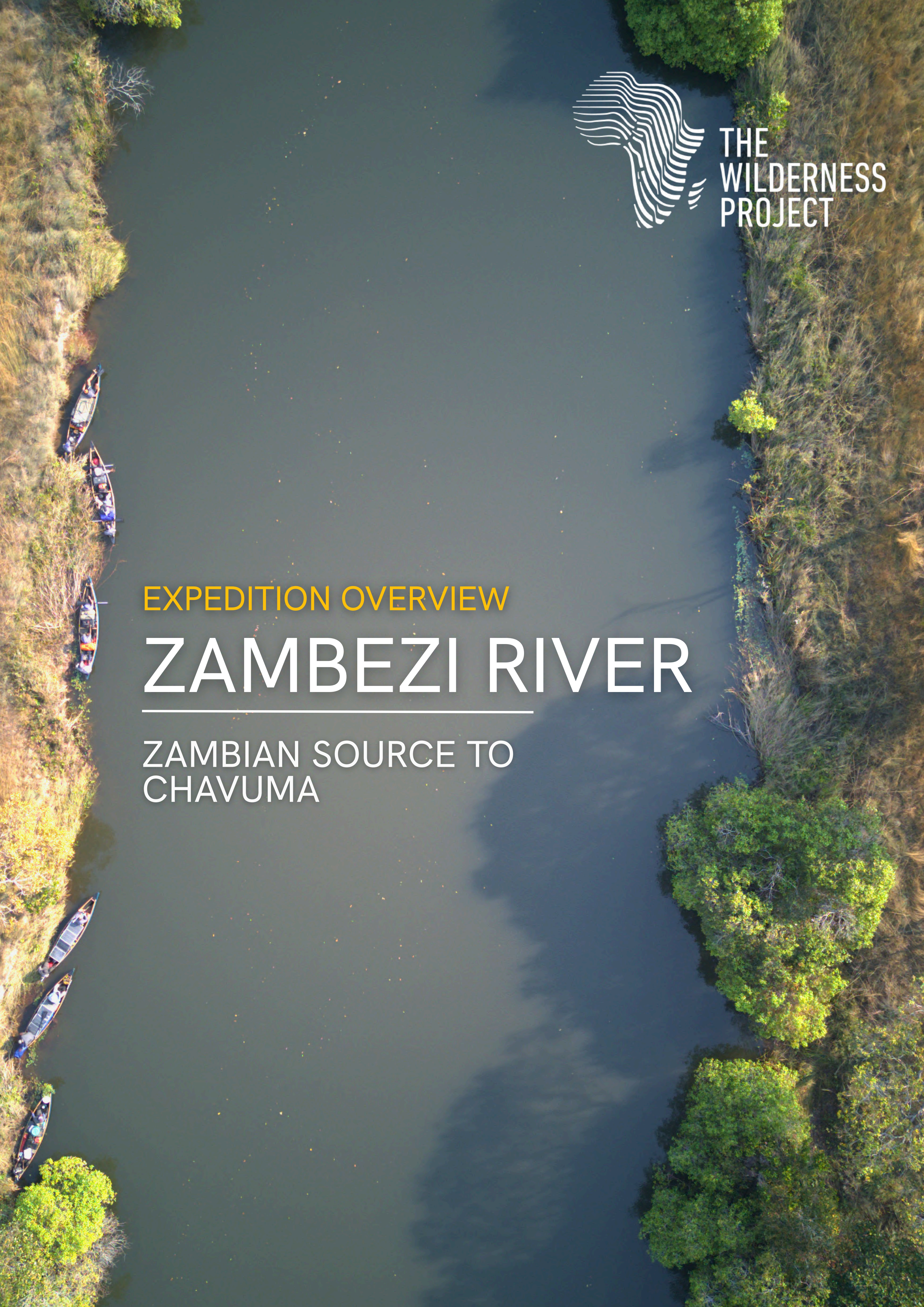


THE WILDERNESS PROJECT

EXPEDITION OVERVIEW

ZAMBEZI RIVER

ZAMBIAN SOURCE TO CHAVUMA

THE WILDERNESS PROJECT

ABOUT THE WILDERNESS PROJECT

By 2035, in partnership with local communities, governments, researchers and NGOs, The Wilderness Project aims to explore, study and better protect 1.2 million square kilometres of irreplaceable African wilderness. Central to this effort is establishing detailed hydrological and ecological baselines of the largely undocumented sources and watersheds of Africa's greatest river basins — Zambezi, Congo, Nile, and Okavango.

ACKNOWLEDGEMENTS

Our research transects would be impossible without the collaboration of our partners, who provide access to the river, permissions to camp, and invaluable local perspectives. For their continued support for our work along the Zambezi River, we thank Department of National Parks and Wildlife, Copperbelt University, African Parks, the Water Resources Management Authority, the University of Zambia, Fundação Lisima, and the Wild Bird Trust.

AFRICAN PARKS · WARMA · DNPW · The University of Zambia · Ministry of Fisheries and Livestock · Copperbelt University · WILD BIRD TRUST · GOVERNO DE ANGOLA MINISTÉRIO DO AMBIENTE · FUNDAÇÃO LISIMA

CONTENTS

INTRODUCTION

The Zambezi Basin is the largest river basin in southern Africa, covering approximately 1.3 million km^2 across eight countries. The Zambezi River itself spans 3,421 km from its headwaters in northwestern Zambia and eastern Angola to its delta on the Indian Ocean coast of Mozambique. It is commonly described in three sections — the Upper, Middle, and Lower Zambezi — each with unique physical and ecological characteristics[1]. The Upper Zambezi, extending from the river's headwaters in the Angolan Highlands to Victoria Falls[2], forms the source region, where rainfall, wetlands, and tributaries shape much of the river's seasonal rhythm.

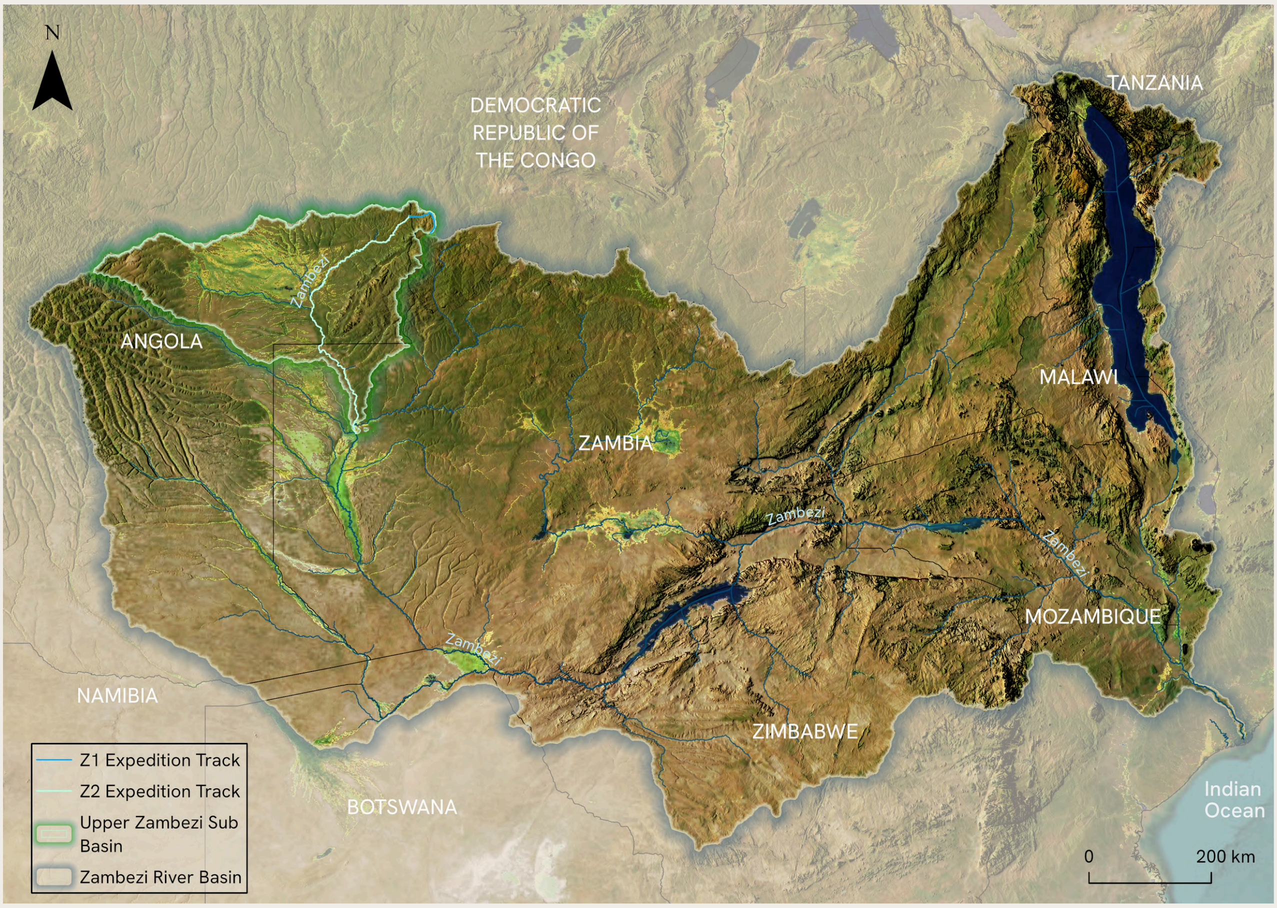
The traditional source lies near Kalene Hill in the northwestern corner of Zambia, where a small spring emerges at an altitude of approximately 1,500 m. From there, the Zambezi flows north for ~30 km before turning southwest and entering Angola[3]. It meanders through the Angola for ~450 km before re-entering Zambia at Chavuma Falls. Along the way, it gathers water from the Angolan Highlands Water Tower (AHWT), particularly through the Luena and Chifumage Rivers.

Further downstream, the Luanginga, Lungwebungu, and countless other tributaries gradually contribute flows that transform the Zambezi from a modest stream into one of Africa's most iconic rivers. These flows contribute over 70% of the water entering the Barotse Floodplain during the late wet season[1]. In recognition of this importance, the Lisima Lya Mwono ("Source of Life") region of the AHWT has recently been designated as a Ramsar Wetland of International Importance. This underscores the vital role of the water tower in regulating the hydrology of the Zambezi River, to the benefit of millions of people downstream.

The Zambezi River is more than a geographical feature — it is a lifeline. It supports agriculture, fisheries, hydropower, tourism and transportation, while providing critical habitat for immense biodiversity. The river also holds substantial cultural and spiritual significance for its riparian communities. However, challenges are ongoing. Climate change, water contamination, and invasive species, all threaten to degrade the river. If not carefully managed, channel modification and overfishing are likely to drive irreversible changes in the biodiversity and hydrology of the river. In this light, ongoing efforts to study and protect the Zambezi River for future generations are increasingly important, and increasingly urgent.

| *The traditional source of the Zambezi River rises as a small spring near Kalene Hill in northwestern Zambia.*

THE BASIN



The Zambezi Basin (bottom map) spans 8 countries and covers a total area of 1.39 million km^2. It can be divided into 13 sub-basins, including the Upper Zambezi Sub-basin (top map). This sub-basin extends from the traditional source near Kalene Hill, to the beginning of the Barotse Floodplain.

THE EXPEDITIONS

575 km

traversed by kayak, mekoro, and canoe

25 — team members from 5 African countries

62 — research sites established

25 — days on expedition

As part of a baseline survey of the entire Zambezi River, The Wilderness Project (TWP) carried out two research transects in 2023: one from the river's traditional source to Jimbe (4–10 May) and another along the Angolan stretch of the river (6–23 July). The surveys generated baseline data on hydrology, water quality, biodiversity, and human activity to inform long-term monitoring and strengthen sustainable river management. Findings revealed critical conservation insights, including ongoing threats to the river system. The expedition team comprised African researchers, storytellers, professional river guides, and a land-based support crew.

METHODS

CONTINUOUS MONITORING

During the transect, teams collected continuous survey data and 360° imagery. Each team included an observer and a recorder. Observers scanned the river and both banks — up to 100 m from the edge — identifying features such as land use, infrastructure, biodiversity, and signs of disturbance. Recorders logged observations in real time using the Survey123 (ESRI) app on a smartphone, ensuring spatially referenced data across diverse indicators.

FIXED SURVEY SITES

Fixed survey sites were established at regular intervals to capture detailed information on water quality, biodiversity, and land use. These sites offer a strong foundation for long-term monitoring by communities, river authorities, and NGOs involved in river stewardship.

- *Every 10km*: using drone imagery and water analysis, researchers revealed patterns not visible through observation alone.
- *Every 50-75km*: eDNA sampling, macroinvertebrate surveys, and further testing provide a foundation of river health and biodiversity.

OPPORTUNISTIC SITES

To complement continuous observations, researchers conducted targeted sampling at selected sites along the transect. Leveraging local river conditions and insights from visual surveys, they deployed overnight bat recorders, set traps for freshwater fish and crustaceans, collected water samples, and measured river discharge. This approach enabled more detailed assessments of the river's hydrochemistry, hydrology, and biodiversity.

RESEARCH SITES

60 fixed sites

58	59	43
water quality measurements	aerial drone surveys	wetland bird species recorded

The locations of 49 fixed and 8 intensive research sites.

HUMAN ACTIVITY

The Zambezi River in Zambia supported a relatively high population density of 83 people per 10 km, compared with just 24 people per 10 km in Angola. This aligns with other transboundary rivers surveyed by TWP, for example, the Lungwebungu and Cubango, both of which have lower riparian population densities in Angola relative to neighboring countries.

Despite a lower number of people counted in Angola, settlement patterns do not explain this difference (*see building analysis on page 10 below*). The driver of spatial variation in riparian population density may be attributed to a combination of cultural and social preferences, the occurrence of pests or diseases such as river blindness (onchocerciasis), resource-use patterns, or survey timing, however further investigation is needed.

Resource use also varied between the two regions. Fishing was common in Angola, while livestock rearing was more prominent in Zambia. This is expected, given that the river in Zambia is still very small and unlikely to support high-volume fisheries. Additionally, survey timing likely exacerbated this pattern: Angola was surveyed in July, the peak fishing season, when receding floodwaters concentrate fish in the main channel.

Observations	Zambia	Angola	Zambezi Basin Average
People/10 km	83	24	46
Fishers/10 km	<1	5	4
Vessels/10 km	1	14	23
Livestock/10 km	3	<1	35

Distribution of people along the transect (left). The summary of observations (right) shows several indicators of human activity, averaged per 10 km along the transect. Note the high density of people in the Zambian stretch.

BUILDING ANALYSIS

Google's Open Buildings dataset is a global mapping resource that uses high-resolution satellite imagery to identify and outline individual building footprints[4]. By mapping the location and density of buildings, the data provides a landscape-wide view of human activity. This perspective allows for consistent, basin-scale analyses that help to identify areas of potential environmental impact. To estimate human use and influence around rivers, we create a 4 km buffer along the main channel—reflecting a pragmatic distance within which people are likely to travel to access surface water.

The building density along the river was lower in Zambia than Angola (*figure below*). This contrasts with the observational survey data above, which found a higher density of people in Zambia, suggesting that riparian human density is not the best indicator of settlement patterns and resource-use in Angola. A holistic approach, including community surveys, will improve understanding of the various economic, cultural and traditional drivers that influence settlement and resource-use along rivers in the two countries.

Building density within 4 km of Zambezi

Zambia	Angola
4 buildings/km^2	9 buildings/km^2

The distribution of buildings within the Upper Zambezi Basin.

WETLAND 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, 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.

A combined total of 1,207 wetland-associated birds and raptors, representing 41 species, were recorded along both transects. Bird density was markedly higher in Angola, with 29 birds/10 km compared to just 2 birds/10 km in Zambia, reflecting the greater extent and continuity of wetland habitat along the Angolan stretch. The avifauna was dominated by fish-eating species such as cormorants and kingfishers, indicating productive aquatic habitats and healthy fish stocks. The frequent occurrence of storks, herons, and egrets further highlights the availability of shallow foraging grounds and intact floodplains.

When compared with the Lungwebungu River, the Upper Zambezi supports lower diversity but a similar abundance of wetland birds. This suggests that habitat heterogeneity is higher along the Angolan Zambezi, however further research is needed.

The 10 most common bird species:

Bird Species	Count
reed cormorant	263
malachite kingfisher	252
pied kingfisher	180
woolly necked stork	84
yellow billed kite	83
striated heron	73
white fronted bee-eater	44
black crowned night	40
western cattle egret	26
great egret	22

WILDLIFE

A combined total of 97 animals were counted along both transects, including only three hippos. This amounts to a density of 13 animals/10 km — far lower than the average of 36 animals/10 km recorded by TWP along the rest of the Zambezi. This scarcity is likely linked to naturally lower densities of large wildlife in the upper reaches of river basins, alongside the legacy of war and intensive poaching in Angola, which substantially reduced existing populations of large mammals such as hippos[5].

Zambia	Angola
<1 animal /10 km	2 animals / 10 km

Wildlife distribution along the Zambezi River.

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, both of which reduce native biodiversity[6]. In addition, AIPs can degrade water quality by increasing evaporation rates and reducing stream flow and dilution capacity[7]. The continuous monitoring of AIPs allows for early detection of threats to riverine ecosystems.

During the Angolan expedition, one alien species was documented: *Mimosa pigra* (giant sensitive plant). Although it was present only at low levels in two localized hotspots (*see map below*), its detection is noteworthy as it represents the most upstream record of the species along the Zambezi River to date. *Mimosa pigra* is considered one of the most aggressive invaders of African rivers, and its spread has severe ecological and social consequences. It forms dense, impenetrable thickets that displace native grasses and forbs, degrade habitat quality for birds and mammals, and obstruct access to water for both people and wildlife. The species can spread rapidly if uncontrolled, making early intervention and regular surveillance essential to prevent large-scale invasion along the upper Zambezi.

The distribution of alien invasive plants along the transect, note invasive alien plants were only present 268 km downstream from the Zambian source.

WATER QUALITY

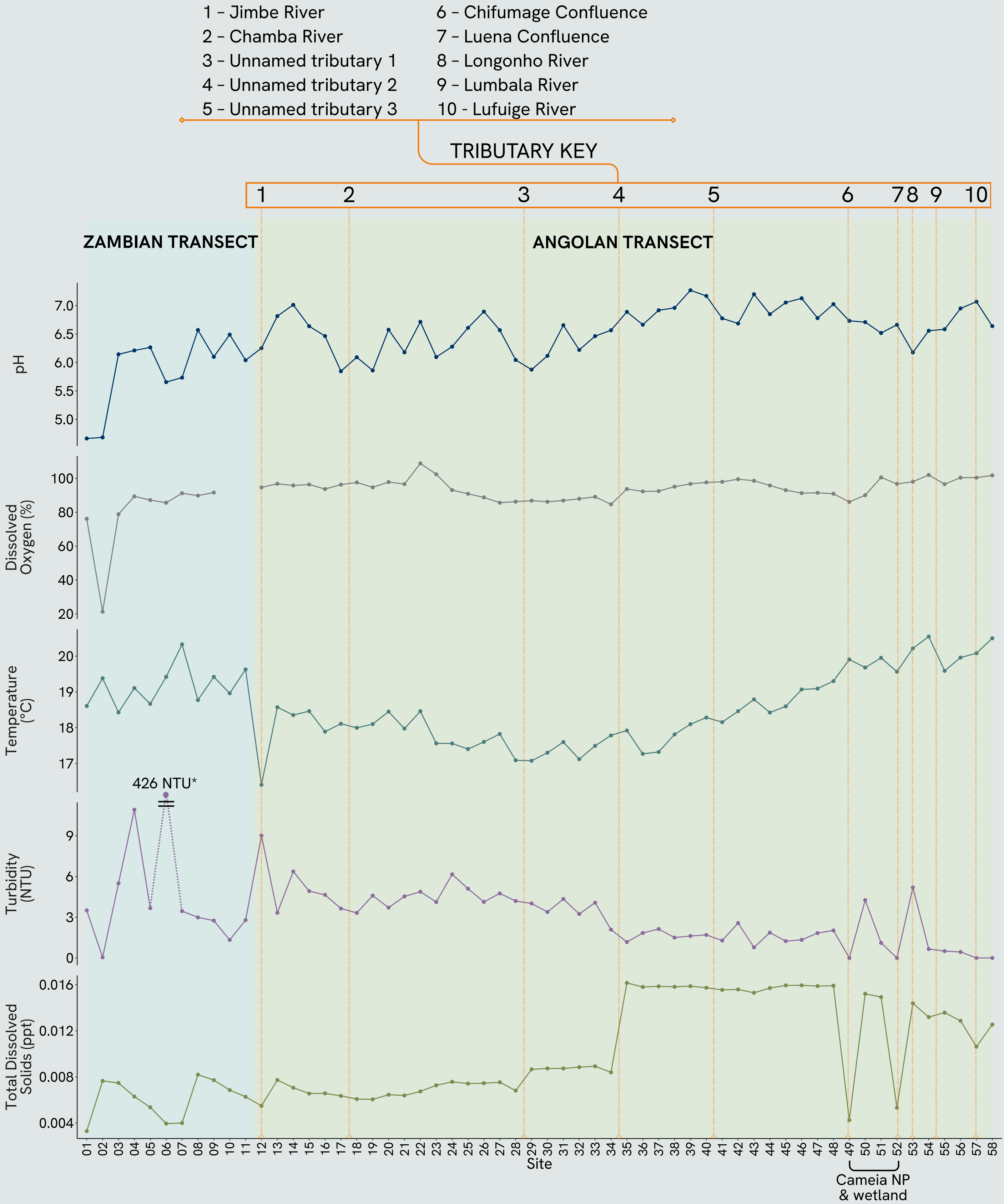
Temperature, pH, dissolved oxygen, conductivity, and turbidity are measurable physical and chemical characteristics that reflect the water's suitability for uses such as drinking, recreation, or sustaining aquatic life. Monitoring standard water chemistry along the Zambezi River supports the assessment of ecosystem health, helps detect potential pollution sources, and reveals temporal or spatial shifts in water quality.

Water quality along the Upper Zambezi was generally good, though slight differences emerged between the two transects. The Zambian headwaters, sampled in May, were relatively acidic, a condition typical of source streams (pH at the source measured 4.5). By contrast, in the downstream Angolan section surveyed in July, pH fluctuated only slightly and remained closer to neutral.

Dissolved oxygen levels remained consistently high, and conductivity stayed low, both characteristic of clean, well-oxygenated aquatic systems. However, a marked rise in total dissolved solids (TDS) occurred at site 35, coinciding with the inflow from an unnamed tributary (tributary 4). This tributary connects to the Luisabo/Mudileje River, which forms part of the Angola–Zambia border. Further investigation into this river's influence could help inform future water management across the Upper Zambezi and its tributaries.

These results should be interpreted with caution, as they reflect different times of year and varying water levels, but overall they suggest stable, high-quality river conditions capable of supporting diverse aquatic life.

WATER QUALITY



Note: These findings reflect water quality at the time of sampling and may vary seasonally or with changes in land use, rainfall, or other factors. Field parameters provide useful insights but do not capture all contaminants, such as heavy metals or some organic pollutants.

**site 6 displayed an outlier turbidity value of 426 NTU, indicating unusually high amounts of suspended material at the time of sampling*

RIVER FLOW

The Upper Zambezi, together with the Angolan Highlands Water Tower[3], forms the heart of the basin's hydrological system. These headwaters collect and release rainfall into the river network; regulating seasonal flows, supporting extensive wetlands and floodplains, and providing water security for communities and economies across southern Africa.

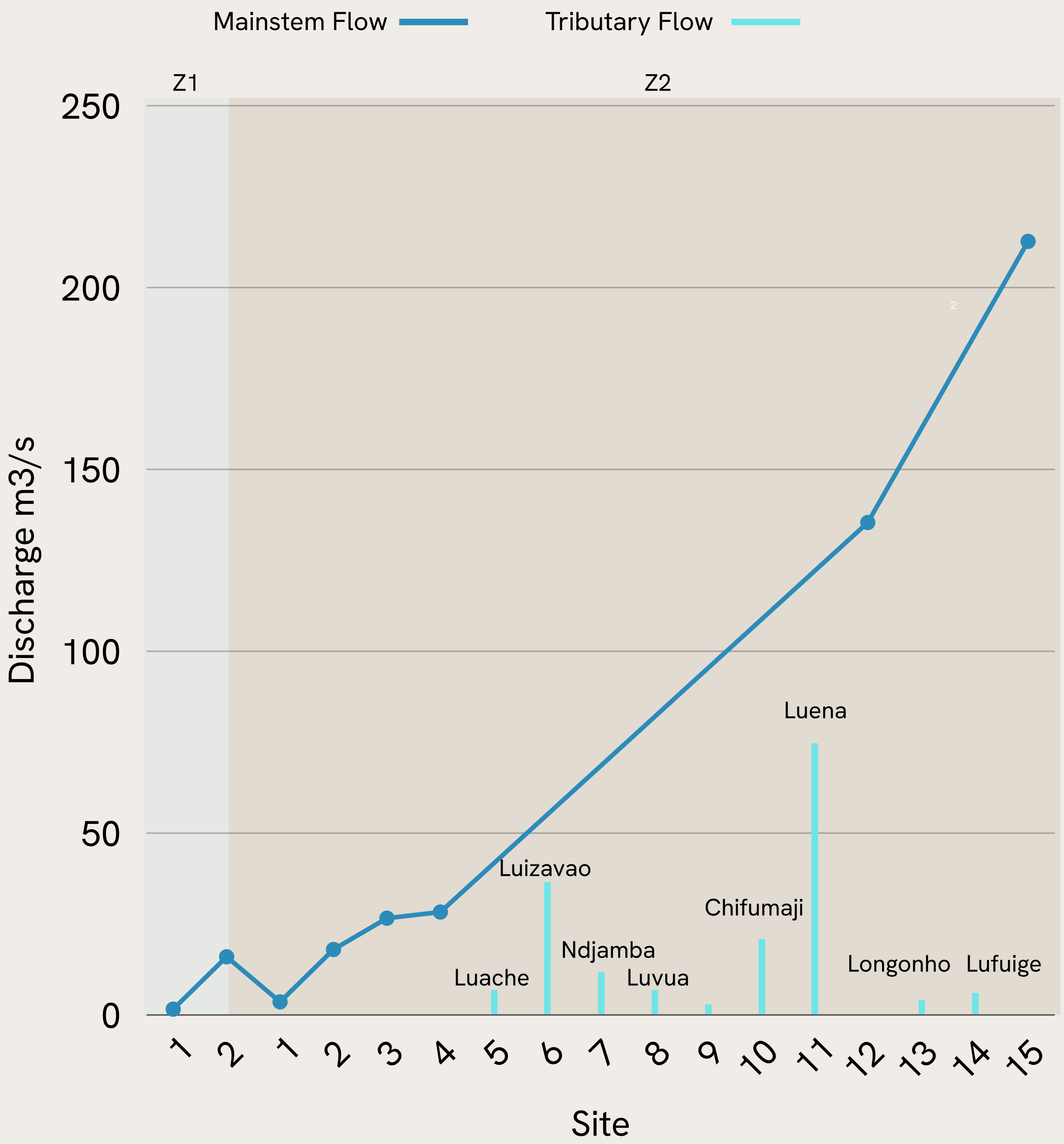
Precipitation is strongly seasonal and generally decreases with elevation. In the northern highlands, annual totals can reach 2,000 mm, with roughly half of this contributing to base flow. With a steep terrain and limited storage capacity, runoff responds quickly to rainfall, producing sharp rises in discharge during the wet season (December–January). Flows usually peak between February and April before gradually receding to their lowest levels in November. This rhythm of rising and falling water underpins the ecological cycles of the floodplains as well as agricultural and fishing practices along the river.

To capture these dynamics, hydrological measurements were taken with an Acoustic Doppler Current Profiler (ADCP) at seventeen sites across two transects: two in Zambia (at the river's source and near the Angolan border), six along the Zambezi mainstem in Angola, and nine on its tributaries. At the Zambian source, discharge was only 1.6 m^3/s, rising to 18 m^3/s at Jimbe on entry into Angola. Within Angola, flows increased more than tenfold, reaching 212 m^3/s near Chavuma at the Angolan–Zambian border. Much of this increase came from major tributaries: the Luizavao River added approximately 38–45 m^3/s, while the Luena River contributed a further 73 m^3/s during the wet season, together providing a significant share of the Zambezi's downstream flow.

Discharges from the Angolan stretch of the Zambezi were similar to those recorded along the Lungwebungu River, with flows reaching 335 m^3/s in the wet season. This underscores the importance of the Angolan portion of the Upper Zambezi and Lungwebungu sub-basins, which together contribute ~73% of the Zambezi's flow upstream of the Barotse Floodplain[3].

Because the Zambian transect was surveyed during the wet season and the Angolan transect during the dry season, these measurements are not directly comparable. Even so, they illustrate how crucial the Angolan tributaries are for maintaining flow in the upper Zambezi. They also point to the value of establishing a permanent monitoring network in this region, to provide consistent data for managing water use and anticipating the impacts of floods and droughts in this transboundary river system.

RIVER FLOW



Graph showing the discharge of the Zambezi River and it's tributaries along the Zambian (Z1) and Angolan (Z2) transects. Site one is the Zambian source of the Zambezi River and site 15 is near the Angolan - Zambian border.

RECOMMENDATIONS

Protection of Zambezi source region

The Upper Zambezi headwaters and the Angolan Highlands Water Tower form the hydrological foundation of the entire basin, regulating seasonal flows, sustaining downstream wetlands, and underpinning water security across southern Africa. With a substantial proportion of discharge upstream of the Barotse Floodplain originating from this region, its ecological integrity is inseparable from the health of the wider Zambezi system.

In light of the recent designation of Lisima Lya Mwono as a Ramsar Wetland of International Importance, we recommend formal recognition of the broader Zambezi source region as a strategic water security landscape. Protection efforts should prioritise maintaining intact wetlands, peat systems, and natural flow regimes, while guiding development in ways that safeguard hydrological function.

Developing a robust baseline

The 2023 transects along the Upper Zambezi represent one of the first integrated, multi-disciplinary assessments of the river's headwaters across Zambia and Angola. By combining hydrological measurements, water quality analysis, biodiversity surveys, invasive species mapping, and spatial data, this work establishes a critical baseline for understanding the condition and functioning of the Zambezi source region at a time of growing climatic and developmental pressure. However, this survey offers only a single temporal assessment and cannot distinguish seasonal variation from longer-term ecological or hydrological change.

It is therefore recommended that the Upper Zambezi headwaters be re-surveyed at regular intervals (ideally every 5–7 years). Periodic assessments would strengthen the baseline established here, enabling detection of shifts in flow regimes, water quality, biodiversity, and invasive species distribution. Repeated surveys would also improve understanding of how the Angolan Highlands Water Tower responds to extreme flood and drought cycles, and how these changes propagate downstream. In a basin where a substantial proportion of discharge originates from this source region, sustained monitoring is essential to maintain the ecological character and hydrological integrity of the Upper Zambezi and to support informed, transboundary basin management.

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