Zambezi River Basin

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Abstract

More than 4.7% of the Zambezi River Basin is wetlands, several of which individually cover areas in excess of 1,000 km^2. The basin contains 13 Ramsar Sites and thousands of lesser known wetlands. It is estimated that 20 million people (ca. 50% of the basin population) live in the vicinity of wetlands largely because of the wide range of ecosystem services, they provide, including support to fisheries, livestock and other forms of agriculture, as well as tourism. The wetlands also support considerable biodiversity, influence the hydrology of the basin and play an important role in the economies of the riparian countries. Currently there are a number of threats to the basin wetlands, including inappropriate agricultural practices, altered hydrology due to hydropower dams and overfishing. Increased irrigation and climate change are likely to add to future stresses on wetlands. However, careful planning and management, including coordinated releases from hydropower dams, could safeguard and rejuvenate many wetlands in the basin.

Keywords

Biodiversity · Dambo · Hydrology · Livelihoods · Ecosystem services · Agriculture · fIsheries

Introduction

The Zambezi River basin is the largest river basin in Southern Africa. With a total drainage area of approximately 1.34 million km^2,it is Africa's fourth largest river after the Nile, Congo, and Niger Rivers. The main river, with a length of 3,000 km, originates in the Kalene Hills in northwest of Zambia at an altitude of 1,500 m and flows first southwest and then south before turning east to the Indian Ocean. The river has three distinct stretches: the *upper Zambezi* from its source to Victoria Falls, the *middle Zambezi* from Victoria Falls to Cahora Bassa Gorge, and the *lower Zambezi* from Cahora Bassa to the delta. Riparian countries are Zambia, Angola, Namibia, Botswana, Zimbabwe, Malawi, Tanzania, and Mozambique. Malawi and Tanzania do not have direct contact with the Zambezi River itself but are linked to it via the Shire River, which drains Lake Malawi. Other principal tributaries are the Luangwa, the Kafue, the Manyame, the Sanyati, the Chobe, and the Kabompo Rivers (World Bank 2010).

Lying between latitude 10° and 20° south and between longitude 20° and 37° east, the climate of the basin is largely controlled by the movement of air masses associated with the Intertropical Convergence Zone (ITCZ). Rainfall occurs predominantly during the summer (November to March), while the winter months (April to October) are usually dry. However, rainfall is characterized by considerable spatial and temporal variation. Droughts of several years duration have been recorded almost every decade (Tyson 1986), and floods also occur frequently. The natural flow regime of the river reflected the rainfall and was characterized by high seasonal and annual variability. The average annual discharge is approximately 130,500 million m^3 (Mm^3) (4,134 m^3s^{-1}).

Currently, due to the absence of large dams and water diversions, the *upper Zambezi* remains the most natural portion of the river. Further downstream, the flow is regulated by two large dams on the Zambezi main stem – Kariba and Cahora Bassa dams – as well as a number of tributary dams (most notably Kafue Gorge and Itezhi-Tezhi on the Kafue River) (Fig. 1). These were built primarily for hydropower generation (Beilfuss and dos Santos 2001). The operation of these dams has resulted in an increase in dry season flows, a delay and decrease in peak flows during the flood season, and an overall reduction in the depth and duration of floodplain inundation in the middle and lower Zambezi reaches. These changes in flow regime have had an impact on the morphology and ecology of the river and the Zambezi Delta (Beilfuss and dos Santos 2001; Nugent 1983; Ronco et al. 2010).

The basin comprises a mosaic of miombo woodland, grassland, savannah, agricultural land, and wetlands. The evolution of the basin and its major biomes and species distribution are described in Timberlake (2000).

Wetlands in the Basin

Permanent and seasonal wetlands comprising swamps, marshes, and floodplains are a major feature of the basin covering a total area of at least 63,266 km^2 (4.7% of the basin) according to Lehner and Döll (2004) (Fig. 1). However, this is certainly an underestimate because in addition to the major wetlands, (Table 1) smaller wetlands, known as dambos, are common in much of the uplands, covering up to 15% of the

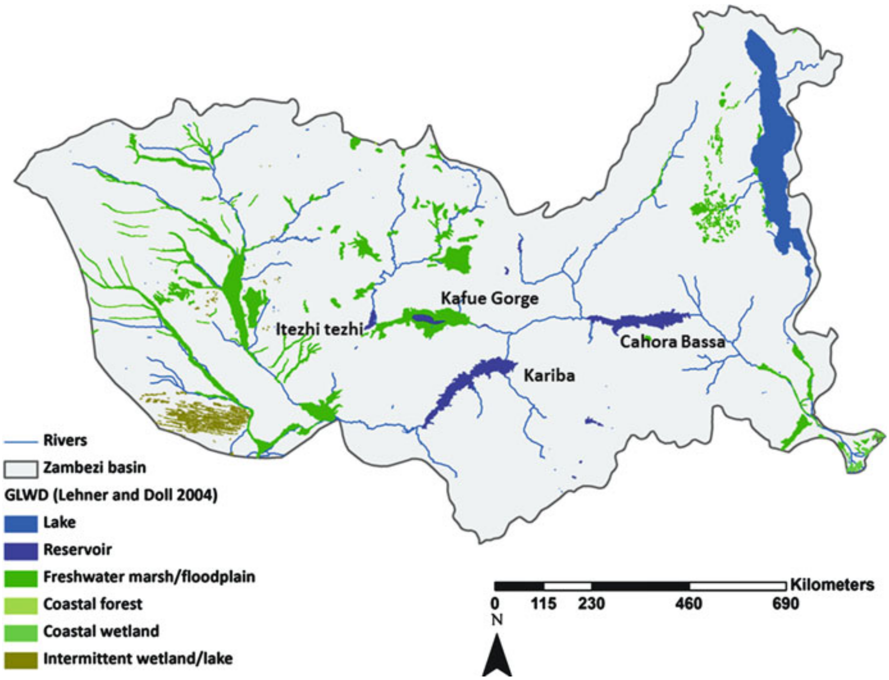

Fig. 1 Dams and major wetland areas in the Zambezi River basin

Table 1 Major wetlands in the basin (Compiled from Hughes and Hughes 1992)

Name	Location (lat and long and subbasin)	Area (km^2)	Description (e.g., wetland type)
Zambia			
Swamps of the Kabompo River	Kabompo	180	Small riparian swamps, extending in narrow strips
Swamps of the Lungue-Bungo River	The Lungue-Bungo River and two tributaries (Litapi and Lutembwe)	1,000	Large permanent swamp in the triangle of land between the two tributaries (*papyrus*, *Phragmites*, and floodplain grasslands)
Luena Flats	Luena River	897	*Papyrus* and *Phragmites* swamps with grass floodplains fed by several small streams (i.e., Nkala, Luambua, Lukuti, and Ndanda)
Nyengo Swamps	Luanginga River	700	Seasonal flood waters spread between the Luanginga, Ninda, and another tributary
Lueti and Lui Swamps	Lueti and Lui Rivers	375	Floodplain wetlands + patches of permanent swamp that merge with Barotse floodplain
Barotse Floodplain	Upper course of the Zambezi River 14°19′–16°32′S/ 23°15′–23°33′E	7,700	Floodplain wetland located on Kalahari sand
Sesheke-Maramba Floodplain	Zambezi along the northern border of the Caprivi Strip	1,500	Floodplain
Busanga Swamp	Kafue 14°05′–14°21′S/ 25°46′–25°57′E	600	Permanent shallow swamp
Lukanga Swamp	Lukanga but with spill from Kafue 14°00′–14°40′S/ 27°19′–28°00′E	2,100	Reed/*papyrus* swamp
Kafue Flats	Kafue River 15°11′–16°11′S/ 26°00′–28°16′E	7,000	Floodplain swamps and marshes located between Itezhi-Tezhi dam and Kafue Gorge dam
Zimbabwe			
Mid-Zambezi Valley and Mana Pools	Zambezi 15°36′–16°24′S/ 29°08′–30°20′E	360	Floodplain – pans and pools
Malawi			
The Shire Marshes	Shire River draining Lake Malawi 16°11′–17°05′S/ 34°59′–35°19′E	740	Two tracts of permanent swamp and lagoons in the Chikwawa and Bangula areas plus floodplain

(*continued*)

Table 1 (continued)

Name	Location (lat and long and subbasin)	Area (km^2)	Description (e.g., wetland type)
Namibia			
Cuando-Linyanti-Chobe-Zambezi (including Linyanti Swamp, eastern Caprivi wetland, Chobe Swamps)	Cuando, Linyanti (Chobe)	Total 3,930	Floodplain, swamps, and shallow lakes through the Caprivi Strip. Near the Chobe-Zambezi confluence in phase flooding of both rivers may inundate 1,700 km^2 of floodplain
	17°39′–18°40′S/ 23°18′–25°10′E	900 (Linyanti Swamp)	
Mozambique			
Lower Zambezi	Downstream of Tete, particularly in the vicinity of the Shire River	>325	Floodplain, swamps, and shallow lakes (e.g., Lake Mimbingue and Lake Tanie)
Zambezi Delta	Zambezi downstream of Caia	1,300	Zambezi discharges via distributaries through wide delta. Swampy floodplain and areas of mangrove forest extending up to 15 km inland along the main channels

landscape in some places (Bullock 1992). Dambos are clay-based, low-lying areas that are flooded by a combination of direct precipitation, surface runoff, and seepage from higher ground (Acres et al. 1985). They occur under a wide range of ecological conditions, and the shape and areal extent vary considerably. However, a common feature is poor drainage. The majority of dambos are characterized by vegetation communities dominated by herbaceous species, typically a large number of sedges (*Cyperacea*) and hygrophilous grasses (Hughes and Hughes 1992).

Riparian reed swamps, dominated by *Phragmites mauritianus* and *Typha domingensis*, occur along the upper courses of many tributary rivers with riverine forest occurring at lower altitudes (e.g., along parts of the Kafue and Zambezi above Victoria Falls where dense stands of *Syzygium* spp. characterize the riverbanks). Further downstream several tributaries flow into large depressions which contain permanent swamps, each of which cover tens of thousands of hectares and across which water flow is diffuse, often taking place in the absence of discrete channels. At even lower levels, the river and its tributaries have formed huge seasonally inundated floodplains.

The Upper Zambezi

Wetlands occur on many of the tributaries of the upper Zambezi (i.e., the Kabompo, the Lungue-Bungo, the Lutembwe, the Litapi, the Luena, the Luanginga, the Lueti, and the Lui), sometimes extending for many kilometers either side of the rivers. Most wetlands are essentially riparian (oxbow lakes, tall reed swamps, pans, and pools) backed by floodplain grasslands that are inundated in the wet season. Some individual wetlands are extensive (up to about 1,000 km^2), but they tend to become narrower and more discontinuous further upstream (Hughes and Hughes 1992). The most important wetland system of these upper tributaries is the vast Liuwa Plain (5,000 km^2) near the confluence of the Lungue-Bungo, Luambimba, and Zambezi Rivers, which supports the second largest migration of wildebeest (*Connochaetes gnou*) in Africa and substantial populations of endangered African painted dog (*Lycaon pictus*), gray crowned crane (*Balearica regulorum*), and wattled crane (*Bugeranus carunculatus*) (Kamweneshe et al. 2003).

The Barotse Floodplain covering an area of 7,700 km^2 is a major wetland on the upper Zambezi that is inundated to depths of 1.5–3.0 m when the flood peaks in April. As well as the main Zambezi River, the Luanginga, Luampa, Lueti, and Lui Rivers all flow into the floodplain.

The annual inundation of the floodplain significantly influences the pattern of life in Barotse, determining seasonal human and livestock migration patterns and production cycles and also making some areas inaccessible for parts of the year. The Lozi people, the native inhabitants of the Barotse, derive a range of diverse livelihoods from the floodplain, including those based on agriculture and fisheries. Every year they celebrate the flooding of the Zambezi with the Kuomboka ceremony when, toward the end of the rainy season, they make a ceremonial move to higher ground. The successful move is celebrated with traditional singing and dancing. This ceremony dates back more than 300 years (IWMI 2013). Across the floodplain, a complex network of more than 5,000 interlinked canals was built by the Barotse Royal Establishment, the traditional authority, in the late nineteenth century. These canals serve a range of different purposes including navigation, irrigation, drainage, livestock and domestic uses, and fisheries habitat. For its important biodiversity, the Barotse was designated a Ramsar Wetland of International Importance in 2007. The area has also been proposed as a World Heritage Site in recognition of both its environmental and its cultural heritage.

The Sesheke-Maramba Floodplain (also called the eastern Caprivi or southern Barotse Floodplain) occurs along the northern border of the Caprivi Strip close to the confluence of the Zambezi and the Chobe River which enters from Botswana. The floodplain is approximately 100 km in length and extends over an area of about 1,500 km^2 much of which lies in Namibia (Hughes and Hughes 1992). This floodplain is contiguous with the eastern portion of the Chobe-Linyanti floodplain system, which begins at the point where the Cuando River (the name given to the Chobe River in Angola) enters Botswana (van der Waal and Skelton 1984). The Linyanti Swamp is about 300 km^2 in area, but its size varies according to the extent of flooding in the upper Zambezi (Marshall 2000). Lake Liambezi, which periodically dries up, lies at the end of the Linyanti Swamp, has an open water surface of 100 km^2 when full, and is bordered by a swamp of 200 km^2 (van der Waal and Skelton 1984).

The Middle Zambezi

Designated in 2010, the UNESCO Middle Zambezi Biosphere Reserve comprising riverine and terrestrial ecosystems, extends from Lake Kariba (the reservoir created by the building of the Kariba dam) and the Matusadona National Park through various national parks and safari areas adjacent to the Zambezi River, including Mana Pools, Sapi, and Chewore which together are designated as a UNESCO World Heritage Site. In total it covers an area of 28,793 km^2.

Just downstream of Kariba dam, the Zambezi is joined by the Kafue River (see below) and then broadens into a braided course for some 130 km to the Mupata Gorge. The numerous streams produce many low-lying sandy islands, containing pans and pools with further pans and pools along the riverbanks. Much of the flat valley floor (ca. 12 km wide) and some river terraces used to be inundated when the river was in high flood, but now that flow is regulated by the Kariba dam, this no longer happens. However, several small tributaries (i.e., Nyamuchera, Chiruwa, Mbera, and Sapi) flow down through swampy land to the Zambezi in the vicinity of the Mana Pools. If floods in these tributaries coincide with major discharges from Kariba, substantial areas along the south bank of the Zambezi may be inundated. The area has a rich riparian flora of sedges, reeds, riverine forest, and grasslands with a clear succession based on flood tolerance (Hughes and Hughes 1992). The Mana Pools are small permanent pools that mark depressions in former river channels that have become isolated as the river moved progressively northward (Hughes and Hughes 1992). The pools have flat, grass- and reed-covered banks surrounded by forest. The main pools are permanent, deriving water from precipitation and groundwater seepage and only occasionally from flooding. The area of the pools, just a few hundred hectares, is a very small (ca 3%) portion of the total area that the Zambezi once flooded in this region.

The Kafue River is one of the major tributaries of the Zambezi, draining an area of 155,000 km^2, entirely within western Zambia. It is the most significant waterway in terms of the national economy in Zambia; most of the mining, industrial, and agricultural activities and approximately 50% of Zambia's total population are concentrated within the catchment area (Burke et al. 1994). Many permanent swamps occur on the Kafue River and its tributaries in the upper catchment. Most are narrow strips occurring on one or both sides of the river, and many are just a few hundred meters in width. However, there are several large permanent swamps: Lushwishi Swamp (100 km^2), Lufwanyama Swamp (74 km^2), Mininga Swamp (144 km^2), and an unnamed swamp on the main stream (310 km^2) (Hughes and Hughes 1992).

At a similar latitude but on different tributaries of the Kafue River, the extensive Busanga (600 km^2) and Lukanga (1,800 km^2) Swamps both lie in shallow depressions and have similar physiography. The Busanga Swamp supports a rich diversity of waterbirds but is isolated and poorly known (Beilfuss et al. 2007) (Photo 1). The Lukanga wetland, although named a swamp, actually comprises a treeless lake and marsh ecosystem – an intricate maze of reeds, pools, channels, and large bodies of open water (Kamweneshe and Beilfuss 2002; McCartney et al. 2011). The palustrine wetland covers approximately 95% of the area and includes stands dominated by reeds (*Phragmites*), mixed grass, cattail/reed mace (*Typha*), and termitaria grasslands. The lacustrine area comprises about 5% of the total wetland. It provides habitat for a wide range of terrestrial and aquatic flora and fauna, including at least 316 species of birds, including cranes, storks, ducks, geese, pelicans, herons, egrets,

Photo 1 The Busanga wetland (Photo credit: R. Beilfuss © Rights remain with the author)

Photo 2 Fishing camps in the Lukanga wetland (Photo credit: R. Beilfuss © Rights remain with the author)

and bitterns. The hydrology of the system is complex: at times of high flow, the Kafue River causes water in the Lukanga River to backup into the swamp, and during very high floods, the Kafue River itself overflows into the wetland (Seagrief 1962). It is estimated that about 60,000 people live in, or close to, the wetland (predominantly from the Lenje and Bemba tribes) and that products, derived from fishing, hunting, and agriculture, support a hinterland population of some 6.1 million people (Ramsar 2005) (Photo 2).

The broad alluvial plain of the Kafue Flats (area 7,000 km^2) lies between the Itezhi-Tezhi and Kafue Gorge dams. The river gradient through the Flats is just 0.022 m/km, and the travel time from Itezhi-Tezhi to Kafue Gorge is on average 6 weeks. Under natural conditions, the Kafue Flats flooded in the wet season (February to May) each year. Flooding usually commenced in December as a result of direct rainfall and tributary inflows, but maximum flood levels were not attained until the inflow in the main river channel reflected the heavy rainfall in the upper part of the catchment. The maximum flood arrived first in the western part of the Flats in February/March and moved slowly east, arriving at the head of the Kafue Gorge in April/May.

The Kafue Flats are one of the most biologically diverse ecosystems in Zambia. Comprising the meandering river and a complex of lagoons, oxbow lakes, abandoned river channels, marshes, levees, and floodplain grassland, they provide habitat for a wide range of birds and animals, including rare species. Over 400 bird species, including the endangered wattled crane (*Bugeranus carunculatus*), and 67 species of fish have been documented (Douthwaite 1982; Muyanga and Chipundu 1982). The Flats are home to the Kafue lechwe (*Kobus leche kafuensis*), an endemic antelope especially adapted to life in marshes (Howard and Chabwela 1986) (Photo 3). Two national parks (Lochinvar and Blue Lagoon) and associated tourist facilities were

Photo 3 Lechwe in the Kafue Flats (Photo credit: R. Beilfuss © Rights remain with the author)

established in the early 1970s. Designated as internationally important locations of high conservation value, the combined area of these parks is 830 km^2.

Traditionally, the natural resources of the Kafue Flats have been utilized in a wide variety of ways, for both commercial and subsistence purposes. It is estimated that more than 100,000 people are in some way dependent on the Flats (Scudder and Acreman 1996). Cattle grazing is a major commercial activity, and it is estimated that up to 290,000 head of cattle (10–20% of the national herd) utilize the Flats during the dry season. There is some commercial farming, primarily sugar and winter wheat. The largest producer of sugarcane is the Nkamabala Sugar Estate, owned by the Zambia Sugar Company, which presently cultivates 13,400 ha and abstracts water from the Kafue throughout the year for irrigation (McCartney and Houghton-Carr 1998). There are reeds and papyrus from which baskets and mats are woven at a subsistence level, but timber and other forest products are not common. Hunting (e.g., of lechwe), although illegal, provides an important source of protein for local people. The Flats support one of Zambia's most productive artisanal fisheries, supplying not only the floodplain communities but also urban centers such as Kafue town and Lusaka.

The Luangwa River, another major tributary, joins the Zambezi close to the border with Mozambique, just upstream of the Cahora Bassa reservoir. The upper reaches have relatively few wetlands, but there are strips of fringing reed swamps and riparian forest in places and patches of swampy forest that occur around springs in the headwaters. In its final 350 km before its confluence with the Zambezi, the floodplain broadens out and there are many oxbows and sections of abandoned channel with levees. In the rainy season, the entire floodplain, several kilometers wide in places, is completely inundated.

The Lower Zambezi

The Zambezi River enters Mozambique at Zumbo and immediately flows into the reservoir of the Cahora Bassa dam. Downstream of the dam, the river is contained within a narrow gorge until the town of Tete. Here the valley broadens and the river develops a narrow floodplain. For much of its course between Tete and the delta, the bed of the Zambezi is 1–5 km wide, and in the dry season, the river flows in several deeply incised channels. However, during the wet season, the entire bed may be one swiftly moving current (Hughes and Hughes 1992).

The most important tributary of the Zambezi in its lower course is the Shire River, which drains Lake Malawi and Malombe. Barrages near Liwonde regulate the flow for hydroelectricity generation. In its lower course before discharging into the Zambezi, the Shire flows through an extensive low-lying area, and a series of swamps extends along the river. The Shire Swamps comprise two tracts of permanent swampland (Elephant Marsh (570 km^2) and Ndinde Marsh (200 km^2)) in the Chikwawa and Bangula areas. The numerous lakes and lagoons which comprise these marshes may have connection with the anastomosing river channels only during the wet season. The marshes are virtually treeless and dominated by

Photo 4 Mangrove forest in the Zambezi Delta (Photo credit: R. Beilfuss © Rights remain with the author)

herbaceous vegetation (Hughes and Hughes 1992). The Shire Swamps support an important fishery, cattle grazing, and agriculture (irrigated cotton and sugar) in the marginal lands.

The Zambezi Delta occurs at the downstream terminus of the river, from the Zambezi-Shire confluence to the Indian Ocean. The delta is a broad, flat alluvial plain, approximately 12,000 km^2 in size. From its apex near the village of Mopeai, 120 km inland, the delta forms a large triangular area with a 200 km coastal frontage along the Indian Ocean. The Zambezi Delta is bordered to the west and north by the gently rising backslope of the African rift escarpment. The delta supports a diverse mosaic of wetland communities grading from acacia and palm savanna at the floodplain periphery, to seasonally flooded grassland, papyrus swamps, evergreen forests, and open water bodies on the low-lying plains, to mangrove forest and mud flats bordered by dunes near the coast (Beilfuss et al. 2000) (Photo 4).

The delta is an immensely productive wetland system, supporting large concentrations of African buffalo (*Syncerus caffer*), African elephant (*Loxodonta africana*), waterbuck (*Kobus ellipsiprymnus*), southern reedbuck (*Redunca arundinum*), sable antelope (*Hippotragus niger*), Lichtenstein's hartebeest (*Alcelaphus lichtensteinii*), and Livingstone's eland (*Taurotragus oryx*). Seventy-three waterbird species have been recorded, including endangered wattled crane, gray crowned crane (*Balearica regulorum*), large breeding colonies of great white pelican (*Pelecanus onocrotalus*), African openbill (*Anastomus lamelligerus*), and many other species of storks, herons, and spoonbills, and numerous Palearctic and intra-African migrants (Beilfuss et al. 2010).

Ninety-four fish species have been recorded in the lower Zambezi River, of which 55 are primarily freshwater species and mostly floodplain dependent (Bills 2000). The mangrove crab (*Scylla serrata*) and other crustaceans (portunids, etc.) are present and exploited by the local population, while prawns spawning in the delta mangroves are of great economic importance as a source of foreign revenue.

The Role of Wetlands

By affecting how water is routed and stored and evaporated, wetlands play an important role in the hydrology of the Zambezi River system. Spill from the Zambezi and its tributaries into wetlands and subsequent evaporation are major components of the basin water budget. A recent study of the effect of natural wetlands on river flow in the Zambezi basin concluded that broadly (i) floodplains decrease the magnitude of flood flows and increase low flows and (ii) headwater wetlands increase the magnitude of flood flows and decrease low flows. However, in all cases examples were found which produced contrary results and simple relationships between the areal coverage of a particular wetland type within a catchment, and the impact on the flow regime was not found. This confirms that the hydrological functions of wetlands depend to a large extent on location-specific characteristics that make it difficult to generalize (McCartney et al. 2013).

Zambezi basin wetlands support considerable biodiversity and productivity in terms of plants, large mammals, birds and fish, and other groups. Knowledge of the taxonomy of the various groups is generally good, with the exception of many invertebrate groups where even a rough indication of numbers of species present is not available. Although there are a number of species restricted to the wetlands of the Zambezi basin in a number of different groups, detailed listings are not yet available except for large mammals, birds, reptiles, amphibians, and fish (Timberlake 2000). It is estimated that there are 122 species of fish in the basin of which 25 are endemics (IUCN 2003). The lechwe antelope (with most of the global population occurring on

Table 2 Ramsar wetlands of international importance in the Zambezi basin

Country	Ramsar wetlands of international importance
Mozambique	Zambezi Delta
Zambia	Busanga Swamps
	Kafue Flats
	Luangwa Floodplains
	Lukanga Swamps
	Zambezi Floodplains
Zimbabwe	Mana Pools
	Monavale Wetland
	Cleveland Dam
	Chinhoyi Caves
	Driefontein Grasslands
	Victoria Falls
	Lakes Chivero and Manyame

Zambezi floodplains) and the wattled crane (seasonally with up to 75% of the world population in the wetlands of the Zambezi basin) are possibly the best “flagship species” for conservation of the wetlands (Timberlake 2000; Beilfuss et al. 2007).

The Zambezi wetlands play an important role in the livelihoods and well-being of many people in the basin and in the economies of the riparian countries. There are 13 Ramsar wetlands of international importance located in the basin (Table 2) which support fisheries, livestock, and other forms of agriculture, as well as tourism in addition to their considerable biodiversity value. For example, the annual gross financial value of the Barotse Floodplain is estimated to be $ 417 per household with a total annual economic value (from fish, crops, cattle, wildlife, reeds, and papyrus) of $ 12.2 million (Turpie et al. 1999). It has been estimated that the Barotse fisheries provide the bulk of the protein in the diet of about 200,000 people (Hughes and Hughes 1992). Similarly, 250,000 cattle, with a market value of $4 million, graze in the Kafue Flats wetland during the dry season each year (Seyam et al. 2001). Altogether flood recession agriculture in the major wetlands of the Zambezi is estimated to be worth US$36 million annually (Seyam et al. 2001). Many thousands of smaller, lesser-known wetlands, such as the dambos, also play a vital role in the everyday lives of poor rural communities, through the provision of clean drinking water and, because they retain extensive wet regions during the dry season, as a valuable agricultural resource in the semiarid regions of the basin (Wood et al. 2013).

Existing Threats to Wetlands

The population of the Zambezi basin is about 40 million of which 70% is rural and poor (Tumbare 2004). Currently resource overexploitation, land drainage and encroachment for agriculture, and modification of the river hydrology for large-scale hydropower and large-scale irrigation schemes are the greatest threats to the wetlands in the basin. As noted above, conversion of wetlands, including dambos, for agriculture is widespread. If conducted in an appropriate manner, it can, and does, make an important contribution to livelihoods, food security, and poverty alleviation (McCartney et al. 2010). However, with limited agricultural inputs and equipment, poor agricultural practices are prevalent resulting in wetland degradation in many places.

Currently 15 hydropower power stations are located within the basin of which by far the largest are Kariba and Cahora Bassa on the main river. The dams built in the Zambezi basin have significantly affected flow regimes, and wetlands have been greatly modified in both obvious and indirect ways through the creation of new habitats, through facilitation of distribution of species, and through reduced flooding. For example, downstream of the Kariba dam, wetlands are under extreme pressure as a result of year-round utilization by large mammals which under natural conditions would have been forced to migrate off the floodplain in the wet season. As result of this and impoverishment of the alluvium, as a consequence of silt removal from the Zambezi water before it reaches the floodplain, changes in the biotic communities of the floodplain are marked. Similarly, the ecology of the delta has been significantly altered as a consequence of flow regulation. Woody savanna and thicket species have increased in density and colonized far into the floodplain grassland mosaic. Relatively drought-tolerant grassland species have displaced flood-tolerant species in the broad alluvial floodplain, and saline grassland species have displaced freshwater species on the coastal plain. Abandoned alluvial channels are undergoing advanced stages of terrestrialization. Coastal mangrove has been replaced by saline grassland at the tidal margin. Sandbars have become stabilized and colonized by grassland and woody species (Beilfuss and dos Santos 2001).

The Itezhi-Tezhi dam was the first major dam in Africa, designed and constructed with additional storage specifically for the purpose of releasing managed floods. Flood releases were incorporated into the release regime of the dam in order to simulate the natural flooding of the Kafue Flats in March and April each year. Approximately 15% of the total live storage of the reservoir was set aside for such flood releases; a very progressive concept at the time the dam was built in the 1970s. Still the dam has undoubtedly had impacts on the Kafue Flats, many of which have been compounded by other socioeconomic changes that have occurred over the years. Substantial efforts are underway to coordinate "environmental flow" releases among Itezhi-Tezhi, Kariba, and Cahora Bassa dam operators to rejuvenate major floodplains of the middle and lower Zambezi (Beilfuss and Brown 2010; SWRSD Zambezi Basin Joint Venture 2010).

Future Challenges

Future challenges to the Zambezi basin wetlands relate to increasing population, economic development, and climate change. The population of the basin is growing rapidly, and this will inevitably increase competition for scarce resources and add to the pressure on wetlands. There are ambitious plans for additional hydropower dams and irrigation on both the main river and the tributaries, especially in Angola which has been to date a minor player in basin development. FAO (1997) estimates a potential area of 422,000 ha for formal irrigation in the basin. One likely consequence of increased water abstraction and greater flow regulation is further reduction in downstream flooding which may have significant impacts on wetland hydrology and functioning.

By changing patterns of rainfall and modifying flow regimes, climate change may also affect the basin hydrology with potentially significant impacts on flooding and hence wetlands. The Zambezi basin exhibits the worst potential effects of climate change among 11 major sub-Saharan African river basins and will experience the most substantial reduction in rainfall and runoff, according to the Intergovernmental Panel on Climate Change (IPCC). Multiple studies cited by the IPCC estimate that rainfall across the basin will decrease by 10–15% and runoff by as much as 40% or more (Beilfuss 2012). These changes will exacerbate existing problems for basin wetlands already degraded by altered and reduced flooding patterns.

Given the importance of the Zambezi wetlands not only for the livelihoods of many millions of people but also for the economies of the riparian countries, it is vital that future development planning takes into account the multiple services that they provide and incorporates measures to safeguard important ecosystem services.

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