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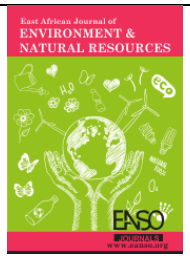

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Original Article

Rubondo Island National Park: Overlooked World's Largest Tropical Lake Island Protected Area in Tanzania

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Rubondo Island, Lake Victoria, Biodiversity Hotspot, Introduced Species, Chimpanzee, Elephants, World's Largest Protected Tropical Lake Island.

ABSTRACT

Rubondo Island National Park in Tanzania is a biodiverse conservation area situated within the complex Lake Victoria Regional Mosaic. While other islands have been modified by human activities, Rubondo Island remains a unique model for island conservation, characterized by diverse ecosystems and endangered species like chimpanzees. This makes it an ideal location for research on wildlife behaviour, species conservation, and human-wildlife coexistence. However, little effort has been made to explore the research potential of this island, and it is underrepresented in conservation literature. Existing studies are limited in scope, often focusing on specific species or isolated ecological features, without providing a comprehensive understanding of the island's biodiversity, ecosystem dynamics, and broader conservation value on regional and global scales. This review addresses this gap by undertaking a comparison analysis of lake island sizes and synthesizing available research. Literature on Rubondo Island was searched in academic databases such as Google Scholar, Web of Science, and Scopus using relevant and specific keywords related to Rubondo Island and its biodiversity. Among the world's lake islands, Rubondo is distinguished as the largest fully protected tropical lake island, free from human habitation or consumptive activities. The island hosts key native species such as sitatunga antelopes (*Tragelaphus spekii*), bushbuck (*Tragelaphus scriptus*), vervet (*Cercopithecus aethiops*), hippopotamus (*Hippopotamus amphibious*), spotted-necked otter (*Hydrictis maculicollis*), African clawless otter (*Aonyx capensis*), and marsh mongoose (*Atilax paludinosus*), avian, amphibians and reptiles such as crocodile (*Crocodylus niloticus*). Some of the introduced species, including elephant (*Loxodonta africana*), giraffe (*Giraffa camelopardalis*), chimpanzee (*Pan troglodytes*), colobus monkey (*Colobus guereza*), suni antelope (*Neotragus moschatus*), have been successfully integrated into the ecosystem. The island is an Important Bird Area (IBA), hosting over 194 bird species, and is home to 19 reptiles and 11 amphibian species, contributing to ecosystem balance. Its primary lowland Congolese forest is the only intact remnant of this forest type in the Lake Victoria and western Tanzania region. Rubondo also protects vital fish breeding grounds critical for sustaining native and endangered fish populations. Historically

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inhabited by the Banyarubondo subgroup of the Zinza people, the island retains cultural and spiritual landmarks that warrant preservation. Future research should focus on chimpanzee behaviour, elephant ecosystem roles, avian and fish species updates, vegetation surveys, herpetofauna diversity, and crocodile adaptations to environmental changes.

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INTRODUCTION

Islands are geographically defined as land masses that are completely surrounded by water and remain above water at all times (Itescu, 2019). Whittaker *et al.* (2023) categorized types of islands based on their geographical characteristics into lake islands and ocean islands. Ocean islands are typically formed in saltwater environments through volcanic activity or the growth of coral reefs. On the other hand, lake islands refer to land masses surrounded by freshwater bodies such as lakes (Matthews and Triantis, 2021). Islands are home to more than 550 million people and encompass the entire population of 43 independent states, displaying immense diversity in size, climate, resources, and political power (Royle, 1989; Matthews and Triantis, 2021; National Geographic, 2023). According to Sayre *et al*., (2022), the World harbours more than 340,000 marine islands and hundreds of thousands of lacustrine islands. The majority of these islands are recognized by Conservation International as biodiversity hotspots due to their unique ecosystems (Gibson *et al.*, 2017).

Despite representing only about 6.7% of the Earth's land area, they are home to approximately 20% of global biodiversity (Fernández-Palacios *et al.*, 2021), including a significant proportion of endangered and endemic plants and animals (Gibson *et al.*, 2017; Llorente-Culebras *et al.*, 2024). However, islands are among the most fragile ecosystems, particularly vulnerable to external pressures such as disease outbreaks, the introduction of invasive species, and habitat loss or degradation. These threats are increasingly exacerbated across island systems due to urban development, infrastructure projects, and the impacts of climate change (Llorente-Culebras *et al.*, 2024). According to Gibson *et al.* (2017), islands are home to 61% of all species that have gone extinct and 37% of all critically endangered species, highlighting their vulnerability. Therefore, effective conservation efforts, including the development of resource management plans that address both ecological and socio-economic factors, are highly relevant interventions (Depraetere and Dahl, 2007; Gillespie and Clague, 2009). Rubondo Island

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National Park, located within Lake Victoria in Tanzania, is among the largest lake islands globally and serves as a critical example of the importance of island conservation efforts.

Lake Victoria, the largest lake in Africa, the world's largest tropical lake, and the world's second-largest freshwater lake by surface area after Lake Superior in North America which spans approximately 68,800 square kilometres (Odada *et al.,* 2003). Its vast surface area is divided among three countries: Tanzania, Uganda, and Kenya. Tanzania hosts the largest portion of the lake amounting to 51% of the total lake surface area, followed by Uganda and Kenya with 43% and 6% of the lake's total surface area respectively (Nyamweya *et al.,* 2023). Lake Victoria's inland fishery is critical for Africa, providing sustenance and economic stability for millions (Balirwa *et al*., 2003; Outa *et al.,* 2020). According to Nyamweya *et al*. (2023), over 42 million people rely on Lake Victoria for food, employment, and clean water. The lake is relatively young in age, its basin was formed only 400,000 years ago when water filled a shallow depression not more than 82 m in depth in the heart of a plateau that stretches between the Western and Eastern Rift Valleys (Johnson *et al*., 2000). Within the lake, there are generally more than 3,000 islands and islets, including the Rubondo island (Kiwango, 2007).

Rubondo Island is located in the southwestern corner of Lake Victoria, Tanzania. The conservation of Rubondo Island began in 1928 when it was declared a Forest Reserve (Petrášová *et al.* 2010). In 1965, the government declared Rubondo Island as a Game Reserve with the key goal of creating a game sanctuary for the introduction of threatened wildlife species (Akiko, 2000; Msindai, 2018). The island was later upgraded to national park status on the 18th day of February 1977 by Government Notice No. 7, Vol. LVIII, and Supplement No. 4 starting on the 18th of January 1977 (TANAPA, 2015). According to this GN, the size of Rubondo Island is 457 km^2 comprising both terrestrial and water ecosystems (Figure 1). The terrestrial part of the Rubondo Island National Park covers 237 km^2 with a length of about 28 km long along a north-south axis and a width varying from 3 to 10 km. Apart from that, the main island is surrounded by 11 small islets of varying sizes (less than 2 km^2) that are highly used by wildlife in particular birds and crocodiles. It consists of a partially submerged rift of four volcanically formed hills, connected by three flatter lower elevation isthmuses. In terms of altitude, the lowest point is the normal Lake Victoria altitude of 1,134 m.a.s.l., and the highest point is the Masa Hills in the southern part of the island, with an elevation of 1,486 m (350 m above the level of the lake). The freshwater ecosystem of the park is made up of 220 km^2 surrounding the island. Rubondo Island is relevant for research related to species adaptation, ecosystem resilience, and long-term conservation strategies.

Rubondo Island is surrounded by a densely populated area that relies heavily on the lake for various aspects of life, including fisheries, agriculture, water supply and transport (Johnson *et al.,* 2000; Odada *et al.,* 2003). Therefore, the conservation of Rubondo Island and its adjacent freshwater ecosystem is vital for the ecological balance of the region and plays a crucial role in the socio-economic development of the surrounding communities. However, Rubondo Island National Park faces significant environmental challenges, such as poaching for fish, invasive species (water hyacinth and *Senna spectabilis*), pollution (from solid wastes and toxic chemicals) and climate change (TANAPA, 2015). Unsustainable fishing practices in unprotected areas have led to the depletion of fish stocks, impacting food security and livelihoods (Nyamweya *et al*., 2023). The introduction of non-native species, such as the Nile perch, has disrupted the lake's ecosystem, leading to the decline of native fish species (Johnson *et al.,* 2000; Odada *et al.,* 2003). Changes in climate patterns affect water levels, temperatures, and the overall health of the lake ecosystem (Nyamweya *et al.,* 2023).

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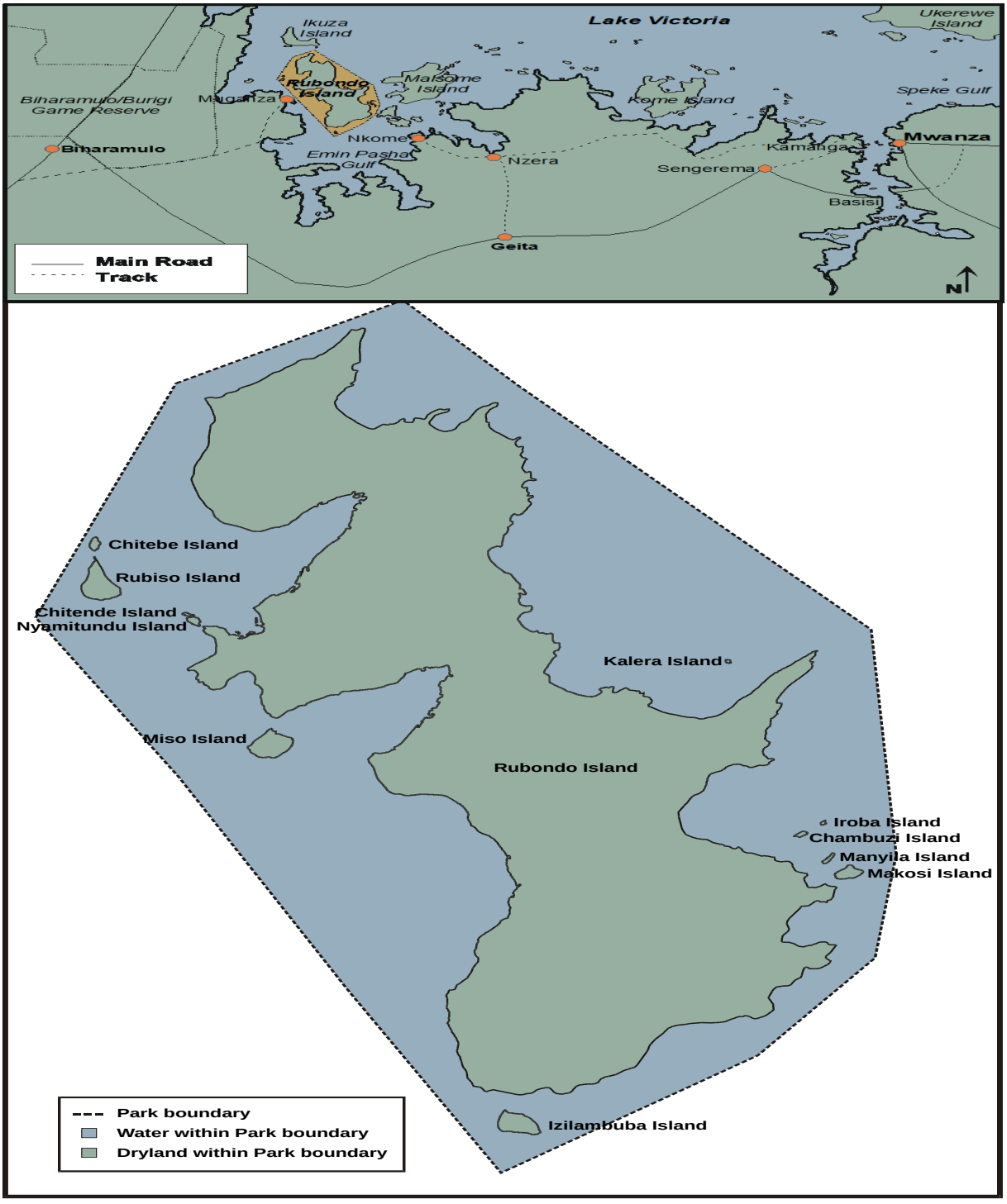
Figure 1: Map of Rubondo Island National Park, Tanzania



Rubondo Island represents a unique and critical ecological zone due to its distinctive size, isolation, and conservation status. While other islands have been modified by human activities, Rubondo Island remains a unique model for island conservation, characterized by diverse ecosystems and endangered species like chimpanzees. This makes it an ideal location for research on wildlife behaviour, species conservation, and human-wildlife coexistence. However, little effort has been made to

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explore the research potential of this island, and it is underrepresented in conservation literature. Existing studies are limited in scope, often focusing on specific species or isolated ecological features, without providing a comprehensive understanding of the island's biodiversity, ecosystem dynamics, and broader conservation value on regional and global scales. The objective of this review paper was to evaluate Rubondo Island's ecological and conservation significance, aiming to enhance its visibility, promote sustainable practices, and identify research gaps for future studies and advocacy. We searched the literature in academic databases such as Google Scholar, Web of Science, and Scopus using relevant keywords related to the island's biodiversity, compiling literature on the island's heritage resources, summarizing key findings, and identifying research gaps. The review aims to increase Rubondo Island's visibility among the scientific community, policymakers, and conservation stakeholders, with the goal of advocating for conservation funding, promoting advanced research, and supporting initiatives to preserve its unique natural heritage.

ISLANDS AREA COMPARISON ANALYSIS

There have been several efforts geared towards mapping and documenting the world islands on the basis of the geographic, ecological, and human dimensions (Dahl, 1991; Sayre *et al.*, 2019; Sayre *et al.*, 2022). However, the authors primarily focused on oceanic islands, excluding freshwater islands. By gathering data on freshwater islands from various websites, we analyzed these islands based on their area, associated countries, lakes, and human dimensions of the 15 largest lake islands in the world (Calder, 2006; Ghosh, 2021). It was revealed that Rubondo Island ranks as the 15th largest island globally within a lake (Table 1). The world's largest lake island is Manitoulin Island in Lake Huron (Canada), with an area of 2,766 square kilometres (Table 1). The distribution of the largest lake islands by region is as follows: Canada: (6 islands), United States (2), Tanzania (2), Russia (1), Indonesia (1), Democratic Republic of Congo (1), island (1), and Uganda (1).

Most of these large islands are inhabited, featuring large cities, high population densities, and significant human activities (Table 1). However, there are two notable exceptions for Isle Royale (Lake Superior, United States) and Rubondo Island (Lake Victoria, Tanzania) which are legally protected for nature conservation. Isle Royale, located in Lake Superior, United States, is the largest lake island in the world that is legally protected and recognized by the International Union for Nature Conservation (IUCN) Category Ib (Wilderness Areas) (UNEP-WCMC, 2024a). Rubondo Island National Park is the second-largest legally protected lake island globally. It falls under IUCN Category II (National Parks) (UNEP-WCMC, 2024b), dictating its significance as a conserved natural area.

Among the ranked 15 largest lake islands, six are tropical islands (Table 1). Rubondo Island ranks as the 6th largest tropical lake island (Table 1). However, the five tropical islands larger than Rubondo are all inhabited and characterized by high populations, large cities, and significant human activities. Thus, Rubondo Island National Park remains the only fully protected tropical lake island with no consumptive utilization or human activities, making it the world's largest protected tropical lake island. Rubondo Island stands out as the world's largest tropical lake island for its legal protection and conservation significance. As the largest tropical protected lake island globally, Rubondo Island is vital for preserving natural biodiversity and supporting global conservation efforts. The IUCN categorizations reflect their importance in maintaining pristine natural environments, free from significant human interference.

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Table 1: List of the 15 Largest Lake Islands Categorized by Size

Rank	Island	Lake	Country	Area (Km^2)	Climate Zone	Human dimensions	Protected Area?
1	Manitoulin	Lake Huron	Canada	2,766	Temperate	inhabited	N/A
2	Rene-Lavasseur	Manicouagan Reservoir	Canada	2,020	Subarctic	inhabited	N/A
3	Olkhon	Lake Baikal	Russia	730	Continental	inhabited	N/A
4	Samosir	Lake Toba	Indonesia	630	Tropical	inhabited	N/A
5	Isle Royale	Lake Superior	United States	535	Humid Continental	uninhabited	IUCN Ib
6	Ukerewe	Lake Victoria	Tanzania	530	Tropical	inhabited	N/A
7	St. Joseph	Lake Huron	Canada	365	Temperate	inhabited	N/A
8	Drummond	Lake Huron	United States	347	Temperate	inhabited	N/A
9	Idjwi	Lake Kivu	DR Congo	340	Tropical	inhabited	N/A
10	Ometepe Island	Lake Nicaragua	Nicaragua	276	Tropical	inhabited	N/A
11	Bugala Island	Lake Victoria	Uganda	275	Tropical	inhabited	N/A
12	St. Ignace Island	Lake Superior	Canada	274	Humid Continental	inhabited	N/A
13	Big Simpson Island	Great Slave Lake	Canada	251	Subarctic	inhabited	N/A
14	Blanchet Island	Great Slave Lake	Canada	240	Subarctic	inhabited	N/A
15	Rubondo Island	Lake Victoria	Tanzania	237	Tropical	uninhabited	IUCN II

Modified from: Ghosh, (2021); Calder, (2006). Note: NA = Not applicable

WHAT ARE THE HERITAGE RESOURCES OF THE RUBONDO ISLAND?

Rubondo Island National Park is a vital component of the Lake Victoria Regional Mosaic within the Afrotropical Biogeographical Realm (IUCN and UNEP, 1986). This region is characterized by a mix of Guineo-Congolian, Sudanian, Zambezian, Somalia-Masai, and Afromontane flora, forming a complex mosaic of vegetation types, including rainforests, grasslands, woodlands, and swamp forests, enriched by both lowland and highland species (IUCN and UNEP, 1986). These are major reasons underlying the reported higher vegetation community within the Rubondo Island.

RESEARCH AREAS COVERING HERITAGE RESOURCES IN RUBONDO ISLAND NATIONAL PARK

This review analyzed research conducted on Rubondo Island, identifying 33 publications, including peer-reviewed articles, theses, and conference proceedings (Appendix 1; Figure 2). The studies primarily focused on key mammalian species, with chimpanzees representing 46% of the research, followed by otters (21%) and elephants

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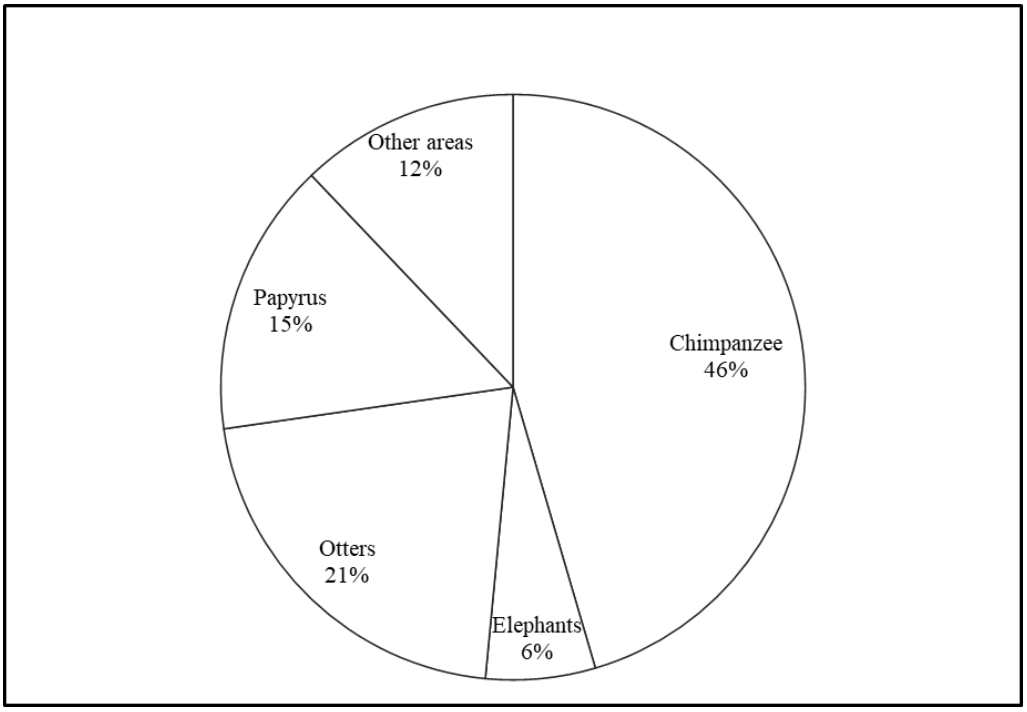
(6%). Vegetation studies were notably limited, with papyrus vegetation receiving the most attention, accounting for 15% of the research topics. Other areas of research (12%) addressed community conservation initiatives, waste management along the lake shores, and issues related to the vernacular naming of wildlife species.

Figure 2: Percentage Distribution of Research Coverage in Rubondo Island National Park



Mammalian Diversity

Rubondo Island National Park is rich in wildlife species, particularly the mammalians. The park has a total of 15 mammalian species with a combination of native species and those introduced (TANAPA, 2015). Some examples of the native species include the Sitatunga antelope (*Tragelaphus spekii*) which is a swampy dweller, mostly adapted to the wetland areas preferably occupied by the papyrus. Other semi-aquatic native mammalian species that can be frequently sighted along the shorelines are otters particularly the spotted-necked otter (*Hydrictis maculicollis*) and African clawless otter (*Aonyx capensis*) (Reed-Smith *et al*., 2021). The other large native mammalian species on the island include bushbuck (*Tragelaphus scriptus*) hippopotamuses (*Hippopotamus amphibious*), vervet monkeys (*Cercopithecus aethiops*), genets, and mongooses (*Atilax paludinosus*). There is also a significant population of bushpigs, presumably brought by floating vegetation, as there is no record of their introduction.

Rubondo Island is a unique example of a successful model for breeding endangered species in captivity (ex-situ) and subsequently releasing them into the wild (in situ) (Borner, 1988; Msindai *et al.*, 2021). The history of this initiative shows that plans for designating Rubondo Island as a game sanctuary began in the 1960s under the Game Division, led by early conservationist Peter Achard, a game warden based in Mwanza, Tanzania (McCulloch and Achard, 1968). Achard later introduced the president of the Frankfurt Zoological Society (FZS) Professor Bernhard Grzimek to the potential of Rubondo Island (Msindai, 2018). Prof. Grzimek, a renowned German zoologist and conservationist, is

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best known for his pioneering work in wildlife conservation across Africa, particularly in Tanzania (FZS, 2024). He committed to collaborating with the government to establish Rubondo Island as a sanctuary for endangered species and to restore ecological balance by introducing both native and exotic animals to this isolated environment (Msindai, 2018; FZS, 2024).

The history shows that a total of 92 mammals from seven species were introduced to Rubondo Island National Park during the 1960s and 1970s (Borner, 1988). These included 16 black rhinoceroses (*Diceros bicornis*), 12 giraffes (*Giraffa camelopardalis*), 5 roan antelopes (*Hippotragus equinus*), 14 suni antelopes (*Neotragus moschatus*), 17 chimpanzees (*Pan troglodytes*), 25 colobus monkeys (*Colobus guereza*), and 6 African elephants (*Loxodonta africana*) (TANAPA, 2015, Msindai, 2018). While some species like chimpanzees, giraffes, suni, elephants, and black-and-white colobus monkeys have successfully adapted to Rubondo Island, others, such as the roan antelope and black rhinoceros, faced challenges that led to their extinction (Msindai 2018). The *Rubondo Island National Park General Management Plan (2015–2025)* acknowledges the significant efforts in wildlife introduction on Rubondo Island. It commits to regular monitoring, maintaining and improving animal welfare, and exploring the introduction of other species based on detailed habitat suitability analyses (TANAPA, 2015).

Introduction of Chimpanzee

The chimpanzee is one of the great ape species listed as endangered by the IUCN Red List (Msindai, 2018). This status is attributed to several significant threats, including habitat loss caused by settlement, logging, and agriculture; illegal hunting for bushmeat and traditional medicine; the live ape trade; and the spread of infectious diseases (Woodford *et al.,* 2002). The release of chimpanzees on Rubondo Island, initiated by Professor Bernhard Grzimek of the Frankfurt Zoological Society (FZS) between 1966 and 1969, represents one of the earliest experiments in rewilding captive primates (Grzimek, 1970; Msindai, 2018). Seventeen wild-born chimpanzees, previously held in zoos and circuses for periods ranging from a few months to nearly a decade, were transported from Europe to Tanzania (Hannah and McGrew, 1991; Msindai *et al.,* 2021). Unlike other wildlife introduction efforts, there was no formal rehabilitation or pre-release training for the Rubondo chimpanzees (Borner, 1988; Grzimek, 1970; Akiko, 2000; Msindai and Sommer, 2022). The founder individuals were reportedly of West African descent, though specific country origins remain largely undocumented (Grzimek, 1970). However, further research by Msindai *et al.* (2021), based on archival records and genetic analyses, revealed that only 19% of the founding chimpanzees had confirmed West African origins, while the majority (56%) were given a more general "Africa" designation, suggesting diverse origins. Genetic testing on descendants supports this, tracing lineages to both *Pan troglodytes verus* (West Africa) and *Pan troglodytes troglodytes* (Central Africa), reflecting the complex captive histories of the founders (Msindai *et al.,* 2021).

Upon their arrival on Rubondo Island, the chimpanzees encountered an entirely new environment without prior exposure to essential survival skills (Borner, 1988). Remarkably, however, within a year, they adapted to the island, learning to forage for native foods and construct nests; behaviours essential to wild chimpanzees (Msindai and Sommer, 2022). Moscovice *et al.* (2007) studied the seasonal patterns in fruit availability, dietary quality, and social grouping among the introduced chimpanzee population on Rubondo Island. The findings indicated that the tree fruit availability had a positive correlation with rainfall, leading to a period of scarcity during the long dry season that was supplemented by liana fruits that were less affected by rainfall season (Moscovice *et al.,* 2007). The author further reported the lack of seasonal change in the group

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size of chimpanzees suggesting the dietary stability, as there is less pressure for chimpanzees to form smaller groups to cope with food scarcity. This stands in contrast to other regions, where larger groups tend to break into smaller units during times of food shortage (Furuichi *et al.* 2001). The Rubondo chimpanzees' grouping behaviour may therefore reflect the lack of competition for limited resources, as food availability appears consistent enough to sustain larger groupings (Moscovice *et al.*, 2007). Today, the population has grown to an estimated 60 individuals, reflecting successful adaptation and reproduction over the decades since their release (Nahonyo *et al.*, 2021). Over time, the chimpanzees reverted to a natural, unhabituated state, exhibiting behaviours and characteristics typical of wild populations (Borner, 1988). This wild state made it challenging for tourists and visitors to observe them, as the chimpanzees could quickly recognize human presence and escape into the forest.

Rubondo Chimpanzee Habituation

The chimpanzee habituation programme in Rubondo National Park represents a long-term initiative to leverage wildlife conservation for sustainable tourism development, particularly photographic tourism (Nahonyo *et al.* 2021). The programme, initiated in 1996, was a collaboration between Tanzania National Parks (TANAPA) and the Frankfurt Zoological Society (FZS), continuing until 2014 (Akiko, 2000). Since then, the project has been jointly operated by TANAPA and the Honeyguide Foundation (HGF), a Tanzanian Non-Governmental Organization (Nahonyo *et al.* 2021). The primary goal of this partnership has been to gradually accustom the island's chimpanzee population to human presence, thus facilitating eco-tourism, conservation research, and public awareness. The habituation process employed the neutral visit approach, a method distinct from food provisioning, fostering natural adaptation by minimizing human intervention. This method involves an extended process in which wild animals, in this case, chimpanzees, slowly decrease or entirely cease their initial responses to humans after repeated, non-threatening exposure, the process driven by neural and behavioural adaptations (Blumstein, 2016). Unlike feeding habituation, where food is used to lure animals closer to humans, natural habituation relies solely on respectful, repeated exposure from a safe distance. This approach respects the chimpanzees' autonomy and minimizes interference with their natural behaviours, which is essential for ecological balance and long-term conservation.

The Rubondo habituation team has worked tirelessly to achieve this goal. Team members spend countless hours trekking into the dense forest, searching for signs of chimpanzee presence, such as vocalizations, broken vegetation, and nests. The team identified six (6) sites used for locating chimpanzees, namely Kasenye, Masekela, Michokoko, Kibandala, and Kamea in the northern part of the island, and Nyakutula in the southern part. Once the chimpanzees are located, the team remains with them, allowing the animals to gradually become accustomed to human presence in a non-invasive way. This calm, consistent exposure over the years has helped the chimpanzees build trust, as they come to recognize that these humans pose no threat. This approach preserves the chimpanzees' natural behaviours and reduces their fear response, making them more likely to remain in areas accessible to researchers and carefully guided eco-tourism groups.

The chimpanzee habituation process is a long-term endeavour that has been consistently yielding positive results over time. According to the Frankfurt Zoological Society (FZS), the monthly mean number of chimpanzees observed by trekkers between 1997 and 1999 ranged from 2.4 to 5.9 (Akiko, 2000). For instance, Prof. Akiko Matsumoto-Oda of the University of the Ryukyus, Japan, stayed in Rubondo with trekkers for two weeks. During this time, he had the opportunity to walk through all chimpanzee sites but managed only

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two indirect encounters with chimpanzees. The chimpanzees were extremely shy, and he could not get closer than 100 meters in either instance, as they consistently avoided meeting observers. Similarly, in 1998, Prof. Anne Pusey of Duke University stayed in Rubondo for eight days but failed to see any chimpanzees (Akiko, 2000). Today, the chimpanzee habituation project has been highly successful, with the likelihood of sightings reaching above 90%. For example, the success rate of the Chimpanzee Habituation Experience (CHEX) has improved from 88% in 2020/21 to 96% in 2023/24, reflecting better management and visitor satisfaction (Table 2). Visitors have witnessed chimpanzees in their natural environment displaying fascinating behaviours, such as hunting and honey-sucking, among others. Likewise, there has been a significant increase in CHEX visitors, from 28 in 2020/21 to 672 in 2023/24, due to positive feedback from CHEX visitors as well as intensified marketing and promotion of the product (Table 2).

Table 2: Statistics on Chimpanzee Habituation Experience Tourism from July 2020 - June 2024

Year	Number of tourists	CHEX Success Rate	% Increase in Tourists	Remarks
2020/2021	28	88%	-	COVID-19 significantly reduced tourist visitors.
2021/2022	342	89.29	1121.43%	Gradual recovery in tourism post-COVID-19.
2022/2023	360	92%	5.26%	Increase in visitors due to positive feedback from CHEX visitors
2023/2024	672	96%	86.67%	Increase in visitors due to positive feedback from CHEX visitors

(**Source:** Chimpanzee habituation unit)

Introduction of Elephants

Elephants (*Loxodonta africana*) were brought to the island from Serengeti as part of a conservation initiative between 1972 and 1973 (Borner, 1988; Msindai, 2018). These elephants comprised 4 sub-adult females and 2 sub-adult males, making a total of 6 elephants (Msindai and Sommer, 2022). According to Mwambola *et al.* (2016), there has been a significant growth of the elephant population from 6 to about 102. Elephants on Rubondo Island, and in ecosystems around the world, serve as umbrella species, keystone species, and ecosystem engineers, the terms that indicate their critical role in maintaining ecological balance within the ecosystem (Fritz, 2017). Within Rubondo island, elephants have been felling trees for both feeding on the leaves and opening paths. Mwambola *et al.* (2014) reported that elephants of Rubondo Island were consuming a total of 22 woody plant species in 13 families, with a notable preference for *Croton sylvaticus*, *Croton macrostachyus*, and other key species. This process has been creating suitable habitats for grazers and other small mammals. The paths of elephants within Rubondo island are highly used by other mammalian species such as hippos, chimpanzees, sitatunga and bushbucks. There is no wonder, that even chimpanzee trackers and researchers are always using the elephant's paths for following chimps (Msindai, 2018). Moreover, elephants consume fruits and then disperse the seeds through their dung, helping plants grow over vast areas (Fritz, 2017). This contributes to forest regeneration and supports biodiversity across the island. There is a limited understanding of the long-term effects of elephant activities on forest dynamics, plant succession, and species habitats on Rubondo Island. Additionally, the population increase from 6 to 102 raises concerns regarding the island's carrying capacity, genetic diversity, and potential inbreeding (Lacy, 1997).

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Avifauna

Rubondo Island is rich in bird species, particularly waterbirds and birds of prey. Globally, Rubondo Island is recognized by BirdLife International as an Important Bird Area (IBA). Over 200 bird species have been recorded on the island, including a notable abundance of herons, storks, ibises, egrets, cormorants, kingfishers, and birds of prey (Nkwabi *et al.,* 2019; Nahonyo *et al.,* 2021). These birds contribute to ecosystem services, specifically supporting services, provisioning and regulating services (Whelan *et al.,* 2008). The island's diverse habitats, ranging from wetlands to forests, provide unique and ideal environments for the survival of various bird species. The park comprises one major island and 11 smaller islets, which provide a conducive, safe, and reliable breeding site for bird species, with the water acting as a barrier to predators and natural threats. There is an undisturbed lake shore characterized by papyrus swamps, which have significant ecological, hydrological, and economic functions (Kiwango, 2007; TANAPA 2015). According to Wanyonyi (2015), some of the bird species that depend on papyrus for their survival include the Papyrus Yellow Warbler (*Chloropeta gracilirostris*), Papyrus Gonolek (*Laniarius mufumbiri*), White-winged Swamp Warbler (*Bradypterus carpalis*), Papyrus Canary (*Serinus koliensis*), and Carruthers's Cisticola (*Cisticola carruthersi*).

Long-legged waders such as Herons and Egrets are also frequently sighted on the Rubondo Island, enjoying the conducive island's wetlands that form their perfect breeding grounds. For example, in January 1995, a total of 107 Goliath herons (*Ardea goliath*) and 12 active nests were counted on the island (BirdLife International, 2024)). Other species such as African Fish Eagles (*Haliaeetus vocifer*) are easily spotted jumping down to catch fish from the lake (TANAPA 2015). Additionally, in January 1995, approximately 638 African fish eagles were counted within the park, with a single concentration of 166 birds, a density far higher than recorded elsewhere on Lake Victoria (IBA, 2024). Numbers of other waterbirds, such as the reed cormorant (*Phalacrocorax africanus*) and the sacred ibis (*Threskiornis aethiopicus*), may well exceed 1% thresholds seasonally, although no counts have been documented (BirdLife International, 2024).

Rubondo's main island hosts a wide variety of other species, including large breeding colonies of four species of Ploceus weavers and a relatively dense population of the brown snake eagle (*Circaetus cinerascens*), which is rare in East Africa (BirdLife International, 2024). There are several species of kingfishers in the Rubondo Island, including the common species such as the pied and malachite kingfishers (Nkwabi *et al*., 2019). Additionally, in January 1995, an unidentified Batis flycatcher was recorded in the forest on the main island (BirdLife International, 2024).

The evergreen dense primary lowland Congolese forest of the Rubondo Island harbours a high abundance of forest birds like the African grey parrot, turacos, and various types of hornbills, which are commonly seen or heard in the treetops (TANAPA, 2015). Moreover, Rubondo also serves as a stopover point for migratory birds, making it an important link in the East African migratory route (TANAPA 2015, BirdLife International, 2024). Apart from contributing to the island's biodiversity, bird species such as fish eagles play critical roles in maintaining the health of the ecosystem, which is crucial for the overall biodiversity of the region. The ecological roles such as control of prey populations, distributing nutrients, and shaping vegetation and water systems (Mariyappan *et al.*, 2023), ensure the balance and sustainability of the island's environment. Despite Rubondo Island's rich diversity of both resident and migratory bird species, the park lacks recent systematic avian surveys, which limits our understanding of bird population dynamics, seasonal fluctuations, and the full checklist of species present (BirdLife International, 2024). It remains unclear how various

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species interact with one another and respond to environmental changes over time.

Herpetofauna Diversity and Composition

The diverse habitats ranging from dense forests to wetlands and open grasslands of Rubondo Island form home for a high diversity of herpetofauna (reptiles and amphibians). There is a total of 19 species of reptiles and 11 species of amphibians identified within the Rubondo Island National Park. These organisms play an important role in the island's ecosystem, contributing to the balance of predator-prey relationships and supporting biodiversity.

Reptiles' Diversity and Composition

Reptiles are a vital component of Rubondo Island's ecosystem, occupying various niches and playing essential roles in maintaining ecological balance. The key reptiles of Rubondo Island include Nile crocodiles, monitor lizards, and a wide range of snakes. The Nile crocodile (*Crocodylus niloticus*) qualifies as an apex predator, dominating their ecosystems, particularly in aquatic environments (Utete, 2021). Within Rubondo Island, these giants are always sighted along the lake shores (TANAPA, 2015). In water, the Nile crocodile is an agile hunter, using pressure sensors along its jaw to detect prey movements, allowing for rapid and effective ambushes (Simon 2016). These reptiles display a well-adapted predatory strategy balanced by a low-energy lifestyle, which suits their role as apex predators in fluctuating environments (Lang *et al.*, 1987; Somaweera *et al.,* 2020). Therefore, *C. niloticus* serve as ecological health indicators, ecosystem engineers, apex predators and keystone species and contribute to nutrient cycling (Aust, 2009; Utete, 2021) in the aquatic ecosystem. However, their dependence on specific hunting grounds and prey availability remains among the potential vulnerabilities, especially as ecosystems face increasing environmental pressures.

The Nile monitor lizard (*Varanus niloticus*) is an important and highly abundant reptile species found throughout Rubondo Island. These reptiles are highly skilled hunters and opportunistic scavengers, targeting a range of prey from invertebrates and small vertebrates to carrion (Bennet, 2002). *V. niloticus* plays a unique role in regulating crocodile populations by preying on crocodile eggs (Somaweera *et al.,* 2013; Ejigu and Tassie, 2020). This complex ecological interaction contributes to the natural population control of crocodiles, helping to balance species dynamics within their shared ecosystems (Somaweera *et al.,* 2013). According to Sprawls *et al*. (2002), Nile monitor lizards also have a unique ecological relationship with termites, as female monitors use termite mounds as nesting sites. This provides natural protection against predators and extreme weather, creating a stable environment ideal for embryonic development (Sprawls *et al*., 2002). Additionally, V. *niloticus* serves as a valuable bioindicator of metallic pollution due to its sensitivity to environmental contaminants and high spatial resolution in relation to pollutant exposure (Ciliberti *et al.,* 2011). This makes it a sentinel species for environmental monitoring, particularly useful for detecting localized metallic pollutants in ecosystems a critical factor for pollution management strategies in wetlands and other key habitats where Nile monitors are prevalent (Ciliberti *et al.,* 2011).

Rubondo Island is home to a variety of snake species, ranging from harmless constrictors to venomous species (TANAPA 2015). Common snakes recorded during the park ecological monitoring include: the African rock python (*Python sebae*), Smyth's water snake (*Grayia smythii*), Emerald snake (*Hypsidophrys Smaragdina*), Large eyed snake (*Telescopus dhara*), Jackson's tree snake (*Thrasops jaksoni*), Lineolate blind snake (*Typhlops lineolatus*), Variable skink (*Trachylepis varia*), Speckled-lipped skink (*Trachylepis maculilabris*), Boomslang (*Dispholidus tpyus*), Stripped skink (*Trechylepis striata*), Spotted bush snake (*Philothamnus*

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semivariegatus) (Kibasa *et al.,* 2015), and recently Forest cobra (*Naja subfulva*), Olive grass snake (*Psammophis mossambicus)* and Eastern Blanding tree snake (*Toxicodryas blandingii*) (Mushi and Kikoti, 2024).

Snakes play a vital ecosystem role in the overall trophic interactions, habitat quality, and biodiversity conservation (Beaupre and Douglas, 2011). For example, snakes control the populations of rodents, birds, and other small animals, thus keeping the food chain balanced (Mullin and Seigel, 2011). In turn, snakes are preyed upon by birds of prey and larger mammals, contributing to the energy flow within the ecosystem. Snakes can also be viewed as indicator species, given their physiological, ecological, and population dynamics (Beaupre and Douglas, 2011). Therefore, changes in snake populations may provide early warning signals for broader ecosystem health and resilience, pertinent for ecosystem-level monitoring and management efforts (Mullin and Seigel, 2011).

Amphibian Diversity and Composition

Amphibians are essential indicators of environmental health due to their sensitivity to changes in water quality and habitat conditions (DeGarady and Halbrook, 2006; Capaldo *et al*., 2006; Lebboroni *et al*. 2006). Frogs and toads form the majority of the amphibian species on Rubondo Island, thriving in the island's wetlands and forests. The park ecological monitoring unit has recorded 11 amphibian species namely: Mascarine-ridged frog (*Ptychadena mascareniensis*), Guttural toad (*Amiephrynus gutturalis*), Red-backed toad (*Schismaderma carens*), Eastern-grooved-crowned bullfrog (*Hoplobatrachus carens*), Lake Victoria clawed frog (*Xenopus victorianus*), Common reed frog (*Hyperollius viridflavus bayoni*), Kivu reed frog (*Hyperolius kivuensis bituberculatus*), Kivu reed-frog (*Hyperolius kivuensis*), Common reed-frog (*Hyperolius viridflavus variabili*), Common reed-frog (*Hyperolius viridflavus destefanii*), and Common-reed frog (*Hyperolius glandcolor*) (Kibasa *et al*. 2015). Ecologically, frogs and toads are key players in insect control, feeding on mosquitoes, flies, and other invertebrates (West, 2018). They also serve as a food source for many predators, including birds, snakes, and small mammals. Despite the island's variety of ecosystems, amphibians on Rubondo Island are understudied, with limited data on species diversity, abundance, habitat preferences, their role as bioindicators, and exposure to global diseases such as chytridiomycosis and ranaviruses.

Vegetations

Rubondo Island National Park hosts a unique and well-preserved ecosystem, dominated by primary lowland Congolese forest, which stands as the only intact remnant of this forest type within Lake Victoria and Western Tanzania. The forest's pristine condition is due to about 100 years of protection from settlement, cultivation, and logging. This intact forest, covering approximately 80% of the island, provides a critical refuge for biodiversity, featuring rare tree species like *Milicia excelsa* (African teak or iroko), *Olea hochstetteri* (a type of olive tree), and *Entandrophragma bussei* (mahogany) (TANAPA, 2015). Other common evergreen lowland and semi-deciduous forests include: *Croton sylvaticus*, *Drypetes gerrardii*, and *Lecaniodiscus fraxinifolius*, often accompanied by a lush understory of lianas and woody vines (Briggs, 2006). The landscape around the island also varies distinctly: the eastern lakeshore is marked by rocky outcrops and sandy beaches, whereas the western shore features expansive papyrus swamps bordered by date palms. The variety in vegetation types supports diverse wildlife, creating essential habitats for an array of species, many of which are otherwise rare in the region.

Like other components of biodiversity, there have been few studies on plant species in Rubondo Island National Park. In 2005, TANAPA's Ecological Monitoring Unit conducted a plant inventory, identifying a total of 185 species (TANAPA, 2005). Other studies focusing on plant species have

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primarily emphasized their use as wildlife food, for example, by chimpanzees (Moscovice *et al.*, 2007) and elephants (Mwambola *et al.*, 2015). Moscovice *et al.* (2007) documented a total of 46 plant food items in the chimpanzees' diet, based on direct observation or presence in multiple faecal samples, with a high preference for *Garcinia huillensis, Antiaris toxicaria, and Drypetes gerrardii*. The authors reported that fruits, primarily from trees and lianas, composed the majority of the chimpanzees' diet, with *Saba comorensis* alone accounting for 35% of their fruit intake. Interestingly, despite seasonal fluctuations in tree fruit availability, the study found no increase in the consumption of lower-quality plant parts (e.g., leaves, stems) between seasons, suggesting a stable dietary quality year-round.

Mwambola *et al.*, (2015) studied the feeding preferences of African elephants (*Loxodonta africana*) in Rubondo Island National Park (RINP), recording a total of 22 plant species from 13 families that were foraged by elephants. The most commonly foraged species included *Croton sylvaticus* (13.33%), *Croton macrostachyus* (11.11%), *Aeschynomene elaphroxylon* (8.88%), *Chaetacme aristata* (8.88%), *Ekerbegia capensis* (8.88%), *Saba comorensis* (6.67%), and *Phoenix reclinata* (6.67%), with a preference for leaves rather than stems, presumably due to their nutritional content or digestibility compared to the more fibrous stems. Although the study was conducted across both wet and dry seasons, it did not clearly indicate whether elephant feeding preferences shift significantly with changing seasonal availability. The knowledge of seasonal feeding preferences is essential in understanding the adaptive strategies elephants employ, particularly in terms of resource use during times of scarcity.

Fish Resources

Rubondo Island National Park stands as a unique conservation area on Lake Victoria, dedicated to protecting vital fish breeding grounds that support the lake's biodiversity (TANAPA, 2015). These breeding grounds are especially crucial for maintaining the populations of several native fish species, some of which are highly endangered due to habitat degradation, overfishing, and the introduction of invasive species across Lake Victoria (Mbabazi *et al.*, 2004; Nyamweya *et al.*, 2023). Several native fish species in Lake Victoria are now at risk of extinction. These include endemic tilapiine species (*Oreochromis esculentus* and *Oreochromis variabilis*), certain catfishes (*Xenoclarias eupogon*), haplochromines, and cyprinids (such as *Labeo victorianus*, *Barbus altianalis*, *Haplochromis pyrrhocephalus* and *Protopterus aethiopicus*) (Outa *et al.*, 2020). Rubondo Island National Park serves an essential role in the ecological balance of Lake Victoria by supporting a wide array of fish species, many of which play distinct roles in the lake's food web (Balirwa *et al.*, 2003). For example, *Haplochromine* cichlids are known for their diversity and specialized niches, helping control insect and algal populations (Mbabazi *et al.*, 2004; Nyamweya *et al.*, 2023). Preservation of these important fish breeding grounds is essential for safeguarding fish populations and promoting genetic diversity, the process that stabilizes fish stocks not only in the park vicinity but across Lake Victoria as currents and migrations disperse juvenile fish throughout the ecosystem (Mnaya and Wolanski 2002). However, there is limited data on the diversity and abundance of fish species in the waters surrounding Rubondo Island.

The history indicates that in the early 20th century, Lake Victoria supported a multispecies fishery based on native food fishes (Balirwa *et al*., 2003). However, overfishing depleted native stocks, prompting the introduction of non-native fish species, including Nile perch (Nyamweya *et al.*, 2023). Nile perch (*Lates niloticus*) became dominant, drastically altering the lake's ecosystem and outcompeting indigenous species, leading to the decline or disappearance of many native species, including the Haplochromine cichlids (Balirwa *et al*., 2003). The previously complex food web of

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Lake Victoria has been simplified and is now dominated by Nile perch (Njiru *et al.*, 2008).

In recent decades, fish kills have been reported in and around Rubondo Island National Park (Kaoneka and Mlengeya, 2000), with the most recent incident in 2021/2022 involving large numbers of Nile perch floating in the lake. These events are not unique to the area, as Lake Victoria has experienced recurrent fish kills affecting species such as Nile perch (*Lates niloticus*), tilapia (*Oreochromis niloticus*), and *Rastrineobola argenteus* (Committee for Inland Fisheries of Africa, 1988). The primary causes of these fish mortalities include dissolved oxygen depletion, algal blooms, and abrupt changes in temperature and wind patterns that disrupt water column stratification. Other contributing factors may include toxic factory effluents, pesticide residues, and low levels of heavy metals (Njiru *et al*., 2008). Algal blooms, intensified by nutrient pollution, further deplete oxygen levels, exacerbating the problem and posing significant ecological and economic challenges for Lake Victoria. While several potential causes of fish kills have been identified, there is a lack of detailed, site-specific studies to determine the primary drivers and interactions among factors such as dissolved oxygen depletion, algal blooms, and water column stratification in waters surrounding Rubondo island.

Cultural Heritages

Rubondo Island National Park is surrounded by the Sinza tribe. Historically, the Sinza people originated from the larger Bantu migrations across Africa between 1000 BCE and 1000 CE and established themselves in the Lake Victoria basin centuries ago (Committee of the Customs and Traditions of the Zinza People, 2007). The key factors that attracted their migration were the fertile land and abundant fish resources. With time, the Zinza developed a unique identity that was shaped by the lake and its ecosystem, supporting both their subsistence and cultural practices. Therefore, Lake Victoria was not only essential for the provision of food and water but also served as a spiritual foundation for the community. This connection is reflected in their religious beliefs and cultural practices that revolve around water bodies, fishing, and ecological respect.

Rubondo Island, now part of Tanzania's protected areas, was historically home to the Zinza's Banyarubondo subgroup, who inhabited it for generations alongside other smaller islands in Lake Victoria (Kiwango *et al.* 2008). The island attracted these early communities due to its natural abundance, which supported fishing, hunting, and small-scale agriculture. Within the Zinza's history, three primary clans Abahonya, Abakeinagi, and Abahwera originally settled on Rubondo Island. Over time, these clans splintered into smaller groups, each developing its distinct cultural markers and identity (Kiwango *et al.*, 2008).

The arrival of colonial forces in East Africa significantly altered the Zinza people's way of life (Committee of the Customs and Traditions of the Zinza People, 2007). During the German colonial period, the Zinza, including those on Rubondo Island, faced forced relocations as they gazetted Rubondo Island as a forest reserve in 1928. However, British colonial rule allowed some few Banyarubondo to resettle on Rubondo, recognizing their historical connection to the land. By the 1960s, with Tanzania moving towards independence, the Tanzanian government declared Rubondo a Game Reserve, necessitating the final relocation of its residents in 1965.

According to Kiwango *et al.* (2008), Rubondo Island is rich in cultural sites, many of which hold significant spiritual and historical meaning for the Zinza. Important sites include:

- Residence of Chief Mukama: This location served as the chief's residence and an administrative hub for meetings and gatherings, particularly in areas like Chikando and Lukaya.

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- Religious Practices: The traditional Zinza religion, known as Uchwezi, revolved around gods such as Kazhoba (the sun), Lughaba (the provider), and Nyamhanga (the creator), who were honoured during various life events. These beliefs were integrated into life events, including birth, where Uchwezi ceremonies were performed to name children. Christianity later arrived in the 1930s, with Catholic and Lutheran missionaries establishing footholds on the island and neighbouring islets.

- Sacred Sites and Caves: Numerous caves, such as the Aharusumbe cave, served as sites of refuge and strategic hideouts during intertribal conflicts, particularly between the Zinza and Baganda. Other sites, like the Chibandala and Chasamile rock platforms, were used for sacrificial offerings and clan gatherings. These places are deeply revered and form an integral part of the community's cultural memory.

- Mythical Places and Stories: Key mythical sites such as Lukaya, which was a breeding site for crocodiles, are seen as significant by the Zinza, who believed that these locations were inhabited by spirits and should be respected. Sacred sites like Izilambuba were often restricted areas, with community members believing that envious or ill-intentioned individuals would face misfortune if they stayed there.

- The island's caves were also historically used by witches and magicians, who lived in exile from their communities. During colonial conflicts, caves like Karobhela were critical for hiding and defence. They also played a role in regional conflicts, especially during British-German confrontations in World War I, when local resistance groups used them for cover and strategic advantage.

The rich cultural heritage of Rubondo Island, with its sacred sites, mythological landmarks, and historical artefacts, signifies that Lake Victoria is a deeply embedded element of the Zinza identity. The cultural landmarks left behind emphasize the need for conservation measures that respect and protect the Zinza's historical and spiritual legacy on the island.

CONCLUSION AND RECOMMENDATION

Rubondo Island National Park holds exceptional ecological, cultural, and conservation value as the world's largest protected tropical lake island. Its diverse habitats and distinctive biodiversity contribute significantly to the ecological balance of the Lake Victoria. The reintroduction of chimpanzees and elephants has enhanced biodiversity and reinforced the island's ecological integrity. Additionally, the ongoing chimpanzee habituation project for eco-tourism has promoted sustainable tourism, generating revenue to support conservation efforts. Native plants, animals, and introduced species shape ecosystems through their roles in food webs, habitat maintenance, and nutrient cycling. Keystone species like elephants and chimpanzees influence landscapes and biodiversity (Fritz, 2017; Msindai and Sommer, 2022), while reptiles and fish serve as indicators of ecosystem health (Lebboroni et al. 2006; Beaupre and Douglas, 2011; Ciliberti et al., 2011). Protecting these resources ensures ecosystem balance, supports livelihoods, and fosters coexistence with local communities. Therefore, it is suggested to strengthen the conservation management on Rubondo Island by focusing on key strategies such as enhanced monitoring and research, community engagement, anti-poaching efforts, invasive species control, climate change adaptation, and strengthening conservation partnerships.

The cultural heritage of the Zinza people is deeply connected with Rubondo Island's land and waters, reflecting a unique relationship between community identity and environmental resources. Despite colonial disruptions and the establishment of Rubondo Island National Park, the cultural landmarks and sacred sites remain crucial for understanding the Zinza's history and spiritual

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practices. As conservation efforts progress, it is vital to acknowledge and honour this rich cultural legacy, ensuring that the preservation of Rubondo Island respects its ecological importance and its role in the Zinza people's identity. Therefore, it is suggested to enhance the integration of cultural and ecological aspects in the overall conservation of Rubondo Island National Park.

Biodiversity research is highly relevant to the sustainable conservation of ecosystems. Within Rubondo Island, research is valuable for evidence-based and effective conservation management by enabling informed decisions on resource management, adaptive strategies, species protection, community engagement, invasive species control, climate change adaptation, and sustainable tourism. However, research on Rubondo Island is limited, focusing mainly on chimpanzees (46%), otters (21%), elephants (6%), and vegetation (15%). This review recommends future research to better understand the island's biodiversity in other areas:

- Detailed studies on the behaviour, social structures, diet, and health of habituated chimpanzees are lacking. It is recommended to investigate these aspects and compare them with native groups in Gombe, Mahale, and neighbouring countries such as Rwanda, the DRC, and Uganda.
- The role of elephants on seed germination success, dispersal patterns, forest regeneration, and the impact of elephant activities on the behaviours and populations of other species, such as chimpanzees, hippos, and sitatunga.
- There has been an increase in the elephant population; therefore, a study on the island's carrying capacity, genetic diversity, and potential inbreeding is recommended.
- An assessment of avian diversity to create an updated bird species checklist and monitor populations to track trends in abundance, breeding success, migration, and habitat use. This will establish baseline data crucial for evaluating future environmental impacts, as birds serve as bio-indicators.
- An inventory of fish resources, including their seasonal variations and responses to lake pollution and climate change, is essential.
- Vegetation surveys are essential to update plant species diversity, composition, reproduction, and pollinator interactions while assessing responses to invasive species. Monitoring changes over time is crucial to understanding environmental shifts and the impact of herbivory by large mammals.
- A study on herpetofauna species composition, diversity, habitat preferences, disease prevalence, and the impacts of climate and environmental changes on their behaviour, breeding, and survival is essential.
- Understanding the mechanisms by which crocodiles adapt their hunting behaviour and metabolic needs in response to environmental stressors or shifts in prey populations is highly significant.

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