacts. *Austral Ecology*. 45:788-799.

present near Mpongwe and is widespread in and around Machiya Fungulwe and Lunga Luswishi GMAs, as well as dominant around Namwala (). Its distribution closely follows cattle grazing areas and is likely linked to overgrazed regions, potentially serving as an indicator of land degradation.



Figure 38. Sponge plant (left) and a dense mat of Azolla (right).

In 2017, the Department of National Parks and Wildlife (DNPW), in collaboration with the International Crane Foundation/Endangered Wildlife Trust Partnership and the World Wide Fund for Nature in Zambia (WWF Zambia), launched a project to control the spread of *M. pigra* while creating jobs for local communities. Since its inception, the restoration project has cleared at least 1,800 ha of the approximately 3,000 ha initially invaded, contributing to ongoing efforts to restore the ecological integrity of the Kafue Flats. While these restoration efforts continue, ongoing management and monitoring are necessary to prevent reinfestation and further spread.

*Azolla filiculoides*, a small floating fern, forms thick mats on the water surface. This species thrives in nutrient-rich waters and spreads rapidly through vegetative fragmentation. The dense coverage reduces sunlight penetration, affecting submerged plant growth and limiting the availability of oxygen for aquatic organisms. In some areas, *A. filiculoides* occurs intermingled with *S. molesta*, further exacerbating the ecological impact by creating extensive surface cover that restricts water movement and disrupts aquatic habitats. It is most abundant from Matabula to Kafue National Park but uncommon within the park itself.

The widespread presence of alien invasive plants along the Kafue River highlights the importance of sustained management and ongoing monitoring efforts. Their rapid spread continues to threaten native biodiversity, alter ecological processes, and impact local livelihoods dependent on the river's resources. Strengthening existing control measures and ensuring coordinated efforts remain essential to managing infestations and preventing further introductions.

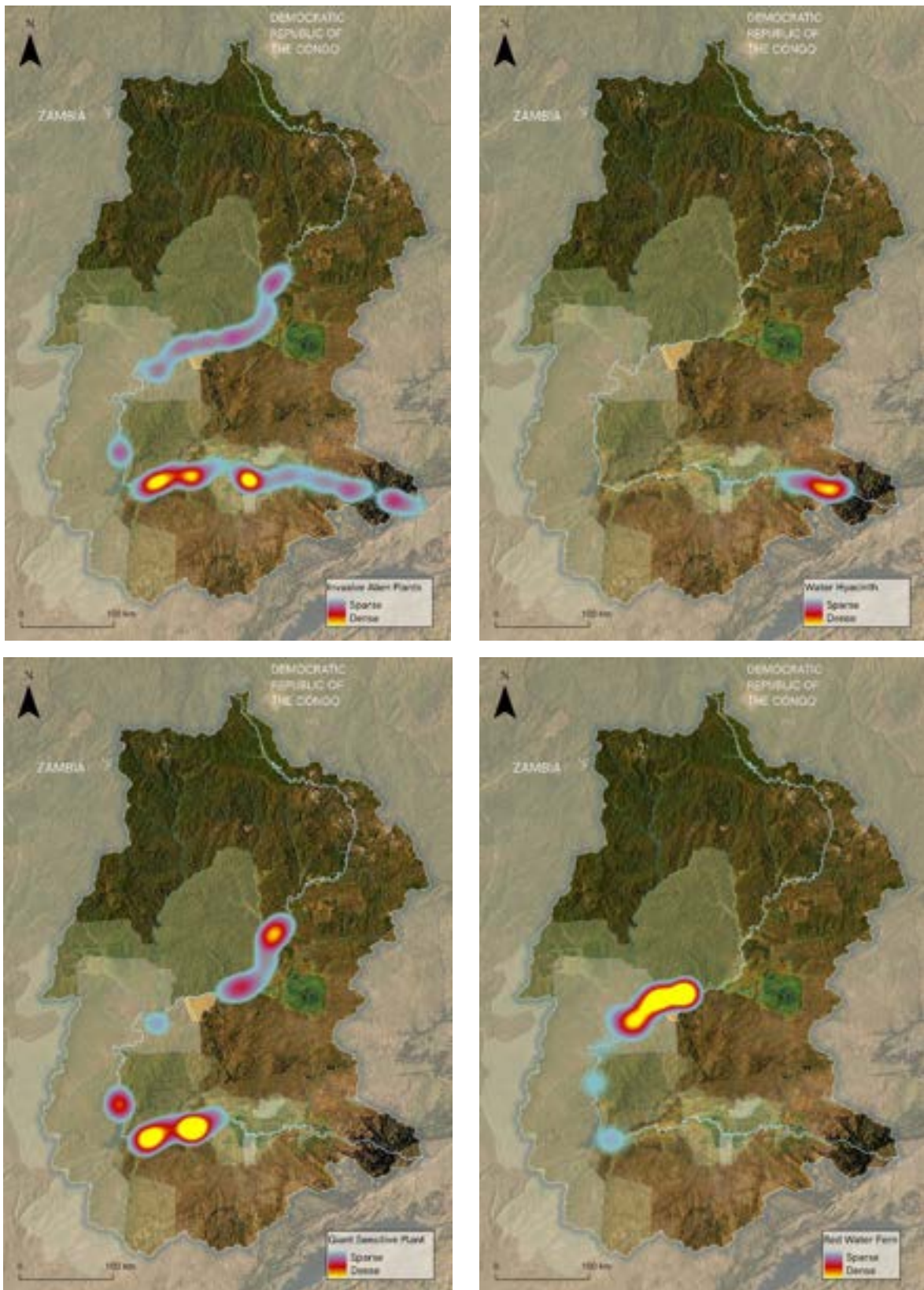


Figure 39: Distribution of various alien invasive plants along the Kafue River.

## 2.7 Papyrus

Papyrus (*Cyperus papyrus*), the world's fastest-growing herbaceous plant, is a defining component of

many African wetlands and plays a critical role in maintaining ecosystem function by regulating hydrological flows, controlling nutrient dynamics, and providing essential habitat for a wide range of wetland species. Despite its ecological importance and extensive distribution, papyrus remains relatively understudied, with limited long-term data on its spatial dynamics, productivity, and response to environmental change. This lack of information constrains effective wetland management and conservation planning.

The distribution of papyrus along the Kafue River is highly uneven, reflecting strong controls by hydrology, geomorphology, and flow regulation. Dense papyrus wetlands are concentrated within the Kafue Flats and extend downstream toward the Upper Kafue Gorge hydropower dam, where low-gradient floodplains, prolonged inundation, and stable water availability create optimal conditions for papyrus establishment and persistence (Figure 38). In contrast, papyrus is scarce in upstream and downstream sections of the river, likely due to steeper channel gradients, more confined riverbanks, and greater flow variability that limit wetland formation. This spatial pattern highlights the Kafue Flats as a critical stronghold for papyrus within the basin and underscores the sensitivity of papyrus distribution to changes in flow regime, floodplain connectivity, and river regulation.

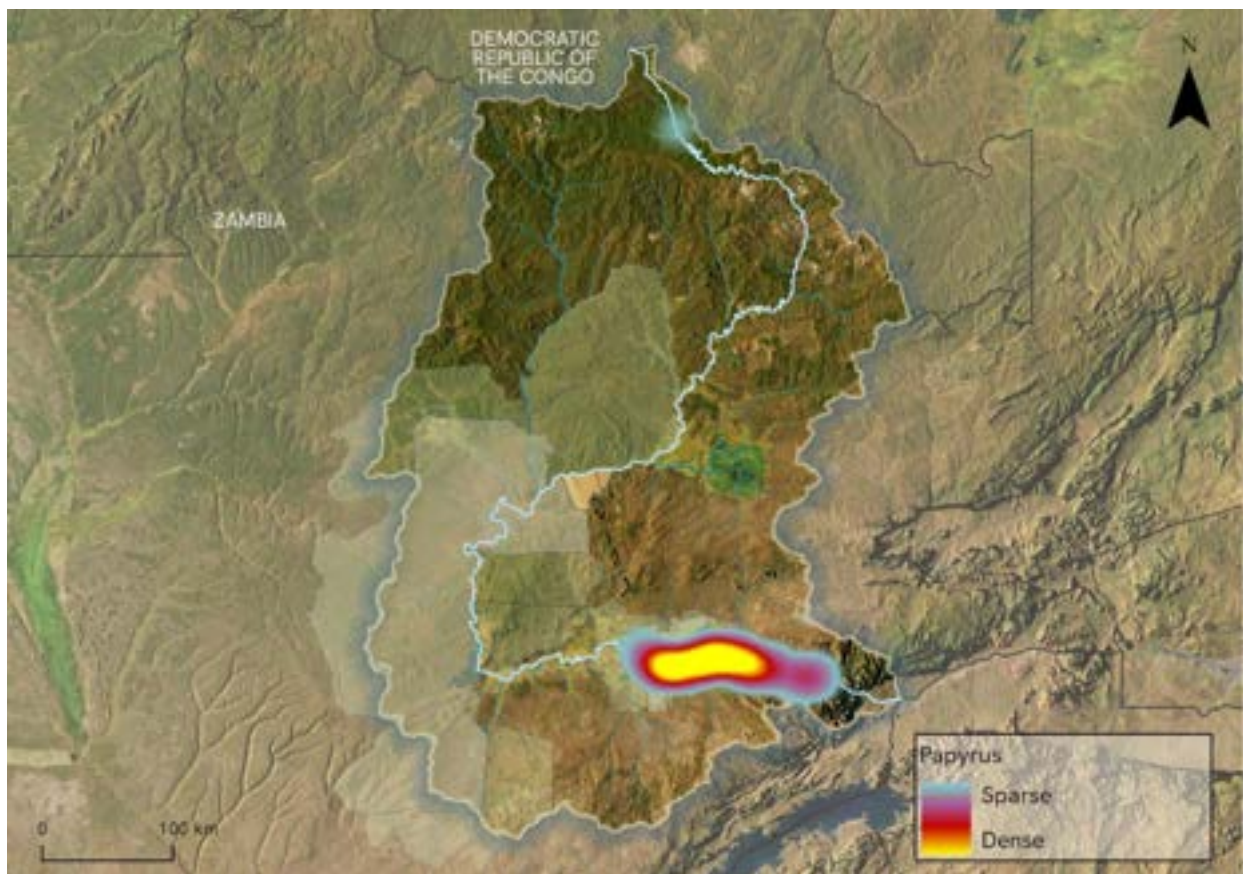


Figure 40: Distribution of papyrus along the Kafue River.

## 2.8 Fire

Fire is one of the most important drivers of ecosystem composition, playing a key role in preventing bush encroachment, clearing dead organic material, promoting grass regrowth, and even facilitating the

germination of some seeds<sup>45</sup>. However, changes to the frequency, intensity and extent of fires can have profound consequences for biodiversity<sup>46,47</sup>. It is important that the ongoing management of the Kafue River includes long-term monitoring of the extent and frequency of fires in the basin.

#### Methods: Fire

To determine the extent of fires along the Kafue River, all recent and ongoing fires within 100 m of the riverbanks were counted. In addition, the following information about the fires was gathered:

- The **freshness of the burn** was estimated based on the level of regrowth in the burned area;
- **Burn intensity** was estimated based on the vegetation remaining in the burned area. Intensity was categorised as follows:
  - *Cool*: groundcover burned but most vegetation remaining;
  - *Medium*: groundcover and some low-level vegetation burned, ~50% of vegetation remaining;
  - *Hot*: all groundcover and vegetation burned.
- The **predominant vegetation type** was identified; and
- The **side of the river** was noted.

#### Results and Discussion: Fire

A total of 346 fires were recorded, with a total burn extent of 52.16 km along the riverbanks. Six of these fires were observed actively burning, while the rest had already burned out, leaving behind scorched land with no visible regrowth. The majority (95%) of these fires occurred in grassland areas, where the abundance of dry grasses and other fine fuels likely contributed to the ignition and spread of fire. These results align with the **MODIS Fire RS Satellite Analysis**, which also identified grasslands and shrublands as having the highest frequency of fires.

Many of the fires detected in the **MODIS Fire RS Satellite Analysis** are not detected in the 2024 survey — likely because of the timing of the expedition in the early dry season. Moreover, the shrublands and grasslands of the Kafue National Park lie inland from the river, and these burn most frequently. As a result, the satellite analyses presented below provides a complete picture of the extent and frequency of fire within the basin.

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<sup>45</sup> Cassidy, L. et al. 2022. *Too much, too late: Fires and reactive wildlife management in northern Botswana's forests and woodland savannas*. 39:160-174.

<sup>46</sup> He, T. et al. 2019. *Fire as a key driver of Earth's biodiversity*. *Biological Reviews*. 94(6):1983-2010.

<sup>47</sup> McLauchlan, K.K. et al. 2020. *Fire as a fundamental ecological process: Research advances and frontiers*. *Journal of Ecology*. 108(5):2047-2069.

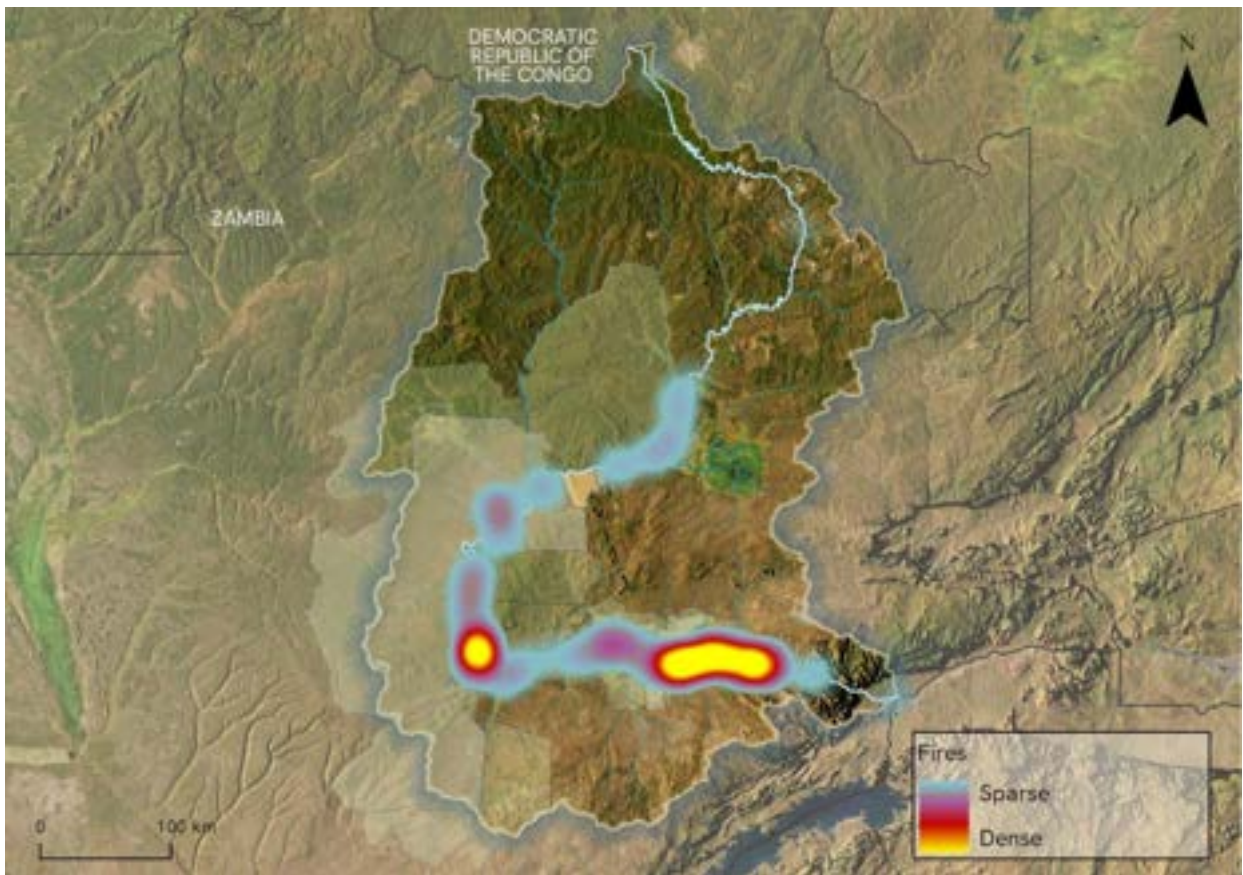


Figure 41: Distribution of fires along the Kafue River in 2024.

### 3. WATER QUALITY

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#### 3.1 The Importance of Water Quality Monitoring on the Kafue River

Water quality is fundamental to ecological integrity, human health, and economic productivity. The Kafue River exemplifies this, providing water for domestic consumption, crop irrigation and hydropower generation. The river also sustains fisheries and a network of wetlands that underpin biodiversity and flood regulation across much of Zambia. The high concentration of mining, agriculture, urban settlements, and industrial activity within the Kafue Basin means that water quality reflects the cumulative influence of both natural processes and multiple land-use pressures operating across space and time.

Effective water quality assessment in large river systems such as the Kafue requires an approach that combines broad spatial coverage with targeted, process-based investigations. In this context, the 2024 and 2025 surveys were designed to be complementary: the former providing a river-wide baseline snapshot of physical water quality and ecological condition, and the latter offering a more focused assessment of hydrochemistry and sediment geochemistry at selected sites of interest. Together, these datasets provide an initial framework for understanding spatial patterns, identifying areas warranting further investigation, and informing longer-term monitoring priorities.

#### 3.2 Water Quality Monitoring Context and Existing Data

The Zambian Water Resources Management Authority (WARMA) operates 19 water quality and flow monitoring stations along the Kafue River (Figure 42). These stations vary in design and capability, ranging from basic gauging installations to telemetric field stations. Water quality measurements are typically undertaken using handheld instruments, with limited continuous or real-time monitoring. Operational constraints, including limited maintenance capacity and vandalism at remote sites, result in variable data availability and a low temporal resolution.

As a result, existing long-term datasets provide limited insight into short-term contamination events, cumulative impacts, or the interaction between river flow and water quality. The 2024 and 2025 TWP surveys therefore represent an important supplementary dataset, offering independent, spatially extensive observations that help contextualise existing monitoring efforts.



Figure 42. The locations of existing water quality and flow monitoring stations along the Kafue River.

### 3.3 Water Quality Assessments 2024 and 2025

#### Water Quality Assessment 2024

In 2024, water quality was assessed at 171 sites along the full length of the Kafue River using an InSitu AquaTROLL 600 multiparameter sonde. Measurements included pH, dissolved oxygen (DO), oxidation–reduction potential (ORP), total dissolved solids (TDS), turbidity, and water temperature (Appendix 3 and 4). Sampling occurred during a predominantly low-flow period, which is typically when contaminant concentrations are most pronounced.

The 2024 survey prioritised spatial coverage and consistency, generating a longitudinal snapshot of physical water quality conditions along the river. Laboratory-based analyses for heavy metals, nutrients, or microbiological indicators were not included in this phase, and results should therefore be interpreted

as indicative of general river condition rather than contaminant-specific risk.



Figure 43: Water quality sampling sites in 2024, with Aquatroll sondes used to collect in situ water chemistry measurements.

#### Water Quality and Geochemical Survey 2025

The 2025 survey adopted a more targeted approach, focusing on selected sites within the Copperbelt and Kafue National Park. Field-based hydrochemical measurements were complemented by laboratory analyses of water and sediments, including major ions, trace metals, and sediment geochemistry. This work included repeat sampling at several sites surveyed in 2024, allowing limited year-on-year

comparison.

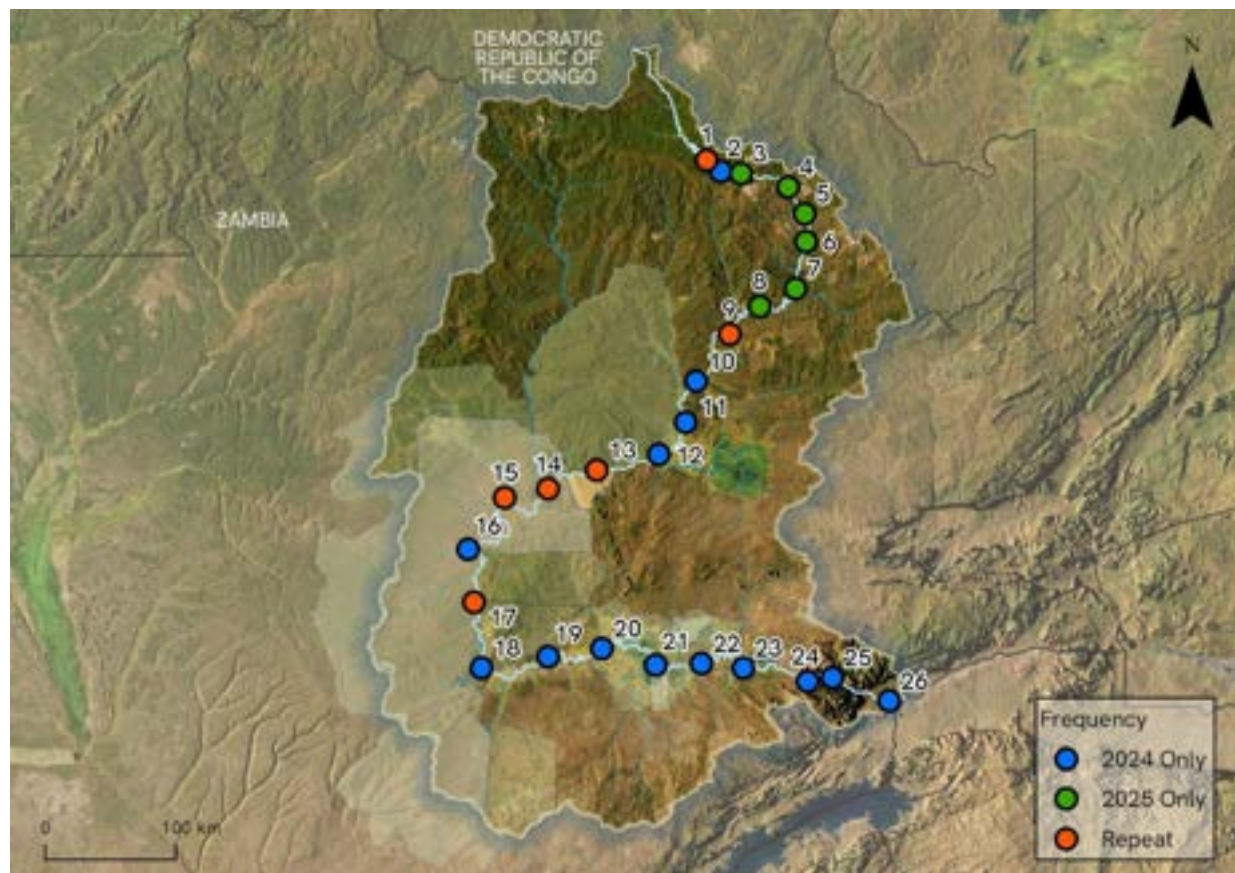


Figure 44. Geochemical survey sites in 2024 and 2025. While the 2024 dataset provides broad spatial context based on in-situ measurements, the 2025 dataset offers greater analytical depth but reduced spatial coverage. Direct comparisons between years are limited to sites with repeat sampling and should be interpreted cautiously.

Sediment and geochemical interpretation were independently reviewed by Jones & Wagener (JAWS), providing a third-party specialist assessment of data quality, analytical methods, and interpretation. The independent review emphasised sediment-bound metals as a key indicator of long-term contamination, given the capacity of sediments to act as persistent contaminant sinks within river systems.

### 3.4 Results and Discussion: Water Quality

#### General Water Quality

Spatial variation in physical water quality parameters along the Kafue River reflects a combination of tributary inflows, land use, channel morphology, and hydrological conditions (Figure 45). Natural features such as wetlands and floodplains exert a strong moderating influence by slowing flows, trapping sediments, and stabilising water chemistry.

Across most of the river, physical water quality parameters measured in 2024 generally fell within guideline ranges for designated water uses, as defined by the Zambian Bureau of Standards (ZABS)<sup>48</sup>. This is notable given the low-flow conditions during sampling, when rivers are often most vulnerable to water

<sup>48</sup>Zambia Bureau of Standards. 2021. *Ambient Water Quality – Specifications (ZS 1182: 2021)*. Lusaka, Zambia.

quality deterioration.

#### *pH and Dissolved Oxygen (DO)*

Measured pH values along the river ranged from circumneutral to slightly alkaline, with all sites remaining within accepted guideline limits. Localised elevations in pH were observed near urban and industrial centres and at select downstream locations (Figure 45). While temperature and geological buffering may contribute to these patterns, their spatial distribution suggests that further investigation would be required to distinguish natural variability from anthropogenic influences.

Dissolved oxygen concentrations showed greater spatial variability. Most sites met recommended thresholds for aquatic ecosystem protection; however, lower DO values were recorded in headwater floodplains, across the Kwesa Floodplain, at the Lukanga River confluence, and in sections of the Kafue Flats (Figure 45). These reductions may reflect low-flow conditions, elevated decomposition of organic matter, reduced mixing, or wetland biogeochemical processes. Conversely, elevated DO values were observed in faster-flowing reaches and downstream of reservoirs, likely linked to increased turbulence and cooler water inputs.

#### *Total Dissolved Solids (TDS), Conductivity, and Salinity*

TDS, conductivity, and salinity followed closely aligned spatial patterns and are presented here using TDS as a representative metric (Figure 45). Stepwise increases in TDS were observed downstream of major tributary confluences and urban or industrial centres. These parameters do not identify specific contaminants but indicate changes in the dissolved load of the river, which may arise from a combination of natural weathering, agricultural runoff, urban effluent, and mine-impacted waters.

#### *Turbidity and Water Temperature*

Turbidity measurements during the 2024 survey were affected by intermittent sensor calibration issues, resulting in incomplete coverage. Where reliable data were available, turbidity values were generally moderate and unlikely to impair key ecological processes (Figure 45). Isolated turbidity spikes coincided with major tributary inputs and should be interpreted cautiously given known sensor limitations.

Water temperature ranged from approximately 19–28 °C and was strongly influenced by time of day, channel morphology, and flow conditions. Elevated temperatures were observed in low-gradient floodplain reaches and at select sites adjacent to human activity (Figure 45). Localised temperature increases may contribute to ecological stress by reducing oxygen solubility and accelerating biogeochemical processes.

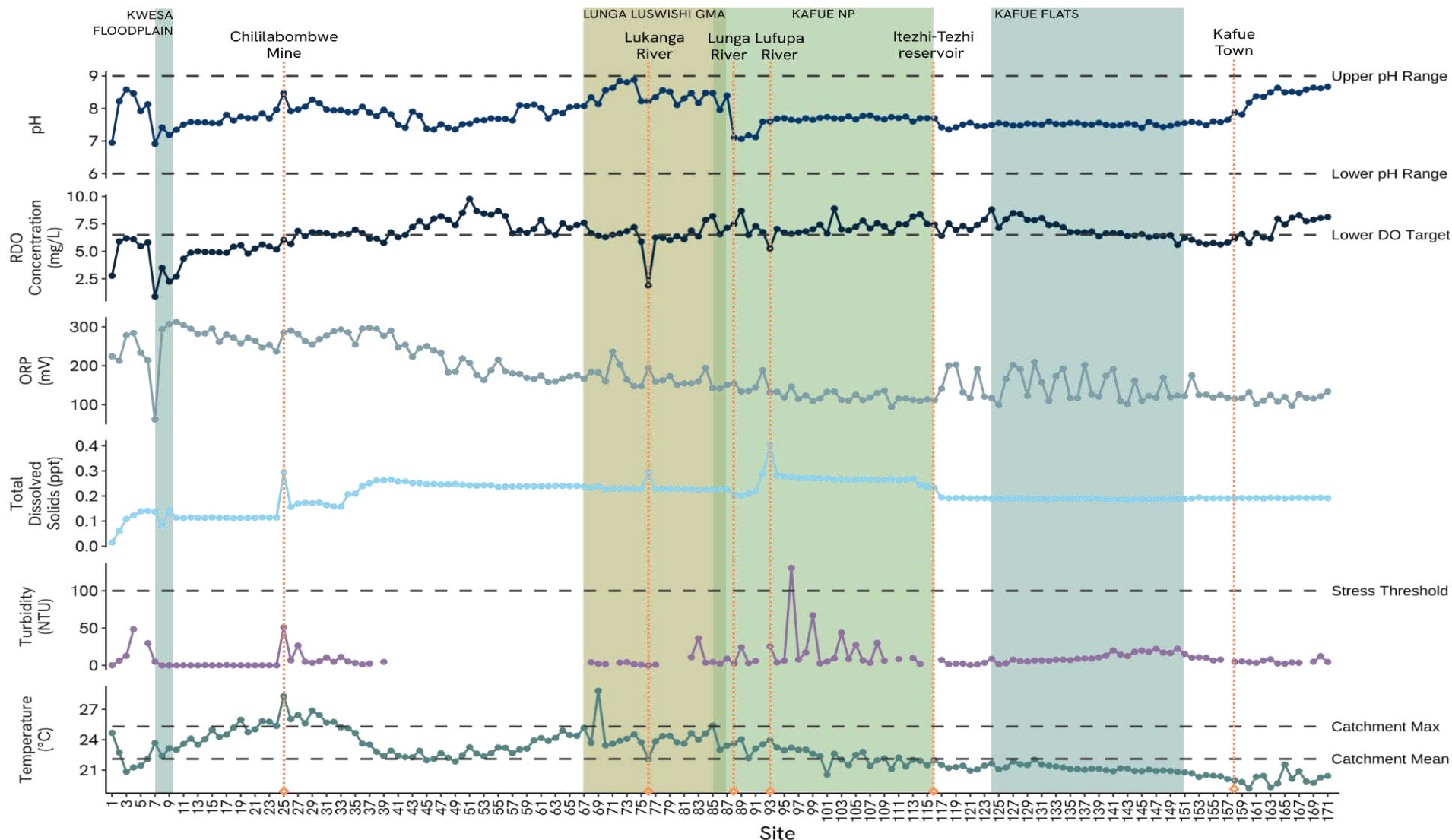


Figure 45. Spatial plots of pH, dissolved oxygen (DO), oxidation-reduction potential (ORP), total dissolved solids (TDS), turbidity, and water temperature measured along the Kafue River in Zambia. Orange lines show sites of interest which are discussed further below.

A pronounced turbidity and temperature spike was recorded at site 25 near Chililabombwe, where the Kakosa River enters the Kafue. Here, water temperatures increased by approximately 3°C relative to adjacent sites. This may indicate thermal pollution, potentially linked to tailing dams or heated effluent from mining operations (Figure 46). Thermal inputs of this kind can contribute to localised warming, which may induce physiological stress in aquatic organisms, disrupt trophic interactions, and accelerate algal growth and eutrophication processes. Given that site 25 also exhibited elevated values for pH and TDS, further investigation is recommended to assess the potential contribution of this site to cumulative water quality changes in this area.



Figure 46: The heavily degraded Kakosa River contaminates the upper Kafue River near Chililabombwe (site 25).

## Heavy Metals and Sediment Geochemistry

Laboratory analyses conducted in 2025, and independently reviewed, indicate that dissolved metal concentrations in the Kafue River water column did not show clear, event-specific trends associated with the Mwambashi spill at the time of sampling (Figure 47). This outcome is consistent with expectations for large rivers, where dilution and rapid mixing can mask short-term water column signals. However, most dissolved heavy metals were elevated directly downstream of the Kakosa River, indicating that this site warrants particular attention in future monitoring and management considerations.

Sediment-bound metals provide a more representative indicator of sustained contamination than water-column concentrations alone, particularly in systems characterized by episodic inputs and strong seasonal flows. Sediment geochemistry revealed clearer evidence of metal accumulation in sediments associated with the Mwambashi River and adjacent depositional zones of the Kafue River. Geo-accumulation index (I-Geo) analysis identified enrichment of cobalt, copper, and, to a lesser extent, arsenic, cadmium, and lead (Figure 48). Elevated sediment metal concentrations are of relevance because sediments can act as long-term contaminant reservoirs, with the potential to release metals back into the water column under changing chemical conditions.

The Mwambashi River is by no means the only contaminated site along the Kafue River. A recent publication by Babek et al. (2026) found that the Kafue River carries some of the most extreme copper–cobalt mining-related sediment contamination documented globally, with contamination detectable at multiple locations along the river corridor<sup>49</sup>. Based on sediment cores collected in May 2024, Babek et al. (2026) identified Chingola/Mushishima River, Hippo Pool (Fitwaola Bridge), and the Kitwe reach as among the most heavily contaminated depositional zones — with sediment heavy metal concentrations above the maxima detected in our survey.

Of particular relevance to the present study is Hippo Pool, a known sediment accumulation zone located downstream of multiple Copperbelt tributaries. While Babek et al. (2026) do not attribute contamination at Hippo Pool to a single source, it is located directly downstream of the Kakosa River (and the highly contaminated Mushishima River), highlighting a spatial consistency between the two datasets. Collectively, these findings support the interpretation that contamination of Kafue River sediments is ongoing, spatially widespread, and strongly influenced by tributary-derived inputs from several mining-affected catchments.

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<sup>49</sup> Babek O, Sracek O, Ettler V, Kapusta J, Křibek B, Mihaljevič M, et al. Trends of Cu and Co contaminated sediment dispersal along the Kafue River, the Zambian Copperbelt. *J Geochem Explor.* 2026;280:107900.

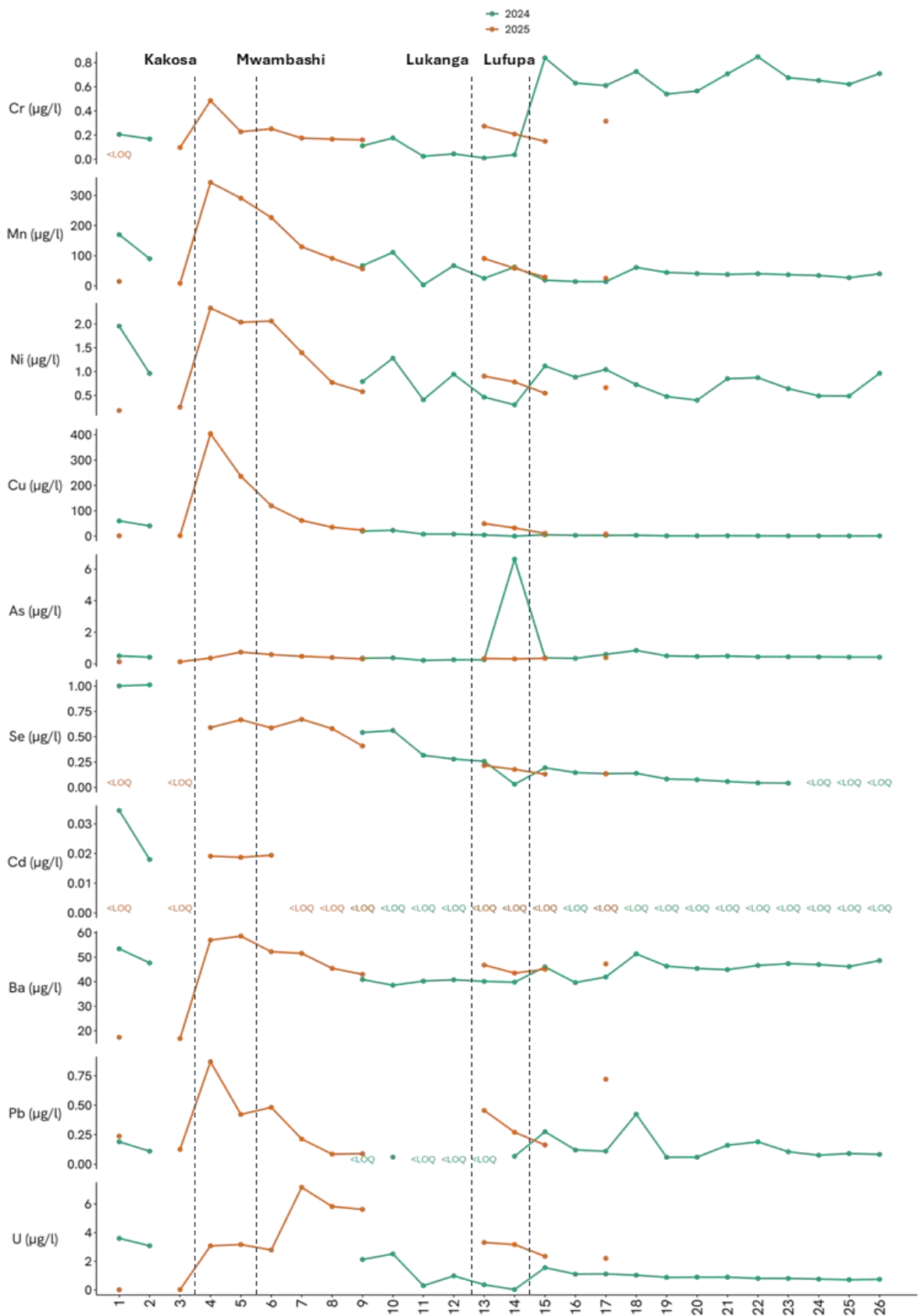


Figure 47. Dissolved heavy metal concentrations in the Kafue River in 2024 (green) and 2025 (orange).

I-Geo (Upstream)	Concentration (mg/kg)	KAFU25 050	KAFU25 051	KAFU25 052	KAFU25 053	KAFU25 053	KAFU25 053	KAFU25 054	KAFU25 055	KAFU25 055	KAFU25 056	KAFU25 058	KAFU25 058	KAFU25 060	KAFU25 060
		At water's edge	At water's edge	At water's edge	At water's edge	Mid-way up bank	Highest point on riverbank	At water's edge	At water's edge	Mid-way up bank	At water's edge	At water's edge	Mid-way up bank	At water's edge	Mid-way up bank
<b>Manganese</b>	767	-3.8	-4.3	0.91	0.26	-0.080	2.3	-0.70	-0.73	-0.93	-1.2	1.6	1.9	0.67	0.74
<b>Cobalt</b>	144	-3.2	-3.7	0.86	0.53	0.13	3.2	0.86	0.57	0.50	1.1	1.9	1.9	1.6	0.90
<b>Copper</b>	2 509	-5.3	-4.4	0.95	-2.3	-2.4	1.9	1.2	-0.65	-0.40	1.1	-0.10	0.30	0.090	0.78
<b>Zinc</b>	48	-0.97	-0.84	-0.11	1.4	0.65	5.0	0.20	1.7	1.7	0.42	1.2	1.7	1.1	1.7
<b>Arsenic</b>	2.9	-1.4	-1.6	0.38	-0.89	-1.1	3.0	0.96	1.4	3.5	1.7	0.21	0.82	0.36	0.40
<b>Cadmium</b>	0.30	-0.10	-0.42	-1.6	0.23	-0.68	3.1	-1.7	0.28	0.020	-1.6	-0.020	0.27	0.25	-0.24
<b>Mercury</b>	0.059	-0.59	-2.1	0.13	-2.4	-0.65	0.16	-1.2	0.73	0.61	0.83	0.28	0.12	1.4	-0.60
<b>Lead (sum)</b>	39	-0.51	-0.94	-0.36	-1.9	-1.5	2.3	0.78	1.7	2.1	2.4	0.85	0.93	1.2	0.78

Figure 48. I-Geo table using the upstream averages. The Mwambashi River (KAFU25\_053) and Kitwe (KAFU\_055) were clear outliers, exhibiting elevated heavy metal levels relative to other sites.

## Role of Wetlands in Water Quality Regulation

Wetlands such as the Kwesa Floodplain, Lukanga Swamp, and the Kafue Flats play a critical role in moderating water quality by trapping sediments, attenuating nutrient loads, and stabilising river chemistry (Figure 49). Observed improvements in water quality downstream of major wetland complexes are consistent with their function as natural biofilters. The buffering capacity of these wetlands is particularly important in the context of cumulative upstream pressures. However, the long-term resilience of these systems under increasing land-use intensity and climate variability remains uncertain.



*Figure 49: The Kwesa Floodplain has abundant aquatic vegetation that traps sediments, oxygenates the water and supports biodiversity of aquatic life, thereby improving overall river health.*

Overall, water quality along the Kafue River reflects the combined influence of natural buffering processes and multiple anthropogenic pressures. Physical water quality parameters measured in 2024 generally fell within guideline ranges, while targeted geochemical analyses in 2025 identified sediment-associated metal enrichment at selected sites. Wetlands play a central role in mitigating downstream impacts, but continued monitoring is required to understand long-term trajectories and emerging risks.

## 4. RIVER FLOW

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The flow of the Kafue River regulates sediment transport, water quality, floodplain connectivity, and habitat availability, while also underpinning hydropower generation, irrigation, and domestic water supply across much of Zambia. With increasing abstraction pressure and climate change projections indicating a potential decline in rainfall and runoff within the basin, understanding spatial patterns of flow — particularly during low-flow periods — is critical for sustainable water resource management.

### Methods: Discharge

River discharge was measured during the 2024 expedition using a SonTek M9 Acoustic Doppler Current Profiler (ADCP) at 14 locations along the Kafue River and one site on the Lunga River (Figure 50). Sites were georeferenced using GPS and selected to capture longitudinal changes in flow from the upper reaches to the lower basin, including key tributary confluences and regulated river sections. Measurements provided instantaneous estimates of discharge, channel depth, and cross-sectional flow profiles, offering in-situ insight into river dynamics during the dry season.

During the 2025 expedition, a subset of these original ADCP sites was re-sampled under comparable dry-season conditions, using the same instrument and measurement protocols. This repeat sampling enabled a preliminary comparison of discharge between years at fixed locations, while recognising that measurements represent instantaneous snapshots rather than continuous flow records.



Figure 50: The ADCP used to measure river discharge being towed across the river.

### Results and Discussion: Discharge

Discharge measurements from both 2024 and 2025 reflect markedly low-flow conditions across much of the Kafue Basin, consistent with recent drought conditions. This is illustrated at Site 10, where discharge measured 69.5 m<sup>3</sup>/s on 22 May 2024 — substantially lower than the historical average of approximately 385 m<sup>3</sup>/s for May and 200 m<sup>3</sup>/s for June (Table 11)<sup>50</sup>. This comparison with long-term records highlights the severity of low-flow conditions during the survey period and provides important context for

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<sup>50</sup> Wamulume, J. et al. 2011. *Exploring the hydrology and biogeochemistry of the dam-impacted Kafue River and Kafue Flats (Zambia)*. *Physics and Chemistry of the Earth*. 36(14–15):775–788.

interpreting observed spatial patterns in discharge.

Table 11: ADCP measurements taken along the Kafue River.

ADCP site	River	Latitude	Longitude	Discharge (m <sup>3</sup> /s) 2024	Discharge (m <sup>3</sup> /s) 2025
1	Kafue	-11.7879	27.16837	1.0	
2	Kafue	-12.3507	27.54869	14.5	11.7
3	Kafue	-12.9046	28.24041	30.8	31.3
4	Kafue	-13.5228	27.71417	38.6	47.1
5	Kafue	-14.1117	27.41105	45.2	
6	Kafue	-14.3731	27.18992	46.3	
7	Kafue	-14.3726	27.18755	44.5	
8	Lunga	-14.577	26.43471	37.0	46.6
9	Kafue	-14.577	26.43615	43.1	115.8
10	Kafue	-14.9452	25.91426	69.5	141.5
11	Kafue	-15.4489	25.95004	68.3	139.9
12	Kafue	-15.7116	27.51778	152.8	
13	Kafue	-15.8329	28.24906	128.9	
14	Kafue	-15.8955	28.56476	108.9	
15	Kafue	-15.942	28.91159	124.1	

At re-sampled sites (2 – 4), discharge values recorded in 2025 were broadly similar to those measured in 2024, indicating limited interannual variation in upper-basin flows during the dry season. While the small number of repeat sites constrains definitive conclusions, this pattern reinforces the hydrological importance of the source-region wetlands in maintaining flow continuity.

A pronounced increase in discharge was observed downstream of the Lunga River confluence, particularly during the 2024 basin-wide drought. In that year, the Lunga River maintained a comparatively stable flow of 37.0 m<sup>3</sup>/s, contributing a substantial proportion of downstream discharge at the confluence and closely matching the Kafue’s upstream flow of 43.1 m<sup>3</sup>/s. This contrasts with 2025, when more typical rainfall conditions drove a sharp recovery in Kafue River flows (115.8 m<sup>3</sup>/s), while the Lunga increased more modestly to 46.6 m<sup>3</sup>/s. The comparison underscores both the severity of the 2024 drought and the Lunga sub-catchment’s relative hydrological stability, highlighting its role as a critical buffer that sustains Kafue River flows during periods of water scarcity and influences downstream hydrological conditions (Figure 51).

Downstream of the Kafue Flats, discharge patterns become increasingly influenced by river regulation and abstraction. Between the Kafue Flats and the Kafue Gorge Upper reservoir, discharge declined from approximately 150 m<sup>3</sup>/s to around 130 m<sup>3</sup>/s, followed by short-term fluctuations of 20–30 m<sup>3</sup>/s further downstream. These variations are consistent with flow regulation associated with hydropower operations at Itezhi-Tezhi, Kafue Gorge Upper, and Kafue Gorge Lower dams.

Dry-season abstraction for irrigation and domestic supply forms an important component of the river’s flow balance. During the dry season, an estimated 9.9–12.1 m<sup>3</sup>/s is withdrawn from the Kafue River to support Mazabuka’s sugarcane industry<sup>51</sup>. Moreover, 44% of Lusaka’s drinking water comes from the Kafue River, with an abstraction plant in Kafue town removing 110,000 m<sup>3</sup> per day (1.27 m<sup>3</sup>/s)<sup>52</sup>. This represents a relatively small fraction of peak wet-season flows but a more significant proportion of

<sup>51</sup> German, L.A. 2020. *The environmental effects of sugarcane expansion: A case study of changes in land and water use in southern Africa. Applied Geography. 121:102240.*

<sup>52</sup> Ummah, M. 2019. *Water demand management field study. Lusaka Water and Sewerage Company.*

discharge during drought conditions.



*Figure 51: Confluence between the Lunga River (left) and the Kafue River (right). The difference water colours is because of variation in water chemistry and suspended sediments.*

## 5. AQUATIC BIODIVERSITY

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Aquatic biodiversity in the Kafue River was assessed using a complementary suite of monitoring techniques, including environmental DNA metabarcoding, macroinvertebrate surveys, fish sampling, and invertebrate trapping. Together, these approaches highlight the importance of integrated aquatic biodiversity monitoring for detecting spatial patterns, tracking change over time, and informing river management.

### 4.1 Environmental DNA

Environmental DNA (eDNA) metabarcoding is rapidly transforming bioassessment and biodiversity monitoring by providing a non-invasive and comprehensive approach to detecting species in aquatic ecosystems<sup>53</sup>. This method is particularly valuable in African river systems, where traditional survey techniques are often constrained by logistical challenges, limited infrastructure, and the scale and remoteness of many regions. By capturing and analysing trace amounts of genetic material shed by organisms into their environment, eDNA surveys allow for the detection of a broad range of taxa – including rare, small, and invasive species – that may otherwise go unnoticed using conventional methods.

#### Methods: eDNA

To assess aquatic biodiversity along the Kafue River, triplicate water samples were collected for eDNA analysis at approximately 60 km intervals, resulting in 26 sampling locations across the river system (Figure 52 and Figure 53). Upon completion of the expedition, all samples were transported to the Wild Bird Trust's molecular laboratory in Maun, Botswana, for DNA extraction. Extracted eDNA samples were subsequently sent to a specialised sequencing facility in Switzerland for amplification and metabarcoding targeting the mitochondrial 12S rRNA gene region. Sequencing and data analysis are currently ongoing. Preliminary results will be made available upon request once processing is complete. Detailed protocols for sample preparation are provided in Appendix 5.

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<sup>53</sup> Takahashi, M. et al. 2023. Aquatic environmental DNA: A review of the macro-organismal biomonitoring revolution. *Science of the Total Environment*. 873(February):162322. DOI: [10.1016/j.scitotenv.2023.162322](https://doi.org/10.1016/j.scitotenv.2023.162322).



Figure 52. eDNA sample sites.



Figure 53: Aquatic eDNA samples were collected by filtering water through a filter.

#### 4.2 Aquatic Macroinvertebrates

The Zambian Invertebrate Scoring System (ZISS) is a standardised field-based bioassessment protocol for rapidly assessing the health of perennial rivers in Zambia. The protocol involves three stages: i) collecting

aquatic macroinvertebrates from several habitats within the river; ii) identifying these organisms to a family level; and iii) comparing the identified macroinvertebrate families to a peer-reviewed matrix of predetermined scores. Using this information, the protocol allows researchers to infer the health of perennial rivers<sup>54</sup>. Generally, higher ZISS scores indicate healthier and more diverse aquatic habitats. Additional metrics for comparison include the total number of taxa recorded and the average score per taxon (ASPT).

#### Methods: Aquatic Macroinvertebrates

Benthic macroinvertebrate assessments were conducted at approximately 60 km intervals along the Kafue River, resulting in a total of 26 sampling sites during the 2024 survey (Table 12). Sampling followed the ZISS protocol, using a D-net to sweep marginal and aquatic vegetation for a total of two minutes, followed by 15 minutes of sorting and family-level identification in the field. Gravel, sand, and mud substrates were not sampled due to logistical constraints and limited accessibility at many sites.

For each site, the total number of taxa, ASPT, and overall ZISS scores were calculated. Representative specimens from each family were preserved in 95% ethanol and transported to the Wild Bird Trust laboratory in Maun, Botswana, for verification.

In 2025, a subset of the ZISS sites established in 2024 — primarily within the Copperbelt and downstream reaches — were re-sampled to assess short-term changes in river condition following documented contamination events. Only sites sampled in both years were included in interannual comparisons, allowing for cautious interpretation of temporal trends.

#### Results and Discussion: Aquatic Macroinvertebrates

Across the 2024 survey, the average ZISS score for the Kafue River was 68.2 ( $\pm 17$ ), with a mean of 13.8 taxa per site and an average ASPT of 5.0 (). Higher ZISS scores and greater representation of sensitive taxa were generally recorded near the river's source and in downstream reaches between the Itezhi-Tezhi Dam and the confluence with the Zambezi River. These patterns are consistent with greater habitat heterogeneity and reduced cumulative anthropogenic pressure in these sections of the river.

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<sup>54</sup> Dallas, H.F. 2018. *Zambian Invertebrate Scoring System (ZISS): A macroinvertebrate-based biotic index for rapid bioassessment of southern tropical African river systems*. *African Journal of Aquatic Science*. 43(4):325-344.

Table 12: Summarised Zambian Invertebrate Scoring System (ZISS) data for the 25 sites conducted on the Kafue River.

ZISS Site	Latitude	Longitude	No. of Taxa (2024)	ASPT (2024)	ZISS Score (2024)	No. of Taxa (2025)	ASPT (2025)	ZISS Score (2025)
1	-11.78794	27.16833	14	6.2	87			
2	-12.13725	27.36157	11	5.6	62			
3	-12.35792	27.5541	16	4.8	77	14	4.8	67
4	-12.4472	27.7928	15	4.4	66	14	5	70
5	-12.54	28.11634	7	6	42	8	5.3	42
6	-12.90478	28.24032	11	4	44	11	4.1	45
7	-13.22029	28.16563	11	4.7	52	9	4.2	38
8	-13.33695	27.91879	10	4.1	41	8	5.3	42
9	-13.5232	27.71383	12	4.6	55			
10	-13.83666	27.48259	11	4.9	54			
11	-14.11171	27.41099	12	4.5	54			
12	-14.32788	27.2277	15	4.6	69			
13	-14.43197	26.80159	15	4.9	73	17	4.9	83
14	-14.54815	26.48299	14	4.4	61	19	4.6	87
15	-14.61211	26.16821				10	4.4	54
16	-14.7941	26.19464	22	4.4	96	15	5.1	77
17	-14.95413	25.91624	15	4.3	65	44	4.9	44
18	-15.30783	25.95684	15	4.7	70	23	4.6	23
19	-15.67101	26.46811	16	6	96			
20	-15.61559	26.83669	18	5.1	92			
21	-15.72418	27.20458	19	4.8	92			
22	-15.71166	27.51772	12	5.1	61			
23	-15.7451	27.80505	12	5	60			
24	-15.83157	28.24923	19	5.2	98			
25	-15.80971	28.41863	12	5.7	68			
26	-15.96071	28.80897	12	5.8	69			
<b>AVERAGE</b>			<b>13.8</b>	<b>5.0</b>	<b>68.2</b>	<b>16</b>	<b>4.85</b>	<b>56</b>

Lower ZISS scores were consistently observed through the Copperbelt, particularly downstream of Kitwe, and remained depressed until the river enters Kafue National Park. This longitudinal decline aligns with patterns identified in the water quality assessment, where changes in hydrochemistry and sediment characteristics suggest cumulative impacts associated with upstream land use. While ZISS results are inherently sensitive to habitat availability, the spatial coherence of reduced scores across multiple sites suggests a broader influence on macroinvertebrate community structure in this reach.

Side-by-side comparison of ZISS results from 2024 and 2025 at repeat sites shows no substantial change in overall scores over the one-year period (Figure 54). This finding suggests that macroinvertebrate communities may be responding to persistent, chronic pressures rather than short-term disturbance alone. In river systems, macroinvertebrate assemblages often recover relatively quickly once pollution sources are removed; the absence of marked improvement between years therefore indicates that underlying stressors may still be influencing river condition within the Copperbelt.

ZISS scores recorded within the Kafue Flats are comparable to historical assessments conducted between 2009 and 2012, which reported an average score of 53.6 ( $\pm 9$ ) for high-order river channels in the wetland. This similarity suggests that aquatic habitat within the main channel of the Kafue Flats has remained broadly stable over time, reinforcing the role of wetlands in buffering downstream sections of the river from upstream pressures.

Taken together, the 2024 and 2025 ZISS results indicate a clear spatial pattern in river condition along the Kafue River, with reduced macroinvertebrate diversity and sensitivity through the Copperbelt and improved conditions downstream. While year-to-year changes were limited at repeat sites, the persistence of lower scores in impacted reaches highlights the value of continued, standardised ZISS monitoring. Repeated assessments at fixed sites will be essential for distinguishing short-term variability from longer-term trends and for evaluating the effectiveness of future management interventions.

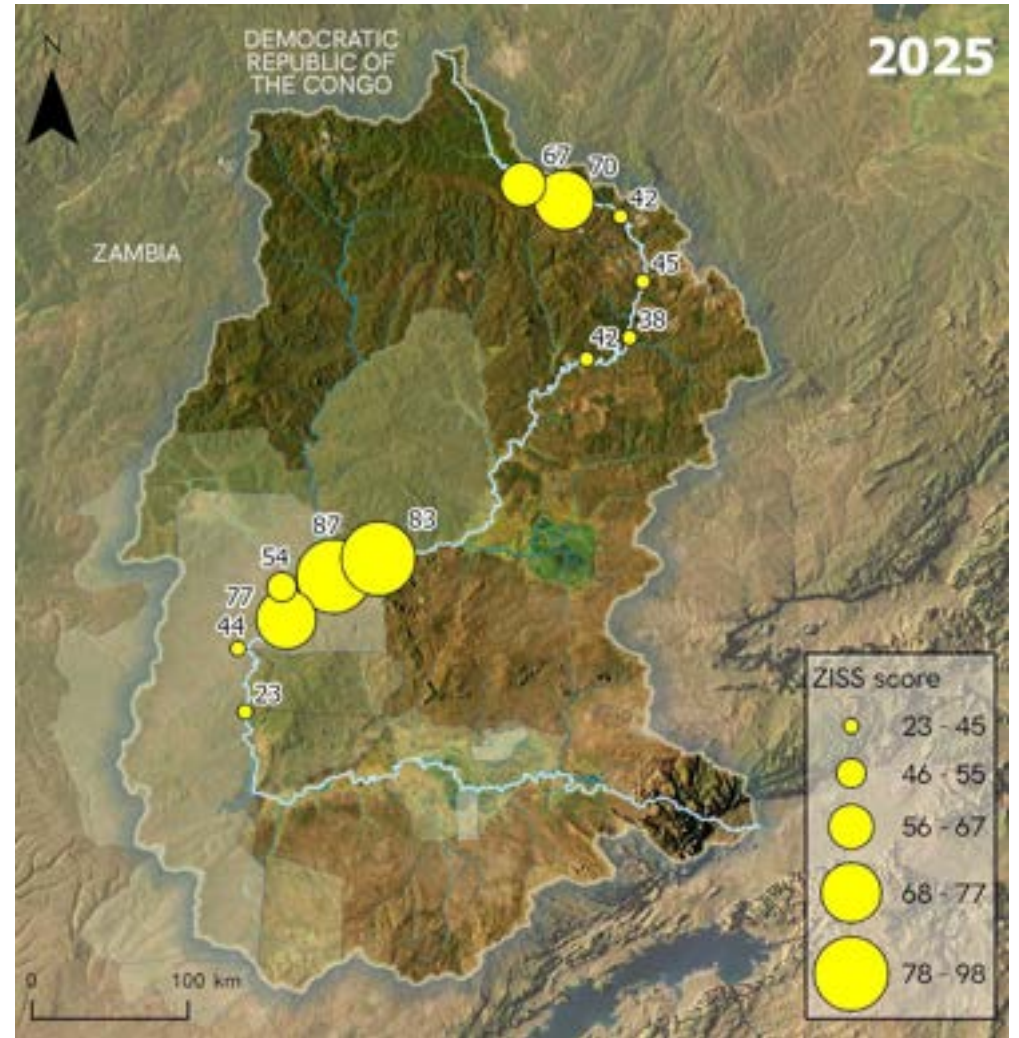
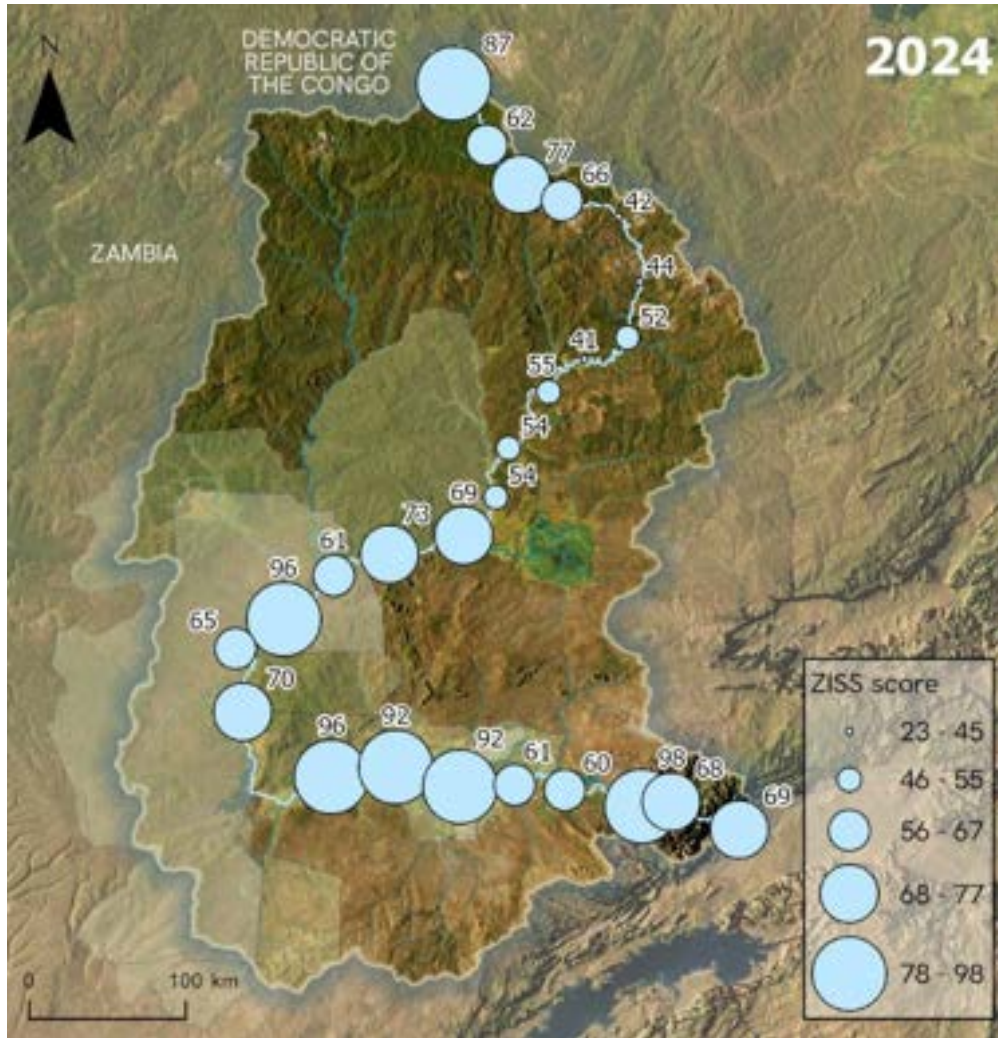


Figure 54: The ZISS results along the Kafue River in 2024 (left) and 2025 (right). Larger circles indicate a higher score — which in turn infers a healthier river ecosystem. As expected, scores are particularly low surrounding Kitwe.

## 4.1 Fish Sampling

The Kafue River supports a diverse array of fish species, shaped by a variety of ecological zones and seasonal flood dynamics that create critical breeding and feeding habitats. While the current study focuses on selected sections of the river, it builds on a substantial foundation of historical and regional knowledge of fish diversity in the Kafue. Prior surveys, particularly those conducted in the Kafue Flats, have recorded high species richness and provide a valuable benchmark for comparison.

Additional reference material is available through curated collections held by institutions such as the South African Institute for Aquatic Biodiversity (SAIAB) and the University of Leuven, which house numerous specimens from the Kafue system. Together with recent regional assessments, including those undertaken as part of broader ecosystem initiatives, these sources inform expectations for species composition and diversity. Drawing on this contextual foundation, the present survey contributes to the ongoing effort to document and monitor fish communities in the Kafue.

### Methods: Fish Sampling

Fish diversity was sampled at 56 sites distributed along the Kafue River, from approximately 40 km downstream of the source to 13 km upstream of the confluence with the Zambezi River (Figure 55). Sampling employed a combination of standardised and opportunistic techniques, including overnight deployment of fyke nets at suitable sites, and the use of dip nets, cast nets, hook-and-line fishing, and inspection of catches from local fishers. Any fish captured incidentally in freshwater crayfish traps (see Invasive Crayfish Sampling below) were also included in the dataset.

A conservative subset of the captured fish was anaesthetised using clove oil, photographed, and preserved in a 10% formalin solution. Duplicate tissue samples were collected from representative specimens of each species at each site and stored in 99% ethanol. These tissue samples will be used for targeted DNA analyses and to support the development of a regional eDNA reference library, strengthening future biodiversity assessments.

Following the expedition, specimens were transported to the American Museum of Natural History for identification verification and accessioning into the institution's ichthyology collection. While final taxonomic confirmation is ongoing, the sampling effort represents a substantial contribution to current knowledge of freshwater fish diversity in the Kafue River.



Figure 55: Fish sample sites along the Kafue River.



Figure 56: Using a cast-net to sample fish diversity on the Kafue River.

## Results and Discussion: Fish sampling

In total, 1,344 fish specimens were captured, representing an estimated 70 species across the river system. The most frequently recorded species were *Tilapia sparmanii* (N = 179), *Lacustricola johnsoni* (N = 168), and *Pseudocrenilabrus philander* (N = 157) (Figure 56). Preliminary results indicate the presence of several taxa in the upper Kafue that may be new to science; ongoing taxonomic work will determine whether these represent previously undescribed species. Full preliminary species counts are provided in Appendices 6 and 7.

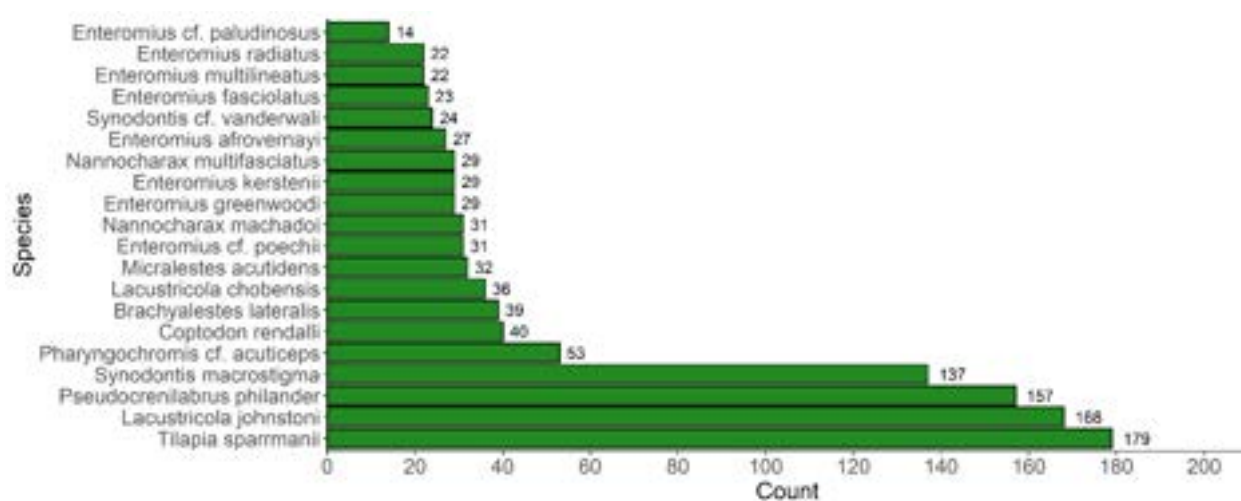


Figure 57: The 20 most detected species on the Kafue River transect.

Overall, species richness and composition reflect the strong influence of river connectivity, habitat heterogeneity, and wetland processes along the Kafue. These findings reinforce the importance of continued, standardised monitoring to detect changes in fish communities over time, particularly in relation to water quality, flow regulation, and invasive species.

### Epizootic Ulcerative Syndrome

Epizootic ulcerative syndrome (EUS) is known from the Kafue River and may pose a significant threat to fisheries and biodiversity. The disease is caused by a pathogenic water mould, *Aphanomyces invadans*, which shows low host specificity and has been documented to infect over 100 species worldwide<sup>55</sup>. Epizootic ulcerative syndrome has been previously reported in the Kafue, first documented in 2010<sup>56</sup>.

Epizootic ulcerative syndrome initially presents as small red spots on the fish, leading to its colloquial name, 'red spot disease'. Disease progression involves the spots becoming ulcers, followed by erosion of the skin, and the development of nodules on internal organs. Ultimately, infected fish succumb to the disease, which can occur on a large scale, severely impacting local fish biodiversity and fisheries.

During this expedition, fish with lesions resembling EUS were observed at multiple locations, from sampling site 6 near Yowela Bridge to the Kafue Flats. However, without genetic confirmation, a definitive diagnosis cannot be made. Some observed lesions may be due to other causes, such as gillnet damage.

<sup>55</sup> Kar, D. & Aurobindo, R. 2021. Epizootic Ulcerative Syndrome (EUS) Fish Disease Chronology, Status and Major Outbreaks in the World. *Transylvanian Review of Systematical and Ecological Research*. 23(2):29–38. DOI: 10.2478/trser-2021-0012.

<sup>56</sup> Kar, D. & Aurobindo, R. 2021. Epizootic Ulcerative Syndrome (EUS) Fish Disease Chronology, Status and Major Outbreaks in the World. *Transylvanian Review of Systematical and Ecological Research*. 23(2):29–38. DOI: 10.2478/trser-2021-0012.

Further analysis of specimen is needed to determine the presence of EUS.

#### *Nile Tilapia*

The invasive Nile tilapia (*Oreochromis niloticus*) has been introduced to the Kafue River multiple times since the 1980s and is widely recognised as a major driver of ecological change in the basin<sup>57</sup>. Introductions have facilitated competition with, and genetic introgression into, native tilapia species.

Several specimens collected during this survey exhibited morphological characteristics consistent with hybrids between Nile tilapia and native tilapia species (Figure 58). These observations add to growing evidence that hybridisation is occurring within the Kafue system, with likely long-term implications for the genetic integrity, distribution, and resilience of indigenous fish populations<sup>58</sup>.



Figure 58: Nile tilapia (*Oreochromis niloticus*; top) and a native tilapia/Nile tilapia hybrid (bottom).

#### 4.2 Invasive Crayfish Sampling

The Australian redclaw crayfish (*Cherax quadricarinatus*) is an invasive freshwater species that has rapidly

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<sup>57</sup> Ian, B. et al. 2014. Hybridization between non-indigenous *Oreochromis niloticus* and native *Oreochromis* species in the lower Kafue River and its potential impacts on fishery. *Journal of Ecology and The Natural Environment*. 6(6):215-225.

<sup>58</sup> Deines, A.M. et al. 2014. Hybridisation between native *Oreochromis* species and introduced Nile tilapia *O. niloticus* in the Kafue River, Zambia. *African Journal of Aquatic Science*. 39(1):23-34.

established populations throughout much of the Zambezi Basin<sup>59</sup>. Native to Australia and Papua New Guinea, redclaw crayfish were first introduced into the Kafue River in 2001 following an escape from a fish farm near the Kafue Flats. Subsequent deliberate releases have occurred in other catchments, including Nyimba, Namwala, and Mushingashi<sup>60</sup>. Their presence has had clear socio-economic impacts on traditional fisheries, increasing processing time and costs as fishers sort damaged catches and repair torn nets<sup>61,62</sup>. Entanglement also leads to abandoned nets, contributing to ghost fishing.

Economic assessments estimate that damage caused by a single invasive crayfish result in an average annual loss of USD 6.15 (176.88 ZMW) per fisher in the Kafue River<sup>63</sup>. In response, some fishers have begun selling crayfish in urban centres, hotels, and local markets—particularly around Itezhi-Tezhi. However, these markets remain too limited in scale to meaningfully control crayfish populations.

In the Kafue River Basin, *C. quadricarinatus* has been the focus of extensive monitoring and research<sup>64,65,66</sup>. Multiple studies document its expanding distribution, high local abundances, and potential ecological impacts, including competition with native decapods, destruction of aquatic vegetation, and disruption of fish populations through scavenging and gear damage.

#### Methods: Invasive Crayfish Sampling

To assess the presence and relative abundance of invasive redclaw crayfish, baited traps (using dry dog food) were set overnight at campsites along the river transect (Figure 59). Captured individuals were counted and released. Results from this survey will be incorporated into the Map of Crayfish database<sup>67</sup>, providing an updated representation of the species' distribution along the Kafue River.

#### Results and Discussion: Invasive Crayfish Sampling

A total of 283 invasive redclaw crayfish were captured at 20 of the 61 sampling sites, yielding an average capture rate of 4.64 individuals per trap per night (Figure 59). This rate is lower than the  $5.34 \pm 2.35$  individuals per trap per night reported in 2017<sup>68</sup>; however, the higher sampling effort in the earlier study likely produced a more precise estimate of local abundance.

Crayfish were absent from the river upstream of Chililabombwe, after which they were routinely captured along most of the remaining transect, with the notable exception of the Kafue Flats. Despite this, redclaw crayfish have been present within the Kafue Flats since at least 2009, indicating spatial variability in

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<sup>59</sup> Douthwaite, R.J. et al. 2018. The introduction, spread and ecology of redclaw crayfish *Cherax quadricarinatus* in the Zambezi catchment. *African Journal of Aquatic Science*. 43(4):353-366.

<sup>60</sup> Madzivanzira, T.C. et al. A review of freshwater crayfish introductions in Africa. *Reviews in Fisheries Science and Aquaculture*. 29(2):218-241.

<sup>61</sup> Douthwaite, R.J. et al. 2018. The introduction, spread and ecology of redclaw crayfish *Cherax quadricarinatus* in the Zambezi catchment. *African Journal of Aquatic Science*. 43(4):353-366.

<sup>62</sup> Madzivanzira, T.C. 2021. Distribution and establishment of the alien Australian redclaw crayfish, *Cherax quadricarinatus*, in the Zambezi Basin. *Aquatic Conservation: Marine and Freshwater Ecosystems*. 31(11):3156-3168.

<sup>63</sup> Madzivanzira, T.C. et al. 2022. Ecological and potential socioeconomic impacts of two globally-invasive crayfish. *NeoBiota*. 72:25-43.

<sup>64</sup> Douthwaite, R.J. et al. 2018. The introduction, spread and ecology of redclaw crayfish *Cherax quadricarinatus* in the Zambezi catchment. *African Journal of Aquatic Science*. 43(4):353-366. DOI: 10.2989/16085914.2018.1517080.

<sup>65</sup> Weyl, O.L.F. et al. 2017. Why suggesting Australian redclaw crayfish *Cherax quadricarinatus* as biological control agents for snails is a bad idea. *African Journal of Aquatic Science*. 42(4):325-327. DOI: 10.2989/16085914.2017.1414685.

<sup>66</sup> Tyser, A.B. and Douthwaite, R.J. 2014. Predation on invasive redclaw crayfish *Cherax quadricarinatus* by native fishes in the Kafue River, Zambia. *African Journal of Aquatic Science*. 39(4):473-477. DOI: 10.2989/16085914.2014.980774.

<sup>67</sup> Ion, M.C. et al. 2024. World of Crayfish™: a web platform towards real-time global mapping of freshwater crayfish and their pathogens. *PeerJ*. 12:e18229. DOI: 10.7717/peerj.18229.

<sup>68</sup> Madzivanzira, T.C. et al. 2021. Distribution and establishment of the alien Australian redclaw crayfish, *Cherax quadricarinatus*, in the Zambezi Basin. *Aquatic Conservation: Marine and Freshwater Ecosystems*. 31(11):3156-3168.

detectability or habitat use within the wetland.

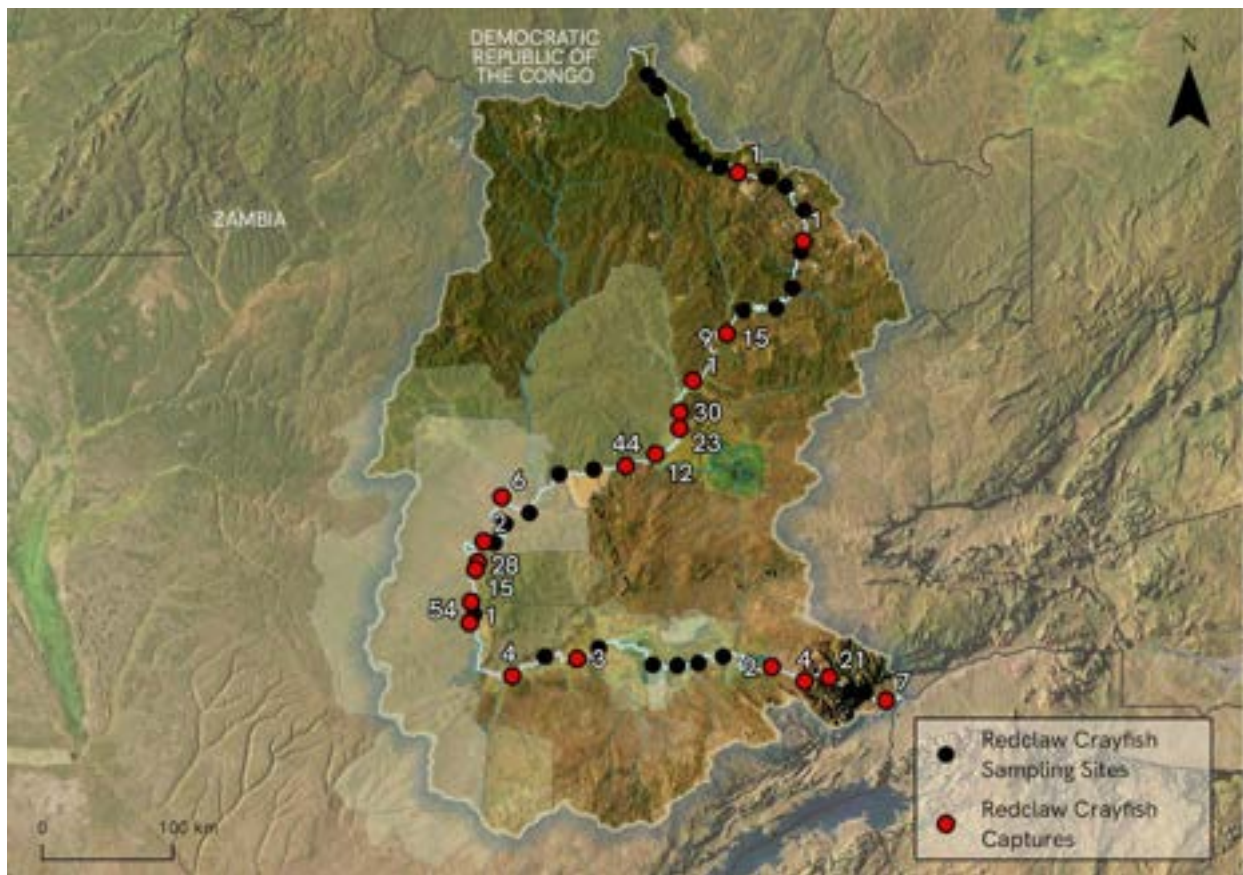


Figure 59: All sites where fish and invasive crayfish were sampled along the Kafue River. Red circles indicate positive detection of freshwater crayfish and are accompanied by the number of individuals captured.



Figure 60: Haul of invasive redclaw crayfish captured at a single site.

## 5. SATELLITE ANALYSES

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### 5.1 MODIS Fire RS Satellite Analysis

#### Methods: MODIS Fire RS Satellite Analysis

To assess the frequency and extent of fires across the broader basin, a burn frequency map is presented for the 2000–2023 period in the Kafue Basin. To generate this map, the 2000–2023 burn frequency of the Kafue Basin was extracted from the MCD64A1.061 MODIS Burned Area Monthly Global 500 m product<sup>69</sup>. A total of six burned area frequency categories were included in the analysis. It must be noted that, although this product does estimate burn area with accuracy, the size of burn area must be greater than 500 m to be recorded. As a result, some smaller fires may not be identified by this product.

#### Results: MODIS Fire RS Satellite Analysis

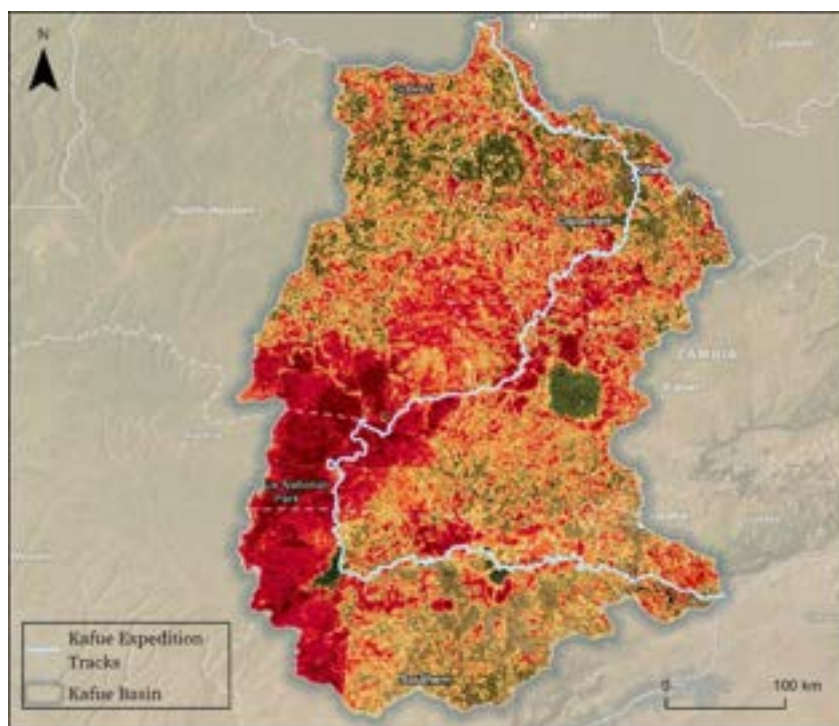
The frequency of fires was highly variable across the Kafue Basin (Figure 61). For example, burns were not detected in 14% of the Kafue Basin for the 2000–2023 period. These “No Burn” areas were predominantly within wetlands, most notably the Lukanga Swamp west of Kabwe. Conversely, the southwestern section of the Kafue Basin burned every year. These fires occurred in areas that are predominantly covered by grassland and shrubland — including most of Kafue National Park and many of its surrounding GMAs. These align with findings of the visual survey, which noted 95% of fires in grassland areas. Further analysis reveals that fires are most common in the dry season (May–September), peaking in August (Appendix 8).

The 2007 fire management plan for Kafue National Park and its surrounding GMAs noted the high frequency of human-induced, unplanned burns within the park — with over 90% of the park burning every year<sup>70</sup>. This is believed to have a negative impact on the ecosystem by causing habitat fragmentation, reducing woodland cover, and promoting the spread of fire-resistant invasive vegetation such as *Combretum* and *Terminalia* at the expense of native flora. Additionally, frequent fires have been linked to declines in key wildlife species, changes in grazing patterns, and a reduction in the availability of high-quality forage for herbivores. The management plan called for a reduction in the frequency and extent of burns across the park, however it appears that this has been met with limited success, as much of the park and surrounding GMAs continues to burn almost annually.

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<sup>69</sup> Giglio, L. et al. 2021. MODIS/Terra+Aqua Burned Area Monthly L3 Global 500m SIN Grid V061. NASA EOSDIS Land Processes Distributed Active Archive Center.

<sup>70</sup> Fire management plan for Kafue National Park and its surrounding game management areas. 2007. Zambian Wildlife Authority.



Legend	Burn Frequency (2000-2023)	Area (km <sup>2</sup> )	Proportion (%)
	No Burn	23,142	14%
	1-5 Burns	58,370	36%
	6-10 Burns	34,416	21%
	11-15 Burns	22,080	14%
	16-20 Burns	16,041	10%
	21-23 Burns	8,129	5%
	<b>Total Area Burnt</b>	<b>162,175</b>	<b>-</b>

Figure 61: Fire frequency within the Kafue Basin for the 2000–2023 period.

## 5.2 Land-Use Land-Cover (LULC) Change Analysis

Understanding land-use and land-cover change is critical for assessing the health of river systems. Land-use changes — driven by agriculture expansion, urbanization, deforestation, and infrastructure development — can significantly alter hydrological processes, sediment transport, and water quality. As a result, analysing these changes provides insight into the drivers of environmental degradation and helps inform sustainable management strategies to balance development with ecological conservation in the Kafue Basin.

### Methods: LULC change analysis

To generate the LULC change analysis, land cover classification maps for 1992 and 2020 were extracted from the European Space Agency Climate Change Initiative. These maps provide an estimate of the land cover change for the Kafue Basin at 300 m resolution. Classes from this global land cover product were combined into general change detection classes according to the product’s user guidelines (Appendix 9). To assess how land utilization differs across protected areas (namely national parks, game management areas and conservancies), land cover was also classified by protected area type.

### Results and Discussion: LULC change analysis

### *Vegetation Cover*

The Kafue basin consists primarily of forests and woodlands (58%) interspersed with shrubland (20%) and cropland (15%) (Figure 62). Forests and woodlands consist primarily of Wetter Zambebian miombo woodland, which is dominated by *Brachystegia*, *Julbernardia* and *Isoberlinia* species. Crops are predominantly wheat, sugar cane, tobacco, maize, cotton, barley, and vegetables<sup>71</sup>.

Between 1992 and 2020, forest and woodland land cover decreased by 2.28% or 2,723 km<sup>2</sup>. However, this is likely an underestimation, as higher-resolution analyses show substantial forest loss in the Greater Kafue system, primarily driven by agricultural expansion and human encroachment. One study found woodland cover in the Copperbelt region declined by 17.9% between 1984 and 2016 — mostly due to cropland conversion — and projected a 26.4% loss by 2050<sup>72</sup>. Another study in the upper Kafue basin reported steady annual forest loss from 2000 to 2020, especially in densely populated headwaters and riparian zones<sup>73</sup>.

Wetland and water coverage increased notably between 1992 and 2020, with wetlands being calculated to have gained 428 km<sup>2</sup> (6.38%) and water having gained 102 km<sup>2</sup> (12.26%). The observed increase in wetland and water coverage between 1992 and 2020 could stem from seasonal differences in satellite imagery acquisition. Images captured during peak rainy seasons, when wetland areas are naturally inundated, might exaggerate changes.

### *Human land-use cover*

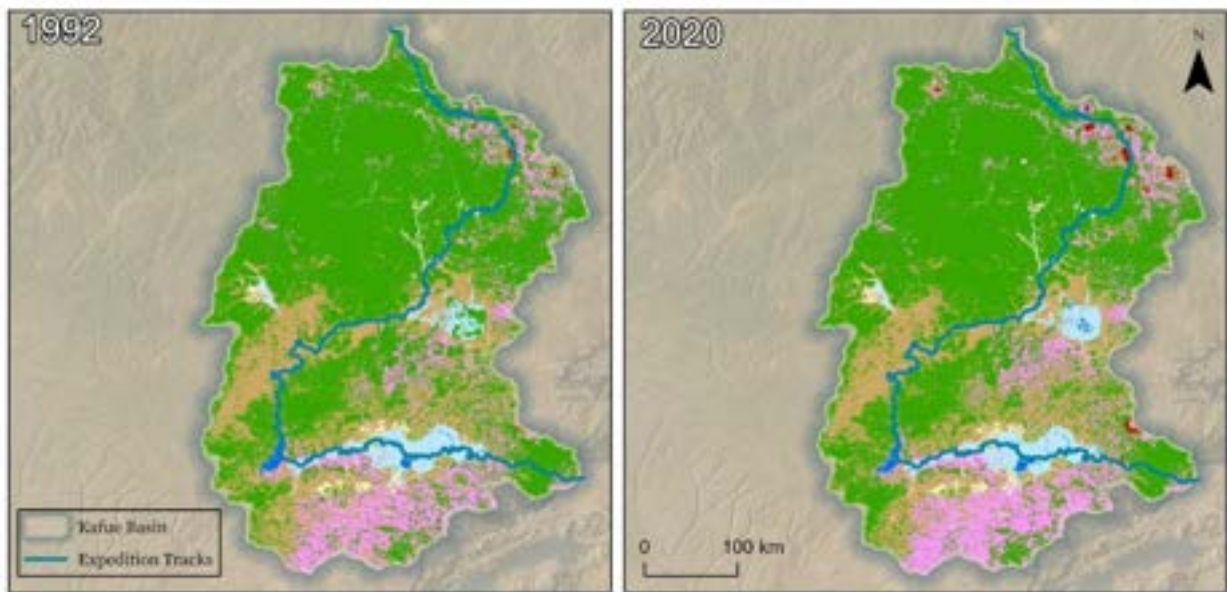
Between 1992–2020, there was a net increase in agriculture (12.93%) and settlements (249.78%) within the Kafue Basin, amounting to 2,629 km<sup>2</sup> and 446 km<sup>2</sup> of landcover change respectively (Figure 62). Kitwe, Lusaka, Ndola and Solwezi accounted for much of the settlement growth. Agriculture was primarily concentrated along the southern fringes of the Kafue Flats and around the towns of Kitwe and Ndola.

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<sup>71</sup> Lower Kafue River basin report card: Methodology report. 2020. University of Maryland Centre for Environmental Science, WARMA and WWF.

<sup>72</sup> Malunga, M.M. et al. 2021. Land use induced land cover changes and future scenarios in extent of Miombo woodland and Dambo ecosystems in the Copperbelt province of Zambia. *African Journal of Ecology*. 59(3):644–658.

<sup>73</sup> Food and Agriculture Organization of the United Nations (FAO). 2025. *Forests, freshwater, and fisheries providing food security and sustainable livelihoods: Upper Kafue River watershed*. FAO Knowledge Repository.

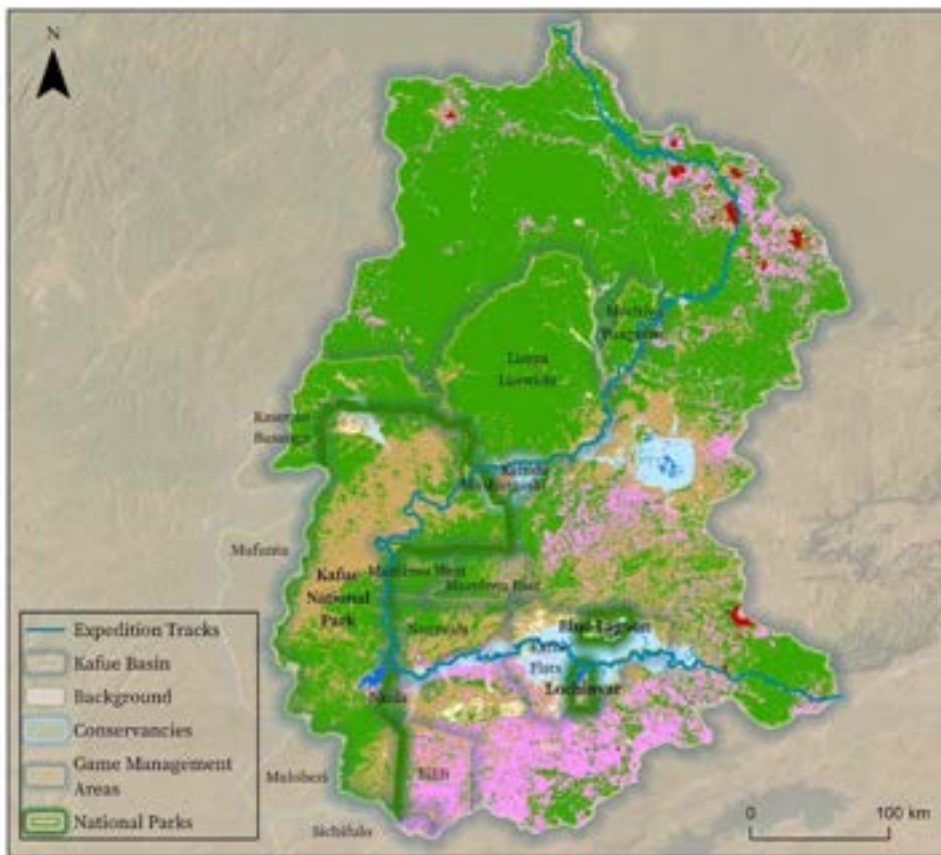


LULC Class	Kafue 1992 (km <sup>2</sup> )	Kafue 2020 (km <sup>2</sup> )	Change (%)
Agriculture	20,336	22,965	12.93%
Forest and Woodland	93,521	90,798	-2.91%
Grassland	2,572	2,602	1.16%
Wetland	6,699	7,127	6.38%
Settlement	179	625	249.78%
Shrubland	31,540	30,625	-2.90%
Bare/ sparse vegetation	15	19	21.91%
Water	830	932	12.26%
<b>Total</b>	<b>155,693</b>	<b>155,693</b>	-

Figure 62: The Climate Change Initiative Land Use Land Cover (LULC) for the Kafue Basin in 1992 (left) and 2020 (right). The percentage change for each LULC class is presented in the table.

#### Protected area land

Natural land (for the purpose of this section considered as all land cover classes excluding agriculture and settlement) accounted for 98.69% of land use in national parks, 99.79% of land use in conservancies and 90.64% land use in GMAs (



LULC Class	Conservancies (Area km <sup>2</sup> )	% of total area	Game Management Areas (Area km <sup>2</sup> )	% of total area	National Park (Area km <sup>2</sup> )	% of total area
Agriculture	1.4	0.21%	2,853.8	9.36%	309.4	1.31%
Forest and Woodland	104.3	16.16%	18,599.9	61.02%	11,030.7	46.71%
Grassland	1.0	0.16%	786.5	2.58%	786.5	3.33%
Wetland	0.2	0.03%	2,953.0	9.69%	488.3	2.07%
Settlement	-	-	0.2	0.00%	-	-
Shrubland	533.4	82.62%	5,108.3	16.76%	10,567.0	44.75%
Water	5.3	0.82%	178.0	0.58%	431.5	1.83%
<b>Total</b>	<b>645.6</b>	<b>-</b>	<b>30,479.7</b>	<b>-</b>	<b>23,613.4</b>	<b>-</b>

Figure 63). The difference between these areas was primarily driven by agriculture, which was prevalent in GMAs (9.36% cover), but insignificant in national parks and conservancies (< 1.4%).

Agriculture was most prevalent in Bilili, Namwala, Mumbwa and Kafue Flats GMAs. These basin-scale patterns provide important context for the field survey results discussed earlier, where GMAs functioned as transitional buffer zones, exhibiting higher levels of human activity and correspondingly fewer wildlife observations than adjacent protected areas, consistent with gradual land-use transformation rather than complete habitat loss.

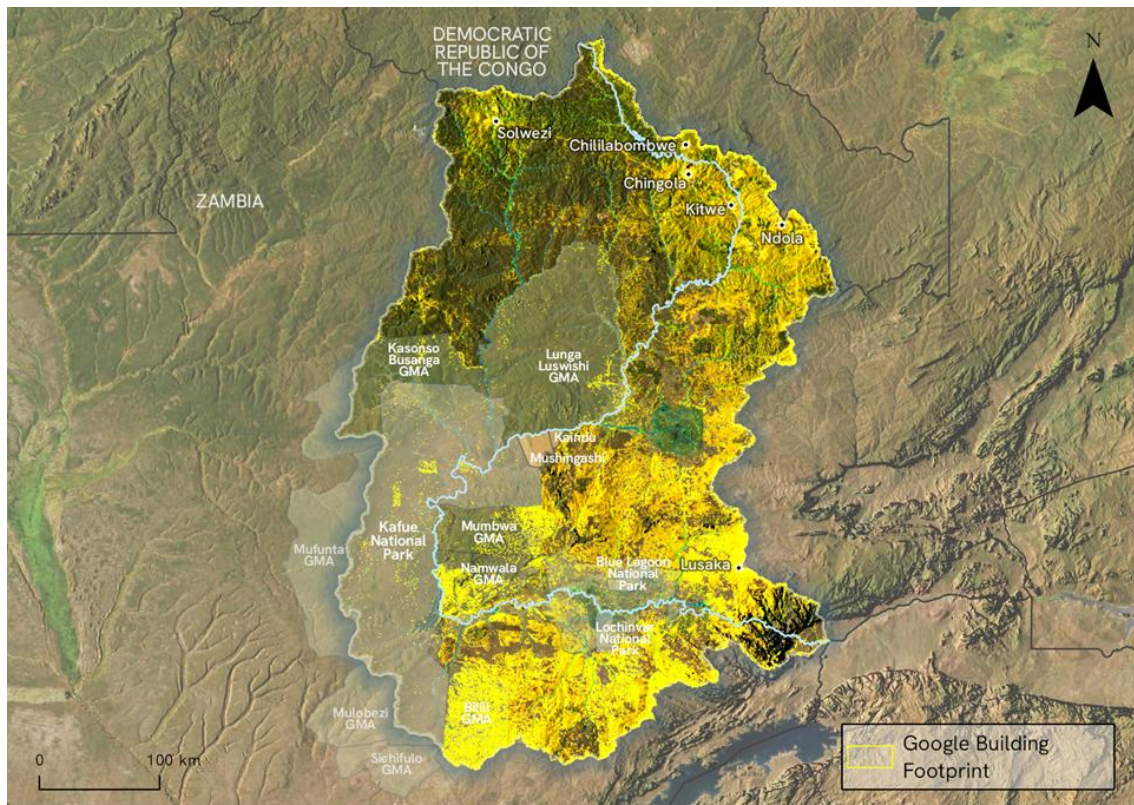


The Kafue River Basin had a total building area of over 181 km<sup>2</sup> (Figure 64). Interestingly, this is lower than the settlement cover detected by the LULC change analysis above suggesting that actual building area is likely between 181–625 km<sup>2</sup>, depending on the data and model used.

There were ~253,679 buildings within a 4 km buffer of the Kafue River, amounting to a density of 24.22 buildings/km<sup>2</sup>. This makes the Kafue one of Zambia's most developed rivers, with notably higher settlement than the Chambeshi (6.22 buildings/km<sup>2</sup>), or the Luangwa (4.28 buildings/km<sup>2</sup>).

Building density along the Kafue River is higher than the basin-wide average of 18.94 buildings/km<sup>2</sup>, reflecting the strong reliance of local livelihoods on the river, as documented during field surveys. Settlements, cultivated fields, and fishing activity were frequently observed along the riverbanks, underscoring the Kafue's central role in sustaining communities. However, increasing development within the riparian zone risks weakening connections between the river and its surrounding landscape through enhanced surface runoff, soil erosion, and habitat modification. Such changes can compromise river health and reduce the provision of critical ecosystem services, including water filtration, flood regulation, and fisheries habitat. In this context, protected areas and wetlands play an essential buffering role, helping to regulate hydrological and ecological processes and sustain the long-term health of the Kafue River system.

Protected areas within the Kafue River Basin have fewer buildings than the basin average, however GMAs have far more buildings than National Parks and Conservancies. Overall, there were ~143,705 buildings within protected areas, resulting in a density of 2.17 buildings/km<sup>2</sup>, far lower than the basin average of 24.22 buildings/km<sup>2</sup>. However, building density was not uniform across protected areas, with the GMA building density (4.01 buildings/km<sup>2</sup>) almost twenty times greater than in the conservancies (0.24 buildings/km<sup>2</sup>) and more than thirty times greater than in the national parks (0.13 buildings/km<sup>2</sup>). Higher settlement densities in GMAs such as Bilili, and parts of Mumbwa East and Namwala, align with field observations of greater human activity and livelihood use along the river corridor. This pattern reflects the role of GMAs as transitional buffer zones, where conservation objectives coexist with settlement and resource use, creating a gradient of human pressure from strictly protected areas to the wider basin.



	Area (km <sup>2</sup> )	Total no. of buildings	No. of buildings/km <sup>2</sup>	Total building area (km <sup>2</sup> )	Building area (%) within area of interest
Kafue River Buffer	10,473	253,679	24.22	16.57	0.1582%
Kafue Basin	155,997	2,954,397	18.94	181.13	0.1161%
National Parks	30,601	3,836	0.13	0.12	0.0004%
GMA's	34,863	139,717	4.01	3.43	0.0098%
Conservancies	641	152	0.24	0.01	0.0008%

Figure 64: Building analysis of the Kafue River, Kafue River Basin and protected areas.

## 5.4 WorldCereal Cropland Analysis

Analysing cropland extent within the Kafue Basin is essential for understanding the relationship between agricultural expansion and the health of the river system. The Kafue Basin is a key agricultural region in Zambia, supplying food and supporting livelihoods. However, changes in cropland extent influence water demand, sedimentation rates, and nutrient runoff, all of which affect river flow dynamics and water quality. By assessing the spatial and temporal trends of cropland expansion, policymakers and resource managers can make informed decisions to promote sustainable agricultural practices while safeguarding the ecological integrity of the Kafue River.

### Methods: WorldCereal Cropland Analysis

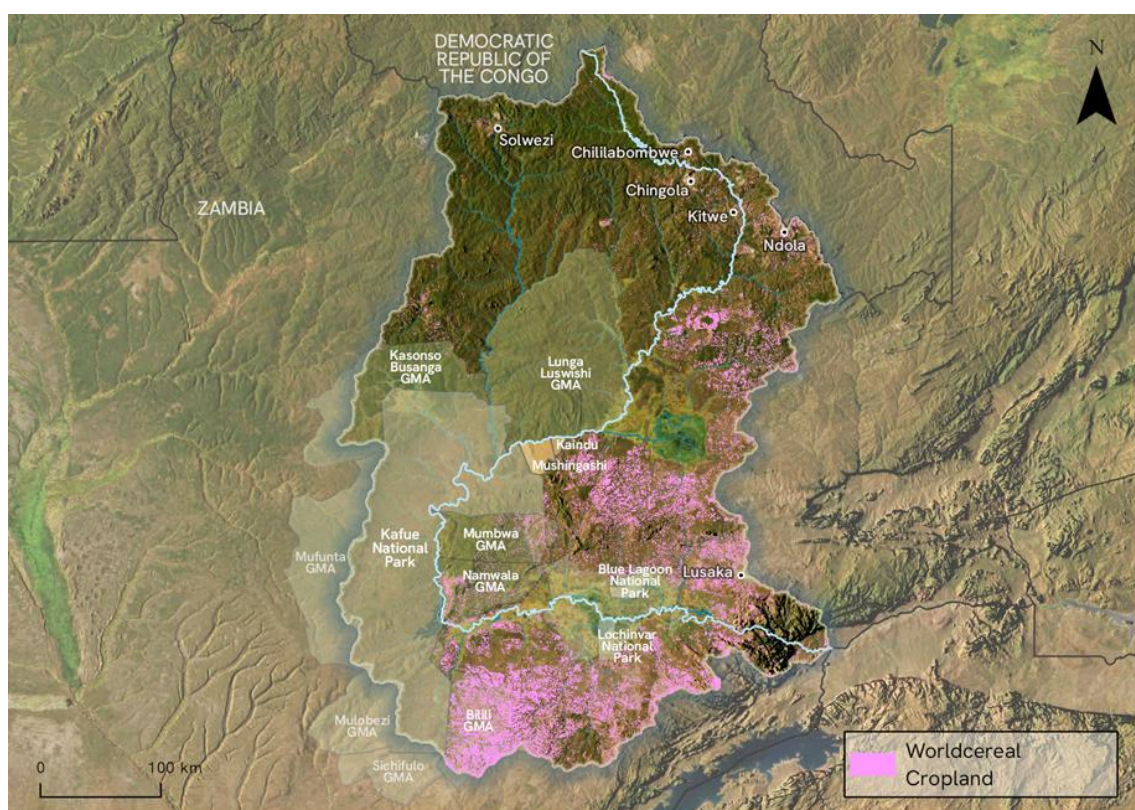
WorldCereal is an open-source system — developed under the European Space Agency’s initiative — that provides comprehensive, seasonal, and reproducible maps of global crop extents<sup>75</sup>. In this analysis, WorldCereal data was used to calculate the extent of cropland within a 10 km buffer zone around the Kafue River. The total cropland area within this buffer zone was determined by summing the areas of identified croplands.

<sup>75</sup> Van Tricht, K. et al. 2023. WorldCereal: A dynamic open-source system for global-scale, seasonal, and reproducible crop and irrigation mapping. *Earth System Science Data*. 15:5491-5515.

## Results and Discussion: WorldCereal Cropland Analysis

There is 823.50 km<sup>2</sup> of cropland within 10 km of the Kafue River, comprising 3.48% of the buffer area. The high cropping density in close proximity to the river highlights potential implications for water quality, biodiversity, and ecosystem services, as agricultural activities can contribute to nutrient runoff, sedimentation, and habitat alteration<sup>76</sup>.

Additionally, about 9% of the basin consists of croplands (Figure 65). This agricultural activity is predominantly concentrated in the eastern and southern sections of the basin, with minimal encroachment into national parks or conservancies. WorldCereal estimates the cropland area at 13,699.20 km<sup>2</sup>, significantly lower than the Land Use and Land Cover (LULC) analysis, which reports 22,965 km<sup>2</sup>. These discrepancies stem from methodological differences, with WorldCereal emphasizing active, seasonal crops and LULC adopting a more generalized land cover approach<sup>77</sup>.



	Area (km <sup>2</sup> )	Total cropland area (km <sup>2</sup> )	Cropland area (%) within buffer
Kafue River Buffer	23,676.0	823.5	3.48%
	Area (km <sup>2</sup> )	Total cropland area (km <sup>2</sup> )	Cropland area (%) within basin
Kafue Basin	155,997.0	13,699.2	8.78%

Figure 65: WorldCereal croplands within the Kafue River Basin. The total cropland within the 10 km buffer and within the entire basin are shown. Protected areas within the basin are also mapped.

<sup>76</sup> Mander, Ü. et al. 1997. Efficiency and dimensioning of riparian buffer zones in agricultural catchments. 9:299-324.

<sup>77</sup> Fritz, S. et al. 2010. Comparison of global and regional land cover maps with statistical information for the agricultural domain in Africa. *International Journal of Remote Sensing*. 31(9):2237-2256.

## 6. CONCLUSION

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The Kafue Basin represents a uniquely complex and nationally significant landscape where conservation priorities, human well-being, energy security, and economic development intersect. More than 15,000 fisher–farmer livelihoods are tied to the health of the Kafue River. The river also provides drinking water to an estimated 40% of Zambia’s population. With more than 680 active mining licenses, the Kafue Basin is both one of the most economically important and environmentally impacted river basins in the country.

In recent years, the water quality of the Kafue River has been the focus of growing national attention. Heavy metal contamination, originating with the onset of mining in the 1920s, continues to pose a substantial threat to the health of the river. Heavy metals have accumulated in the river’s sediments, forming a contaminated layer up to 2 m thick<sup>78</sup>. While the effects of this on the aquatic ecosystem are poorly understood, early evidence from benthic macroinvertebrate surveys suggests river degradation.

The basin’s natural infrastructure plays a critical role in maintaining river health. Wetland systems including the Kafue Flats, Kwesa Floodplain, Busanga Swamp, and Lukanga Swamp act as natural filters, regulating river flows and buffering against downstream impacts. To secure these essential ecosystem services, it is imperative that wetlands and their immediate surrounds are protected from drainage, land clearing, and mining activities. In parallel, effective management of mining discharges and abstractions in the Copperbelt will remain vital to safeguarding downstream water quality and community livelihoods — an urgency that is amplified by increasingly extreme climate variability.

More than one-third of the Kafue Basin is already under some level of conservation designation. The Greater Kafue Ecosystem (GKE) consists of a 66,000 km<sup>2</sup> network of national parks, conservancies and game management areas (GMAs), that is vital to regional biodiversity. Within this network, the Kafue National Park is home to one of Zambia’s largest hippo populations, and, further downstream, the endangered Kafue lechwe is found only within the Kafue Flats. The Kafue Flats wetland is also home to one quarter of the global wattled crane population, making this a vital habitat for the endangered species.

Despite this, biodiversity within the GKE faces several risks. The network of GMAs surrounding the Kafue National Park, which have historically served as a buffer to development, are undergoing rapid deforestation for agriculture. If this pattern continues, functional loss of GMAs would amount to the effective loss of over half of the protected land area within the basin. Whilst a staggering loss, this would also practically isolate the KNP from the greater KAZA landscape, undermining regional efforts to enhance protected area connectivity across national borders.

Notably, the distribution of hippos may provide an indicator of broader ecological change along the Kafue River. Surveys conducted in 2007 recorded hippos across both protected and unprotected reaches of the river. Contemporary observations suggest that hippo populations are now largely confined to Kafue National Park and adjacent protected areas, indicating a contraction in range and a probable decline in abundance. This trend should be validated through an updated, basin-wide hippo survey.

Overfishing poses another serious risk. The average number of fishers along the Kafue River is estimated to be three times higher than that of the Zambezi, many of whom do not adhere to seasonal fishing bans, catch limits or gear restrictions. This is believed to have driven a substantial decline in fisheries productivity over recent decades. The relative abundance, biomass, and average size of fish have all declined, and

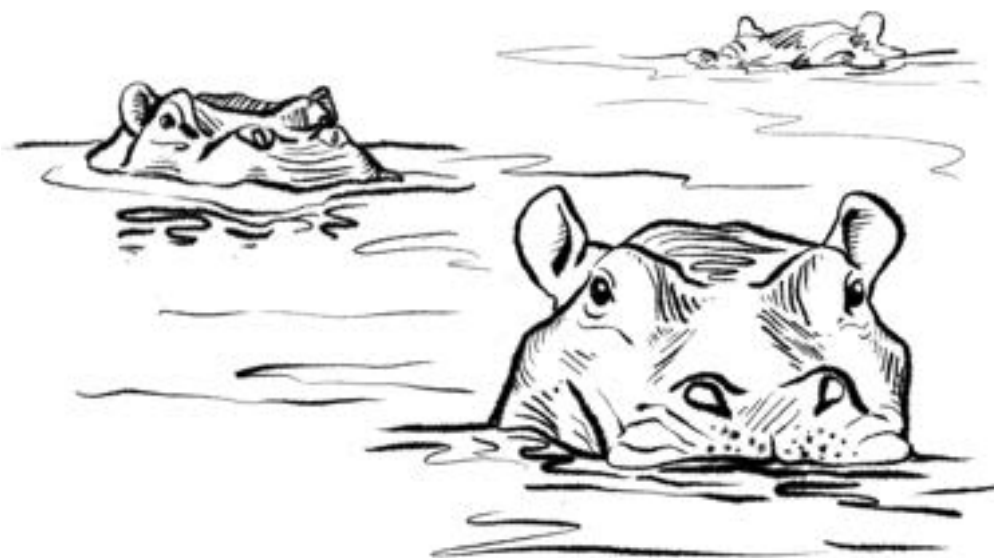
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<sup>78</sup> Babek O, Sracek O, Ettler V, Kapusta J, Křibek B, Mihaljevič M, et al. Trends of Cu and Co contaminated sediment dispersal along the Kafue River, the Zambian Copperbelt. *J Geochem Explor.* 2026;280:107900.

several species within the fishery are now commercially extinct<sup>79</sup>. A 91% decline in the occurrence of Great White Pelicans within the Kafue Flats between 2001–2018 suggests that declining fisheries have affected the broader ecosystem<sup>80</sup>.

Compounding this, invasive species, which are rapidly spreading throughout the basin, continue to displace native biodiversity and drive fundamental changes in riparian habitat. The redclaw crayfish, distributed throughout most of the Kafue River, is one of the most expensive invasions in both real and ecological terms. Comparatively understudied, invasive alien plants, including the giant sensitive plant (*Mimosa pigra*), spongeplant (*Limnobium laevigatum*) and Kariba weed (*Salvinia molesta*), are present along at least 150 km of the river, with efforts already underway to clear them from the Kafue Flats.

Significant momentum exists for coordinated action. Conservation partners, including the Department of Parks and Wildlife (DNPW), African Parks (AP) and The Nature Conservancy (TNC), have initiated *in situ* protection efforts and are jointly developing an integrated conservation plan for the greater landscape. Within the Kafue Flats, the International Crane Foundation (ICF), DNPW, the World Wide Fund for Nature (WWF), and the Endangered Wildlife Trust (EWT) are supporting the restoration and management of Lochinvar and Blue Lagoon National Parks. Building on these efforts, a coordinated, cross-jurisdictional approach that ties together terrestrial and freshwater conservation, supported by current institutional investments, is essential for securing the ecological and social integrity of the Kafue landscape.



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<sup>79</sup> Aquatic Ecosystem Services and WWF. 2020. *Situational Analysis of Fish and Fisheries of the Kafue Flats Wetland Ecosystem*. WWF Summary Report. (August 2020):1–20.

<sup>80</sup> Lower Kafue River basin report card: Methodology report. 2020. University of Maryland Centre for Environmental Science, WARMA and WWF.

## 7. RECOMMENDATIONS

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### 7.1 Strengthen the Baseline

The 2024 and 2025 surveys form the most comprehensive, multi-disciplinary picture of the state of the Kafue River to date. By integrating water quality, sediment chemistry, biodiversity, human activity, invasive species mapping, and open-source spatial data, this work provides a critical snapshot of the current condition of the Kafue River system at a time of intensifying pressures. However, as a single temporal assessment, the 2024 survey cannot on its own capture the dynamic nature of river processes or distinguish short-term variability from longer-term trends.

It is therefore strongly recommended that the Kafue River survey be repeated at regular intervals (ideally every 2–3 years). Periodic re-surveys would contribute to a robust baseline, enabling detection of changes in water and sediment quality, shifts in biodiversity and invasive species distributions, and emerging risks linked to extreme flood and drought events. By using consistent methodologies, data cross-comparison would allow trend analysis, and provide an evidence base for adaptive, basin-wide decision-making. In a river system as socially, ecologically, and economically important as the Kafue, repeated surveys are essential to move from descriptive assessment toward proactive, long-term stewardship.

#### Hippopotamus as Sentinel Species

Hippos are uniquely suitable as a sentinel species because they are tightly river-dependent, sensitive to changes in water availability and disturbance, and highly visible for monitoring. The 2024 survey recorded 2,413 hippos, substantially lower than the 4,000 individuals recorded in 2007 using comparable methods. While interannual changes may reflect redistribution rather than true population decline (e.g., 1,810 recorded in 2025), the spatial pattern is highly instructive: 98% of hippos were concentrated between the start of Mushingashi Conservancy and Itezhi-Tezhi, indicating that this stretch is the last remaining functional refuge for the species along the river.

It is therefore recommended to:

- Conduct an updated, basin-wide aerial hippo survey designed to differentiate redistribution from population decline and to capture habitats missed by boat surveys (backwaters, wetland edges, braided sections, reservoir margins).
- Prioritise effort adjacent to KNP and Mushingashi Conservancy, where ~97% of hippos were recorded, while also explicitly surveying historically occupied but now depleted reaches to validate range contraction.
- These data can directly inform patrol planning, river-use zoning and habitat management.

### 7.2 Existing Protected Areas

The 2024–2025 river surveys confirm that the KNP and Mushingashi Conservancy function as the primary wildlife refugia along the Kafue River, particularly in drought times. Wildlife density within protected areas was substantially higher than in unprotected reaches (88 animals/10 km vs 17 animals/10 km), and the distribution of wildlife was strongly inverse to the distribution of people. These results mirror broader trends across the GKE, where surrounding GMAs, which historically acted as buffers, are experiencing accelerating conversion and encroachment that threatens to isolate KNP from the wider KAZA landscape.

The Mushingashi Conservancy illustrates that sustained investment in protection measures can maintain

high wildlife densities, including a substantial puku population along a short river reach. While full fencing is not feasible or desirable across the basin, the principle is transferable: focused investment in well-defined refuge areas can stabilise wildlife populations and improve downstream conservation outcomes. Considering this, support is urgently needed at a national level to coordinate landscape-level planning across the Kafue Basin, and particularly within the GMA portfolio of the GKE.

### 7.3 Secure Livelihoods: Headwaters, Wetlands, and Fisheries Management

#### Headwater Conservation and Baseline Protection

The headwaters of the Kafue River, including the Kwesa Floodplain, offer vital ecosystem services to downstream water users. However, these critical source areas are often under-protected and undervalued. As a result, they face significant threats from early mining contamination, deforestation, and altered flows, all of which pose serious risks to the availability and quality of water.

Currently, background monitoring sites near the headwaters exhibit lower heavy metal concentrations that remain near or below natural global crustal averages before the river enters the heavily industrialized Copperbelt. Protecting these headwaters must be a top conservation priority to prevent further degradation of the river. Securing this area ensures the river's resilience by buffering ongoing contamination and preventing a permanent and irreversible decline in river health.

#### Restoration and Protection of the Kafue Flats

Further downstream, the Kafue Flats represent a vital hotspot for fisher-farmer livelihoods, economic productivity, and avian biodiversity. Wetland fisheries here account for up to 22% of the national harvest, representing an estimated annual value of ZMW 714 million (US\$30 million)<sup>81</sup>. To protect this critical asset, the 20-year co-management initiative led by the International Crane Foundation (ICF), the Department of National Parks and Wildlife (DNPW), the Endangered Wildlife Trust (EWT), and WWF Zambia requires robust national support.

While current focus on law enforcement, community engagement, and ecological restoration (such as the removal of *Mimosa pigra*) is well-placed, these efforts should be strategically expanded to upstream wetlands like the Lukanga/Kafue confluence. These upstream zones provide essential fisheries habitats, flood regulation, and natural water filtration services. Importantly, interactions with organic matter in these wetlands actively buffer and reduce downstream heavy metal concentrations.

#### Sustainable Fisheries Assessment and Enforcement

Fishing remains a primary livelihood activity along the Kafue River, directly supporting at least 15,000 fishers and over 70,000 people across 160 villages<sup>82</sup>. While 70% of this activity is concentrated within the Kafue Flats, fishing is also widespread in the Copperbelt, adjacent to the Lunga Luswishi GMA, and directly upstream of the Itezhi-Tezhi dam.

Given its widespread importance to regional food security and the local economy, a comprehensive, river-wide fisheries assessment is recommended. This assessment must account for the historically overlooked fishers upstream of Itezhi-Tezhi. It could also be significantly enhanced by incorporating fish tissue isotopic analyses (such as sulfur S) — a proven tracer for identifying mine-derived stress in aquatic ecosystems.

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<sup>81</sup> WWF. 2019. *Status of the Kafue Flats Fishery*.

<sup>82</sup> *Zambian Ministry of Fisheries and Livestock. 2024. Capture Fisheries Frame Survey: Summary Report.*

Finally, to facilitate the recovery and long-term sustainability of the fishery, managers should identify opportunities to establish fish-protected breeding areas within the wetlands. These have proven successful elsewhere in the region, including the Zambezi/Chobe system, where they are directly associated with larger and more abundant fish<sup>83</sup>. Importantly, these zones should be co-designed with local fishing communities to ensure compliance and long-term legitimacy. They should also be prioritised alongside the regular and strict enforcement of the December–February seasonal fishing ban to protect valuable spawning stocks.

## 7.4 Comprehensive Invasive Species Management

The Kafue River is increasingly affected by invasive species, including water hyacinth (*Eichhornia crassipes*), Nile tilapia (*Oreochromis niloticus*), giant sensitive plant (*Mimosa pigra*) and redclaw crayfish (*Cherax quadricarinatus*). These species threaten native biodiversity, destabilize aquatic ecosystems, and impact fisheries and water use. A catchment-wide invasive species approach is needed, which ties together the efforts of several stakeholders within the basin. This should include the following actions:

- *Preventing New Introductions*: Absolute priority must be given to preventing the introduction of additional invasive species. This includes enforcing strict biosecurity protocols across aquaculture, fishing gear transport, and water infrastructure development.
- *Early Detection and Surveillance*: Establish regular monitoring at designated sentinel sites across the Kafue catchment to enable rapid detection of new outbreaks or shifts in species distribution. This will require trained personnel, community engagement, and data-sharing mechanisms.
- *Managing Established Populations – Control and Containment*: Most invasive species are now fully established across the Kafue system, making total eradication impractical. However, control and containment remains vital.
- *Policy and Public Awareness*: Enforce environmental regulations on species transport and trade. Raise public awareness on the risks posed by invasive species and the role communities can play in prevention and control.

## 7.5 Improve Water Quality and Flow Monitoring

### Heavy Metal Monitoring in the Copperbelt

Tributaries in the Copperbelt are the most obvious avenues of contamination of the Kafue River (Appendix 10). To better understand this impact, their relative contribution to the contaminant load of the river should be determined by conducting regular tests for dissolved and sediment-associated heavy metals. This will guide the enforcement of improved mine effluent management in the Copperbelt region — a shift which is urgently needed. Monitoring must be paired with regulatory enforcement mechanisms, including effluent compliance audits and transparent reporting requirements for mining operators.

Five tributaries are identified as priority sites for regular heavy metal testing because of their relative size, overlap with large-scale mines, and documented history of contamination. These are the: i) Lubengele; ii) Kakosa; iii) Mushishima; iv) Mufulira; and v) Mwambashi. In addition, the Musakashi, Mindolo, Uchi and Wanshimba are ephemeral tributaries that are likely to carry elevated heavy metal loads in the rainy season. These latter tributaries should be tested at the onset of seasonal rainfall to determine the seasonal dynamics of heavy metal flows.

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<sup>83</sup> Hamutenyah, J. et al. 2017. *An assessment of fish assemblages between protected and non-protected areas on the Zambezi/Chobe River.*

Consistent with the findings of Babek et al. (2026), future monitoring should prioritise sediment chemistry and tributary-focused assessments, alongside conventional water-column analyses. A list of tributaries recommended for ongoing heavy-metal monitoring is provided in Appendix 11. Sediment-focused management and strict control of mining sources are urgent given the high potential for redistribution and re-mobilisation of heavy metals within the rivers of the Copperbelt.

### Evaluating Contaminant Sinks and Ecosystem Services

Wetlands offer vital ecosystem services to water users within the Kafue catchment. However, they are often under-valued and under-protected. To build a strong case for improved wetland protection, standard water quality parameters — such as turbidity, temperature, dissolved oxygen, and conductivity — should be tested above and below major wetlands to quantify their filtration capabilities.

Building on this, targeted research should evaluate the current state of heavy metal saturation through paired sediment and vegetation testing to determine how much longer these wetlands can safely cope with incoming pollution before becoming toxic. Similar targeted assessments should be directed at the Itzhi-Tezhi dam by analyzing deep reservoir sediments to confirm its role as a long-term sink and evaluate its impact on improving downstream water quality. Ultimately, sediment-focused management, strict source control, and a deeper understanding of these natural and artificial sinks will contribute significantly to future conservation efforts.

### Expanded Hydrological Monitoring

There are five stream flow monitoring stations along the Kafue River, all of which are located downstream of Kitwe. These provide river flow data that inform sustainable water resource management. By combining data from these gauging stations with monthly measurements of heavy metals at sentinel sites, the relationship between river flow and heavy metals should be determined. This relationship can be further examined by including groundwater assessments and remote sensing indices (such as elevation, land-use and evaporation) to develop a detailed water resources management tool that will guide improved integrated water resource management (IWRM) within the catchment.

### Participatory Environmental Monitoring at Sentinel Sites

Participatory Environmental Monitoring (PEM)<sup>84</sup> may offer a cost-effective and collaborative option for enhanced water quality monitoring along the Kafue River. Through consultation with local communities, PEM can be implemented at key locations, particularly within the Copperbelt. This will enhance the spatial and temporal resolution of existing data, allowing stakeholders to respond rapidly to water quality deterioration events.

To further build the Kafue River water quality baseline dataset, stakeholders involved in PEM should aim to measure water quality variables as often as possible — ideally daily. Monitoring should focus on designated sentinel sites along the river. The preliminary recommendation for these sites is: i) at Hippo Pools; ii) adjacent Kitwe; and iii) downstream of Kitwe, below the Wanshimba River. If monitoring is continuous, the data collected at these sites will also allow for rapid response to contamination events and climate emergencies.

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<sup>84</sup> UNDP and Swedish Environmental Protection Agency. 2025. *Participatory Environmental Monitoring in Mining Contexts: A Practitioner Checklist to Start PEM*. Available at: <https://www.learningfornature.org/en/participatory-environmental-monitoring-in-mining-contexts/>

## 8. APPENDICES

Appendix 1. The past and ongoing initiatives in the Kafue Basin.

Organization	Timeframe	Project Title	Project Description
African Development Bank (AfDB) with Zambia's government	2013–2020	Strengthening Climate Resilience in the Kafue Sub-Basin.	Improve adaptive capacity and infrastructure to support vulnerable communities in the Kafue Sub-Basin. Key components include climate-resilient roads, micro-credit support for small-scale farmers, and community-based adaptation efforts to mitigate risks from droughts and floods.
WWF Zambia and Water Resources Management Authority (WARMA)	2016-ongoing	Integrated Flow Assessment for the Kafue Flats (Phase 1)	Assess and manage water resources on the Kafue Flats to balance ecological preservation with hydropower, agriculture, and fisheries development. This project examines hydrological changes caused by the Itezhi-tezhi and Kafue Gorge Dams and their impact on wetland productivity, ecosystem services, and livelihood activities.
the Department of National Parks and Wildlife (DNPW) The World Wildlife Fund (WWF) and The International Crane Foundation/ Endangered Wildlife Trust (ICF/EWT)	2017-2020	Restoration of Kafue Flats	The project aims at controlling the continued spread of <i>Mimosa pigra</i> , whilst creating jobs in the local community. <i>Mimosa pigra</i> , which is spreading rapidly across the floodplain grasslands of the Kafue Flats, is being removed by using an integrated approach that combines physical, chemical and biological control options.
International Crane Foundation (ICF)	2017-2020 // 2021-2024	Securing the Kafue Flats for Vulnerable Kafue Lechwe and Wattled Cranes	The main goal is to stabilize wildlife populations on the Kafue Flats through increasing the effectiveness of anti-poaching law enforcement at the Lochinvar and Blue Lagoon National Parks
The International Federation of Red Cross and Red Crescent Societies (IFRC) and World Wide Fund For Nature (WWF)	2023-10+	Nature-based Solutions (NbS) in the Kafue Flats, Zambia	The projects aim to explore how NbS can strengthen the resilience of vulnerable landscapes and communities to climate and disaster risk.
ZESCO partnership with Sinohydro hydropower engineering and construction company)	2015-2023	Kafue Gorge Lower Power Station	To construct a 750 MW hydroelectric power station along the Kafue River, enhancing Zambia's power generation capacity and supporting economic growth
Pilot Program for Climate Resilience (PPCR)	2013-ongoing	Strengthening Climate Resilience in the Kafue Sub-Basin (SCRiKA)	To enhance the adaptive capacity of rural communities in the Kafue Sub-Basin, enabling them to better respond to climate variability and long-term

			climate change. The project contributes to sustainable development goals, including climate action, poverty reduction, gender equality, and infrastructure development.
ZESCO Limited	2011-Ongoing	Kafue Gorge Lower Hydro Power Project (KGL)	Expand Zambia's renewable energy capacity while addressing the environmental impacts on water flow and surrounding ecosystems in the basin.
Global Water Partnership	2017–2021	Integrated Water Resources Management (IWRM) in the Kafue Basin	Promote sustainable water use and integrated water resource management practices to balance ecological and economic needs.
The International Crane Foundation	2023-20+	International Crane Foundation Partners in Zambia to Manage and Restore Blue Lagoon and Lochinvar National Parks of the Kafue Flats in Zambia,	supporting a wealth of wildlife and natural resources,
World Wildlife Fund (WWF) in collaboration with the University of Maryland Center for Environmental Science (UMCES)	2018-2019	Lower Kafue River Basin Report Card Development	To develop a standardized report card assessing the health of the Lower Kafue River Basin. The project aimed to train WWF-Zambia staff in the report card process, leverage actions to ensure the basin's health, and raise awareness about the significance of freshwater systems to Zambian citizens.
Federal Institute for Geosciences and Natural Resources (BGR), Germany	2016-2019	Groundwater Management with Focus on the Upper Kafue Catchment	To support the Water Resources Management Authority (WARMA) in developing groundwater management plans for catchments and sub-catchments in the Upper Kafue Catchment.
World Wildlife Fund (WWF)	2005-2007	Integrated Water Resources Management (IWRM) and Food Security Project	To improve water management and food security in the Kafue Basin by implementing IWRM practices. The project focused on enhancing rural water supply in areas like Namwala District, aiming to provide sustainable access to water for domestic use and agriculture.
Solidaridad	2019-ongoing	Sustainable Landscape Management in the Kafue River Basin (NAMBOLA Project)	To contribute to the creation of resilient communities living adjacent to the the Kafue Basin through the promotion of sustainable livelihood practices, and the introduction of holistic integrated management of natural resources.
African Parks + Zambia Department of National Parks and Wildlife (DNPW)	2021-2022	Priority Support Plan for Kafue National Park	A 15-month plan aimed at strengthening law enforcement, management capacity, and conservation outcomes in Kafue National Park.

<b>African Parks</b>	2022-2042	Long-term Management of Kafue National Park	A formal agreement with the Zambian government to manage Kafue National Park, focusing on improving infrastructure, law enforcement, wildlife protection, and community engagement.
<b>African Parks</b>	Ongoing	Black Rhino Reintroduction Initiative	A conservation project to reintroduce black rhinos to Kafue National Park, aiming to restore species lost due to poaching and habitat loss.
<b>ICF, Elephant Charge</b>	2019 - 2023	Community Environmental Education and Outreach	Initiatives to enhance environmental education through school programs, community outreach, and infrastructure improvements in the Kafue Flats region.
<b>The Nature Conservancy (TNC)</b>	2022 - 2027	Conservation Collaboration Agreement for Kafue GMAs	A five-year agreement focusing on enhancing governance and management of the Kafue GMAs through community engagement, sustainable resource management, and conservation efforts.
<b>The Nature Conservancy (TNC), USAID, Kashikoto Conservancy Ltd., Amatheon AGRI Zambia Ltd.</b>	2021–2026	Eastern Kafue Nature Alliance (EKNA)	A five-year, \$21.3 million initiative aimed at improving governance, biodiversity protection, and sustainable livelihoods in the eastern Game Management Areas (GMAs) surrounding Kafue National Park.

Appendix 2. The counts of wetland-associated bird species and raptors observed on the 2024 Kafue River transect.

Species	Scientific Name	Count
Reed Cormorant	<i>Microcarbo africanus</i>	5,272
Western Cattle Egret	<i>Bubulcus ibis</i>	4,290
White-faced Whistling Duck	<i>Dendrocygna viduata</i>	1,550
African Openbill	<i>Anastomus lamelligerus</i>	1,100
African Jacana	<i>Actophilornis africanus</i>	969
Little Bee-eater	<i>Merops pusillus</i>	957
Whiskered Tern	<i>Chlidonias hybrida</i>	905
Pied Kingfisher	<i>Ceryle rudis</i>	767
Blacksmith Lapwing	<i>Vanellus armatus</i>	714
African Wattled Lapwing	<i>Vanellus senegallus</i>	573
Grey-headed Gull	<i>Chroicocephalus cirrocephalus</i>	496
White-breasted Cormorant	<i>Phalacrocorax lucidus</i>	489
Little Egret	<i>Egretta garzetta</i>	429
Yellow-billed Duck	<i>Anas undulata</i>	427
African Darter	<i>Anhinga rufa</i>	425
White-fronted Bee-eater	<i>Merops bullockoides</i>	344
Squacco Heron	<i>Ardeola ralloides</i>	313
African Fish Eagle	<i>Haliaeetus vocifer</i>	298
Striated Heron	<i>Butorides striata</i>	289
Great Egret	<i>Ardea alba</i>	233
Spur-winged Goose	<i>Plectropterus gambensis</i>	226
Glossy Ibis	<i>Plegadis falcinellus</i>	191
African Skimmer	<i>Rynchops flavirostris</i>	159
Malachite Kingfisher	<i>Corythornis cristatus</i>	154
Giant Kingfisher	<i>Megaceryle maxima</i>	146
Black Crane	<i>Zapornia flavirostra</i>	143
Hadada Ibis	<i>Bostrychia hagedash</i>	141
Hamerkop	<i>Scopus umbretta</i>	140
White-backed Vulture	<i>Gyps africanus</i>	133
Black-winged Stilt	<i>Himantopus himantopus</i>	128
Water Thick-knee	<i>Burhinus vermiculatus</i>	128
African Sacred Ibis	<i>Threskiornis aethiopicus</i>	126
African Spoonbill	<i>Platalea alba</i>	110
Coppery-tailed Coucal	<i>Centropus cupreicaudus</i>	94
Grey Heron	<i>Ardea cinerea</i>	86
Purple Heron	<i>Ardea purpurea</i>	83
Rufous-bellied Heron	<i>Ardeola rufiventris</i>	80
Half-collared Kingfisher	<i>Alcedo semitorquata</i>	78
Long-toed Lapwing	<i>Vanellus crassirostris</i>	77
Pied Crow	<i>Corvus albus</i>	74
Egyptian Goose	<i>Alopochen aegyptiaca</i>	61
Red-billed Teal	<i>Anas erythrorhyncha</i>	60
Lesser Jacana	<i>Microparra capensis</i>	57
African Finfoot	<i>Podica senegalensis</i>	51

Unknown Raptor		51
Goliath Heron	<i>Ardea goliath</i>	47
Black-headed Heron	<i>Ardea melanocephala</i>	45
Brown-hooded Kingfisher	<i>Halcyon albiventris</i>	43
Hooded Vulture	<i>Necrosyrtes monachus</i>	43
Yellow-billed Stork	<i>Mycteria ibis</i>	38
Bateleur	<i>Terathopius ecaudatus</i>	37
Unknown Vulture		37
Black Heron	<i>Egretta ardesiaca</i>	33
Knob-billed Duck	<i>Sarkidiornis melanotos</i>	32
Grey Crowned Crane	<i>Balearica regulorum</i>	30
African Marsh Harrier	<i>Circus ranivorus</i>	27
European Bee-eater	<i>Merops apiaster</i>	27
Black-winged Kite	<i>Elanus caeruleus</i>	25
Woolly-necked Stork	<i>Ciconia microscelis</i>	25
Black-crowned Night Heron	<i>Nycticorax nycticorax</i>	23
Intermediate Egret	<i>Ardea intermedia</i>	20
African Harrier Hawk	<i>Polyboroides typus</i>	18
African Pygmy Goose	<i>Nettapus auritus</i>	18
Black Coucal	<i>Centropus grillii</i>	16
Black-chested Snake Eagle	<i>Circaetus pectoralis</i>	15
Blue-cheeked Bee-eater	<i>Merops persicus</i>	14
Long-crested Eagle	<i>Lophaetus occipitalis</i>	11
Wattled Crane	<i>Grus carunculata</i>	9
White-headed Vulture	<i>Trigonoceps occipitalis</i>	9
Böhms Bee-eater	<i>Merops boehmi</i>	8
Little Sparrowhawk	<i>Tachyspiza minulla</i>	8
Marsh Owl	<i>Asio capensis</i>	8
Western Marsh Harrier	<i>Circus aeruginosus</i>	8
White-winged Tern	<i>Chlidonias leucopterus</i>	8
African Snipe	<i>Gallinago nigripennis</i>	6
Common Greenshank	<i>Tringa nebularia</i>	6
Common Moorhen	<i>Gallinula chloropus</i>	6
Lappet-faced Vulture	<i>Torgos tracheliotos</i>	6
White-browed Coucal	<i>Centropus superciliosus</i>	6
Common Sandpiper	<i>Actitis hypoleucos</i>	5
Kittlitz's Plover	<i>Anarhynchus pecuarius</i>	5
Swallow-tailed Bee-eater	<i>Merops hirundineus</i>	5
Three-banded Plover	<i>Charadrius tricollaris</i>	5
Western Banded Snake Eagle	<i>Circaetus cinerascens</i>	5
Gabar Goshawk	<i>Micronisus gabar</i>	4
Little Stint	<i>Calidris minuta</i>	4
Marabou Stork	<i>Leptoptilos crumenifer</i>	4
Martial Eagle	<i>Polemaetus bellicosus</i>	4
Pel's Fishing Owl	<i>Scotopelia peli</i>	4
Saddle-billed Stork	<i>Ephippiorhynchus senegalensis</i>	4
Unknown Plover		4

Woodland Kingfisher	<i>Halcyon senegalensis</i>	4
Brown Snake Eagle	<i>Circaetus cinereus</i>	3
Common Ringed Plover	<i>Charadrius hiaticula</i>	3
Great White Pelican	<i>Pelecanus onocrotalus</i>	3
Lanner Falcon	<i>Falco biarmicus</i>	3
Unknown Sandpiper		3
Western Osprey	<i>Pandion haliaetus</i>	3
African Goshawk	<i>Accipiter tachiro</i>	2
Augur Buzzard	<i>Buteo augur</i>	2
Grey-headed Kingfisher	<i>Halcyon leucocephala</i>	2
Pink-backed Pelican	<i>Pelecanus rufescens</i>	2
Red-necked Falcon	<i>Falco chicquera</i>	2
Tawny Eagle	<i>Aquila rapax</i>	2
White-backed Night Heron	<i>Calherodius leuconotus</i>	2
Abdim's Stork	<i>Ciconia abdimii</i>	1
African Barred Owlet	<i>Glaucidium capense</i>	1
African Crake	<i>Crecopsis egregia</i>	1
Black Stork	<i>Ciconia nigra</i>	1
Corn Crake	<i>Crex crex</i>	1
Lizard Buzzard	<i>Kaupifalco monogrammicus</i>	1
Marsh Sandpiper	<i>Tringa stagnatilis</i>	1
Marsh Widowbird	<i>Euplectes hartlaubi</i>	1
Senegal Coucal	<i>Centropus senegalensis</i>	1
Unknown Owl		1
Western Barn Owl	<i>Tyto alba</i>	1
Wood Sandpiper	<i>Tringa glareola</i>	1
Yellow-billed Kite	<i>Milvus aegyptius</i>	1
<hr/>		
TOTAL		24,431
<hr/>		

Appendix 3. Description of water quality parameters.

Water Quality Parameter	Description
<b>pH (or hydrogen ion concentration)</b>	pH (or hydrogen ion concentration) is a general indicator of water quality that is affected by all manner of contaminants and other changes in water chemistry. pH of water determines the solubility (amount that can be dissolved in the water) and biological availability (amount that can be utilised by aquatic life) of chemical constituents such as nutrients (phosphorus, nitrogen, and carbon) and heavy metals (lead, copper, cadmium, etc.) Extremes in pH can make a river inhospitable to life. The pH of most raw waters should lie between 6.5-8.5, above and below that warrants detailed water analyses.
<b>Dissolved oxygen (DO)</b>	Depleted oxygen results in eutrophic conditions that can be detrimental to ecosystem health. Invasive weeds such as water hyacinth and certain algae, reduce available oxygen in the river. Weed invasions and algal blooms often result from fertiliser runoff and other poor land use practices. 80-120% saturation (~ 6.9 – 10.3 mg/L concentration) is safe.
<b>Oxidation-reduction potential (ORP)</b>	Oxidation-reduction potential (ORP) measures the ability of a river to break down waste products, such as contaminants and dead organic matter. In general, the higher the ORP value, the healthier the river is. Safe drinking water should have an ORP of greater than 650mV.
<b>Total dissolved solids (TDS)</b>	Total dissolved solids (TDS) is measured as a volume of water with the unit milligrams per litre (mg/L), otherwise known as parts per million (ppm). According to the EPA secondary drinking water regulations, 500 ppm is the recommended maximum amount of TDS for your drinking water.
<b>Electric conductivity (EC)</b>	Electric conductivity (EC) measures the water’s ability to carry an electric current and is related to the total dissolved salts or ions in the water. These conductive ions come from dissolved salts and inorganic materials such as alkalis, chlorides, sulphides and carbonate compounds that are often associated with pollutants. Total dissolved solids (TDS) and salinity are similar measures to conductivity.
<b>Salinity and its inverse — resistivity</b>	Salinity and its inverse — resistivity — are measures of salt content in the water. Salts are highly soluble in surface and groundwater and can be transported with water movement. Increases in salinity are often associated with excessive vegetation clearance (fires), poor land management, irrigation, and industrial practices.
<b>Turbidity</b>	Turbidity is the condition resulting from suspended solids in water (silt, clays, industrial waste, sewage and plankton). Such particles absorb heat in the sunlight, thus raising water temperature, which in turn lowers dissolved oxygen levels. Elevated turbidity also limits light penetration, reducing photosynthesis and food availability, while suspended sediments disrupt feeding, respiration, and habitat quality. Increases in turbidity can result from elevated erosion rates due to poor land use practices. Resistivity is a similar measure of turbidity.
<b>Temperature and water density</b>	Temperature and water density impacts aquatic organisms in terms of their growth and metabolic rates and their sensitivity to disease, parasites, and toxins. Temperature also affects the rate of photosynthesis and the solubility of oxygen in river water.

Appendix 4. Locations of the 171 water quality sampling sites on the 2024 Kafue River transect.

Water Quality Site No.	Latitude	Longitude
1	-11.613	27.052
2	-11.641	27.124
3	-11.688	27.164
4	-11.751	27.161
5	-11.788	27.168
6	-11.859	27.239
7	-11.894	27.262
8	-12.137	27.362
9	-12.192	27.381
10	-12.236	27.415
11	-12.247	27.458
12	-12.268	27.449
13	-12.279	27.486
14	-12.306	27.506
15	-12.336	27.509
16	-12.358	27.554
17	-12.390	27.579
18	-12.415	27.625
19	-12.431	27.652
20	-12.413	27.691
21	-12.416	27.735
22	-12.412	27.763
23	-12.447	27.793
24	-12.415	27.818
25	-12.414	27.818
26	-12.441	27.825
27	-12.464	27.851
28	-12.481	27.920
29	-12.467	27.976
30	-12.479	28.013
31	-12.495	28.081
32	-12.540	28.117
33	-12.584	28.152
34	-12.605	28.153
35	-12.701	28.242
36	-12.748	28.232
37	-12.801	28.262
38	-12.850	28.260
39	-12.905	28.240
40	-12.971	28.223
41	-13.042	28.190
42	-13.096	28.179
43	-13.158	28.174
44	-13.220	28.166
45	-13.275	28.143
46	-13.289	28.090
47	-13.333	28.078
48	-13.372	28.039
49	-13.350	27.992
50	-13.350	27.942
51	-13.337	27.919
52	-13.371	27.848
53	-13.402	27.819
54	-13.402	27.787
55	-13.472	27.749
56	-13.507	27.700
57	-13.523	27.714
58	-13.527	27.637
59	-13.559	27.603
60	-13.638	27.607
61	-13.701	27.625
62	-13.755	27.583
63	-13.816	27.534

64	-13.837	27.482
65	-13.891	27.461
66	-13.920	27.421
67	-13.979	27.366
68	-14.112	27.411
69	-14.064	27.397
70	-14.158	27.393
71	-14.225	27.374
72	-14.269	27.342
73	-14.304	27.302
74	-14.328	27.228
75	-14.373	27.190
76	-14.373	27.190
77	-14.373	27.188
78	-14.375	27.110
79	-14.406	27.043
80	-14.420	26.939
81	-14.423	26.854
82	-14.432	26.802
83	-14.453	26.722
84	-14.450	26.647
85	-14.462	26.567
86	-14.500	26.518
87	-14.548	26.483
88	-14.595	26.422
89	-14.661	26.372
90	-14.721	26.343
91	-14.695	26.286
92	-14.664	26.206
93	-14.619	26.193
94	-14.612	26.168
95	-14.694	26.133
96	-14.758	26.108
97	-14.794	26.195
98	-14.872	26.193
99	-14.888	26.133
100	-14.908	26.082
101	-14.907	26.018
102	-14.943	25.964
103	-14.954	25.916
104	-14.979	25.994
105	-15.044	26.003
106	-15.095	25.988
107	-15.162	25.957
108	-15.238	25.985
109	-15.308	25.957
110	-15.393	25.980
111	-15.448	25.949
112	-15.513	26.006
113	-15.573	26.026
114	-15.647	26.022
115	-15.716	26.004
116	-15.758	26.020
117	-15.764	26.030
118	-15.788	26.109
119	-15.819	26.170
120	-15.796	26.242
121	-15.759	26.296
122	-15.725	26.343
123	-15.709	26.414
124	-15.671	26.468
125	-15.646	26.553
126	-15.702	26.584
127	-15.698	26.645
128	-15.682	26.690
129	-15.678	26.730

130	-15.663	26.817
131	-15.621	26.827
132	-15.572	26.887
133	-15.575	26.952
134	-15.620	26.991
135	-15.588	27.060
136	-15.630	27.121
137	-15.656	27.161
138	-15.704	27.194
139	-15.723	27.255
140	-15.749	27.297
141	-15.732	27.337
142	-15.731	27.374
143	-15.746	27.434
144	-15.715	27.485
145	-15.712	27.517
146	-15.654	27.571
147	-15.683	27.612
148	-15.662	27.646
149	-15.671	27.687
150	-15.644	27.752
151	-15.665	27.832
152	-15.716	27.810
153	-15.745	27.805
154	-15.720	27.881
155	-15.759	27.931
156	-15.714	27.981
157	-15.748	28.072
158	-15.784	28.158
159	-15.831	28.250
160	-15.797	28.315
161	-15.800	28.398
162	-15.810	28.419
163	-15.849	28.485
164	-15.850	28.493
165	-15.870	28.523
166	-15.895	28.562
167	-15.899	28.636
168	-15.940	28.702
169	-15.964	28.764
170	-15.961	28.809
171	-15.943	28.914

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### Sample Collection

Triplicate river water samples were filtered immediately on site using a sterile 50 ml piston syringe to manually push the water through a Sterivex™ filter unit (Merck Millipore; pore size 0.22 µm), until the filter reached saturation, and no further water could be passed through. Following filtration, each Sterivex™ unit was filled with 2 ml of ATL lysis buffer (Qiagen) to preserve the DNA, then sealed at both ends using Helapet Combi-Caps and a protective layer of parafilm.

All filters were stored at room temperature until laboratory processing. To minimise contamination risk during fieldwork, fresh sterile gloves were worn between each sampling event, and strict handling protocols were followed. Field blanks (n = 3) were prepared at regular intervals by filtering 1 L of sterile, distilled water through new Sterivex™ units and treating them identically to the environmental samples throughout the workflow. Upon completion of fieldwork, all samples and blanks were transported to the Wild Bird Trust's molecular biology facility in Maun for DNA extraction.

### Environmental DNA Extraction

DNA extractions were performed in a disinfected, PCR-free area that was thoroughly cleaned using 10% sodium hypochlorite solution, with worktops and pipettes exposed to UV light for 30 minutes before and after setup. DNA was extracted directly from the filter units using the DNeasy Blood and Tissue kit (Qiagen) with a modified protocol<sup>85</sup>. To monitor potential contamination in the laboratory workflow, negative controls were included using sterile, UV-treated Ultra Clean DNA-free water, processed alongside the environmental samples. All DNA extracts were subsequently quantified using a Qubit dsDNA HS Assay Kit (Thermo Fisher Scientific) and stored at -20°C prior to downstream molecular analysis.

### Amplification and Sequencing

At the time of reporting, all extracted DNA samples, field blanks, and laboratory blanks, have been submitted to SimplexDNA (Switzerland) and are pending amplification and sequencing. Targeted amplification will focus on the hypervariable region of the 12S rRNA gene (163–185 bp), using MiFish-U-F/R primers (Forward: 5'-GTCGGTAAACTCGTGCCAGC-3'; Reverse: 5'-CATAGTGGGGTATCTAATCCCAGTTTG-3')<sup>86</sup>.

<sup>85</sup> Czachur, M.V. et al. 2022. Novel insights into marine fish biodiversity across a pronounced environmental gradient using replicated environmental DNA analyses. *Environmental DNA* 4:181–190. <https://doi.org/10.1002/edn3.238>.

<sup>86</sup> Miya, M. et al. 2015. MiFish, a set of universal PCR primers for metabarcoding environmental DNA from fishes: Detection of more than 230 subtropical marine species. *Royal Society Open Science*. 2(7):150088. DOI: [10.1098/rsos.150088](https://doi.org/10.1098/rsos.150088).

Appendix 6. Results of the opportunistic fish sampling that was conducted on the Kafue River in 2024.

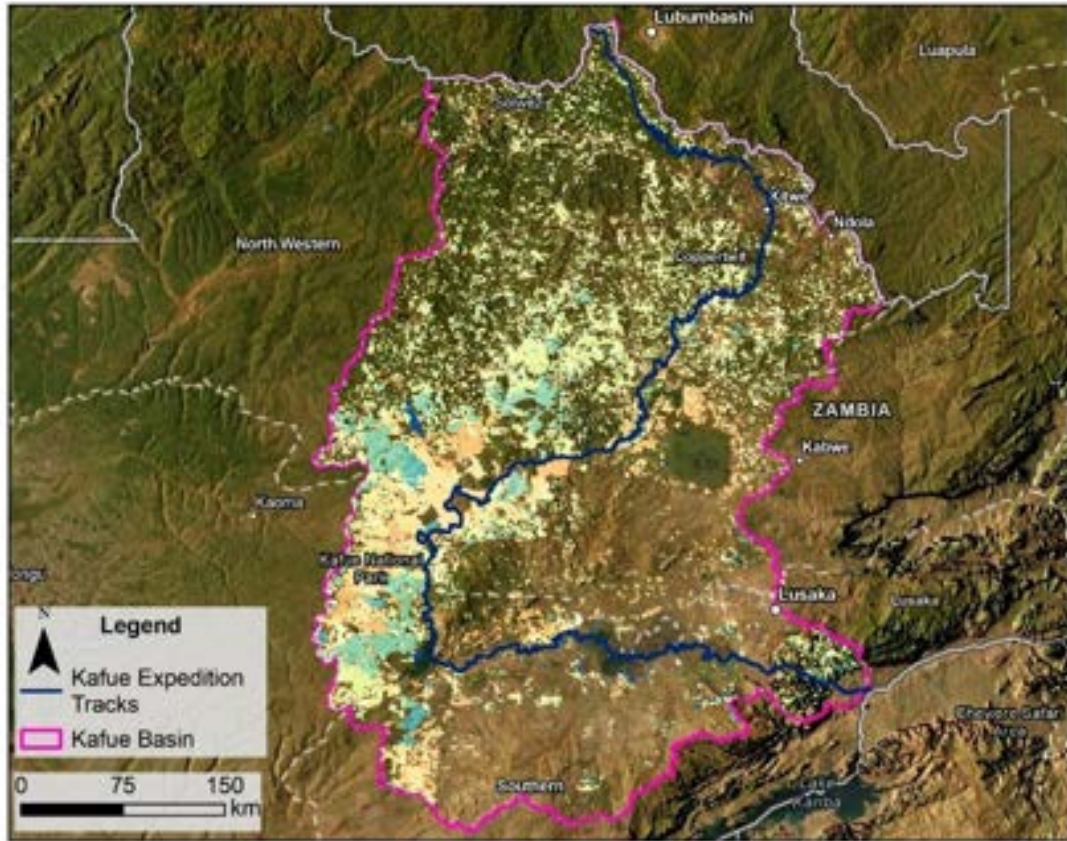
Fish Sampling Site	Latitude	Longitude	No. of Specimen	No. of Species
1	-11.788	27.168	8	7
2	-11.859	27.239	9	6
3	-11.883	27.248	88	14
4	-11.859	27.239	18	7
5	-12.162	27.368	2	2
6	-12.137	27.362	3	3
7	-12.219	27.417	113	15
8	-12.301	27.473	6	6
9	-12.358	27.554	27	7
10	-12.406	27.661	1	1
11	-12.406	27.675	10	9
12	-12.447	27.793	90	12
13	-12.464	27.851	0	0
14	-12.479	27.905	0	0
15	-12.476	27.986	10	4
16	-12.479	28.013	6	4
17	-12.54	28.117	1	1
18	-12.701	28.242	34	6
19	-12.905	28.240	1	1
20	-12.906	28.240	4	3
21	-12.978	28.221	5	2
22	-13.22	28.166	59	10
23	-13.352	28.051	7	2
24	-13.337	27.919	29	13
25	-13.523	27.714	17	8
26	-13.703	27.626	0	0
27	-13.837	27.482	96	11
28	-14.046	27.392	1	1
29	-14.158	27.393	54	6
30	-14.328	27.228	6	3
31	-14.404	27.024	3	2
32	-14.462	26.567	1	1
33	-14.548	26.483	0	0
34	-14.718	26.358	55	8
35	-14.612	26.168	1	1
36	-14.794	26.195	22	10
37	-14.915	26.117	22	8
38	-14.906	26.044	4	3
39	-14.954	25.916	0	0
40	-15.044	26.003	3	3
41	-15.095	25.988	3	2
42	-15.308	25.957	3	2
43	-15.393	25.980	4	4
44	-15.448	25.949	5	3
45	-15.647	26.022	1	1
46	-15.745	26.008	0	0
47	-15.796	26.242	37	5
48	-15.671	26.468	3	2
49	-15.682	26.690	70	12
50	-15.616	26.837	99	9
51	-15.588	27.060	0	0
52	-15.724	27.205	8	6
53	-15.731	27.374	5	3
54	-15.712	27.517	4	3
55	-15.671	27.687	97	12
56	-15.745	27.805	0	0
57	-15.738	28.022	123	9
58	-15.831	28.250	11	4
59	-15.81	28.419	3	2
60	-15.895	28.562	6	2
61	-15.905	28.666	17	6
62	-15.961	28.809	8	4
Opportunistic	Various	Various	21	>72
<b>TOTAL</b>			<b>1,344</b>	<b>&gt;72</b>

Appendix 7. The counts of fish species caught on the Kafue River in 2024.

Species	Count
<i>Tilapia sparmanii</i>	179
<i>Lacustricola johnsoni</i>	168
<i>Pseudocrenilabus philander</i>	157
<i>Synodontis macrostigma</i>	137
<i>Pharyngochromis cf. acuticeps</i>	53
<i>Coptodon rendalli</i>	40
<i>Brycinus lateralis</i>	39
<i>Lacustricola chobensis</i>	36
<i>Micralestes acutidens</i>	32
<i>Enteromius cf. poechii</i>	31
<i>Nannocharax machodoi</i>	31
<i>Enteromius greenwoodi</i>	29
<i>Enteromius kerstenii</i>	29
<i>Nannocharax multifasciatus</i>	29
<i>Enteromius afrovernayi</i>	27
<i>Synodontis cf. vanderwalli</i>	24
<i>Enteromius fasciolatus</i>	23
<i>Enteromius multilineatus</i>	22
<i>Enteromius radiatus</i>	22
<i>Enteromius cf. paludinosus</i>	14
<i>Schilbe intermedius</i>	13
<i>Serranochromis angusticeps</i>	12
<i>Pharyngochromis sp. (rapids adapted)</i>	11
<i>Synodontis cf. woosnami</i>	11
<i>Microctenopoma intermedium</i>	9
<i>Synodontis sp.</i>	9
<i>Enteromius eutaenia</i>	8
<i>Enteromius haasianus</i>	8
<i>Enteromius sp.</i>	8
<i>Nannocharax sp.</i>	8
<i>Serranochromis alvum</i>	8
<i>Lacustricola sp. (yellow fin)</i>	7
<i>Nannocharax dageti</i>	7
<i>Chiloglanis sp.</i>	6
<i>Clarias cf. theodora</i>	6
<i>Synodontis cf. leopardinus</i>	6
<i>Synodontis macrostoma</i>	6
<i>Hepsetus odoe</i>	5
<i>Labeo cylindricus</i>	5
<i>Oreochromis niloticus (hybrid?)</i>	5
<i>Clarias cf. stappersii</i>	4
<i>Clarias sp.</i>	4
<i>Lacustricola katangae</i>	4
<i>Mastacembelus frenatus</i>	4
<i>Enteromius barotsensis</i>	3
<i>Oreochromis niloticus</i>	3
<i>Petrocephalus cf. magnitrunci</i>	3
<i>Petrocephalus cf. okavangensis</i>	3
<i>Petrocephalus longicapitis</i>	3
<i>Pollimyrus castelnaui</i>	3
<i>Serranochromis cf. thumbergi</i>	3
<i>Chiloglanis fasciatus</i>	2

<i>Enteromius cf. thalamakensis</i>	2
<i>Enteromius unitaeniatus</i>	2
<i>Labeobarbus sp.</i>	2
<i>Serranochromis alcrum</i>	2
<i>Synodontis cf. thalamakensis</i>	2
<i>Enteromius bifrenatus</i>	1
<i>Enteromius cf. unitaeniatus</i>	1
<i>Hydrocynus vittatus</i>	1
<i>Marcusenius altisambesi</i>	1
<i>Nannocharax intermedius</i>	1
<i>Opsaridium zambense</i>	1
<i>Oreochromis cf. macrochir</i>	1
<i>Petrocephalus sp.</i>	1
<i>Pharyngochromis sp.</i>	1
<i>Pollimyrus cf. cuandoensis</i>	1
<i>Sargochromis cf. carlottae</i>	1
<i>Serranochromis altus</i>	1
<i>Serranochromis jallae</i>	1
<i>Serranochromis cf. macrocephalus</i>	1
<i>Serranochromis sp.</i>	1
<hr/>	
Total	1,344
<hr/>	
<i>Cherax quadricarinatus</i> (Yabby)	283
Crab	12
<i>Xenopus sp.</i> (Clawed frog)	1
<hr/>	

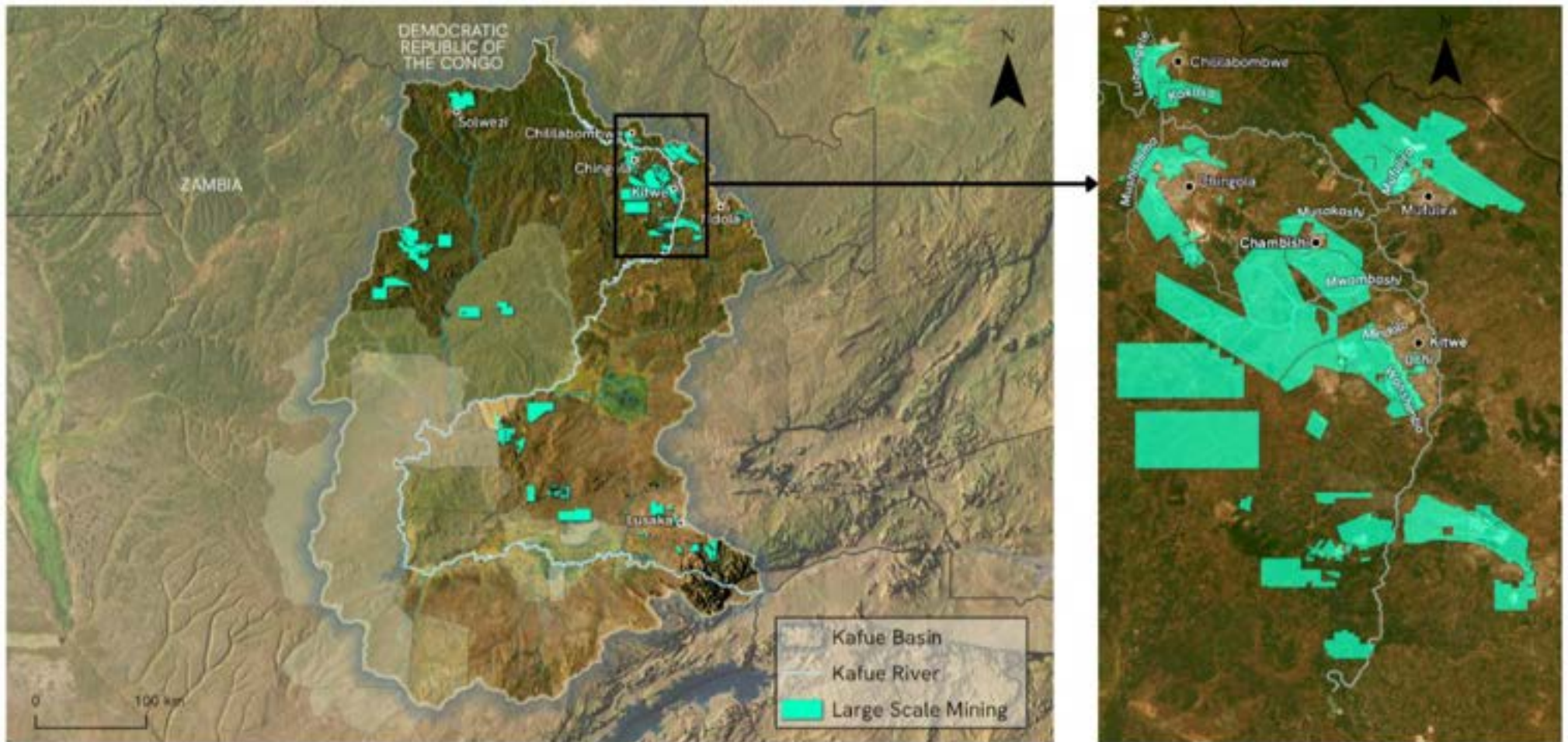
Appendix 8. Burned area and proportion of basin burnt per month in 2023 in the Kafue Basin.



Legend	2023 Area (km <sup>2</sup> )	Burn Proportion (%)
No Burn	116,621.00	-
January	0.50	0.001%
February	0.00	0.000%
March	15.00	0.033%
April	310.00	0.677%
May	4,677.00	10.212%
June	10,089.50	22.029%
July	8,270.75	18.058%
August	14,427.25	31.500%
September	6,113.50	13.348%
October	1,185.50	2.588%
November	473.25	1.033%
December	40.24	0.088%
<b>Total Burn Area</b>	<b>45,800.75</b>	<b>-</b>

Appendix 9. LULC description of classes.

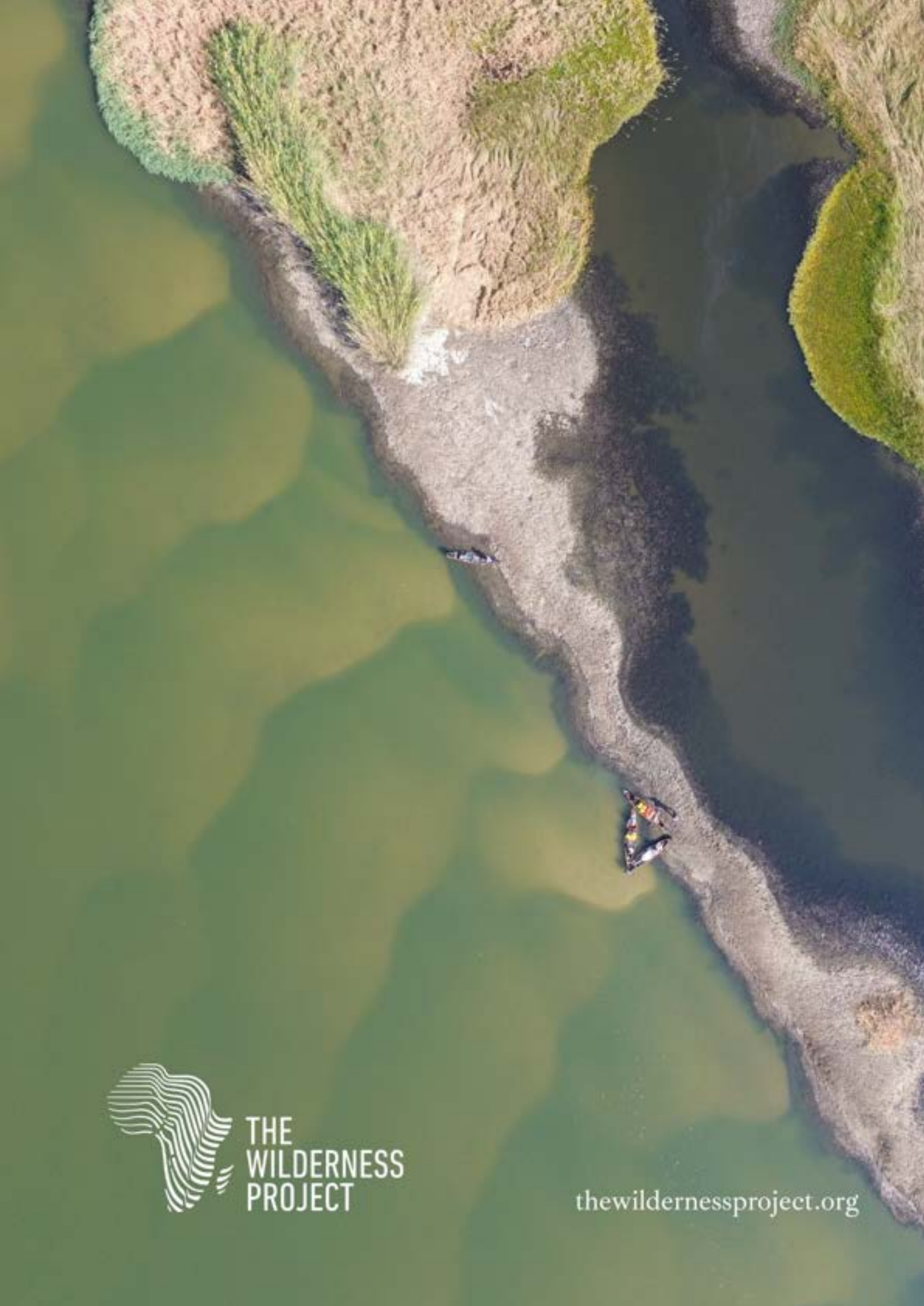
IPCC Classes considered for the change detection (with colour)	LCCS legend used in the CCI-LC maps	
1. Agriculture	Code	Description
	10, 11, 12	Rainfed cropland
	20	Irrigated cropland
	30	Mosaic cropland (>50%) / natural vegetation (tree, shrub, herbaceous cover) (<50%)
	40	Mosaic natural vegetation (tree, shrub, herbaceous cover) (>50%) / cropland (< 50%)
2. Forest	50	Tree cover, broadleaved, evergreen, closed to open (>15%)
	60, 61, 62	Tree cover, broadleaved, deciduous, closed to open (> 15%)
	70, 71, 72	Tree cover, needle leaved, evergreen, closed to open (> 15%)
	80, 81, 82	Tree cover, needle leaved, deciduous, closed to open (> 15%)
	90	Tree cover, mixed leaf type (broadleaved and needleleaved)
	100	Mosaic tree and shrub (>50%) / herbaceous cover (< 50%)
	160	Tree cover, flooded, fresh or brackish water
	170	Tree cover, flooded, saline water
3. Grassland	110	Mosaic herbaceous cover (>50%) / tree and shrub (<50%)
	130	Grassland
4. Wetland	180	Shrub or herbaceous cover, flooded, fresh-saline or brackish water
5. Settlement	190	Urban
6. Shrubland	120, 121, 122	Shrubland
7. Bare / sparse vegetation	140	Lichens and mosses
	150, 151, 152, 153	Sparse vegetation (tree, shrub, herbaceous cover)
	200, 201, 202	Bare Areas
8. Water	210	Water



Appendix 10: Large-scale active mining operations within the Kafue River Basin. The inset focuses on the Copperbelt region around Chingola and Kitwe, illustrating the dense concentration of mining areas and their proximity to the Kafue River and its tributaries.

Appendix 11. Recommended sites for water and sediment quality monitoring within the Kafue River and associated tributaries.

River	Location	Category	Testing Frequency	X	Y	Heavy Metals	Cations	Anions	Standard Parameters	Nutrients
Kafue	Hippo Pools	Sentinel Site	Continuous	27.850953	-12.464394	X	X	X	X	X
Kafue	Upstream Kitwe	Sentinel Site	Continuous	28.164404	-12.644442	X	X	X	X	X
Kafue	Downstream Kitwe	Sentinel Site	Continuous	28.255541	-12.919965	X	X	X	X	X
Lubengele	Directly upstream of Kafue confluence	Tributary	Monthly	27.810871	-12.418408	X	X	X	X	
Kakosa	Directly upstream of Kafue confluence	Tributary	Monthly	27.818163	-12.412940	X	X	X	X	
Mushishima	Directly upstream of Kafue confluence	Tributary	Monthly	27.824233	-12.491067	X	X	X	X	
Mufulira	Directly upstream of Kafue confluence	Tributary	Monthly	27.824233	-12.491067	X	X	X	X	
Mwambashi	Directly upstream of Kafue confluence	Tributary	Monthly	28.181412	-12.709590	X	X	X	X	
Musakashi	Directly upstream of Kafue confluence	Tributary	Seasonal (when flowing)	27.810871	-12.601637	X	X	X	X	
Mindolo	Directly upstream of Kafue confluence	Tributary	Seasonal (when flowing)	28.245051	-12.76114	X	X	X	X	
Uchi	Directly upstream of Kafue confluence	Tributary	Seasonal (when flowing)	28.25444	-12.820747	X	X	X	X	
Wanshimba	Directly upstream of Kafue confluence	Tributary	Seasonal (when flowing)	28.151379	-13.248718	X	X	X	X	
Kafue	Kwesa Floodplain	Wetland	Quarterly	27.469635	-12.288072		X	X	X	X
Kafue	Lukanga Floodplains	Wetland	Quarterly	27.754247	-14.414274		X	X	X	X



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