The influence of the Shire River on Liwonde National Park, Malawi, with special reference to elephant movements

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Liwonde National Park (538 km²), Malawi, is a riverine-lacustrine park. The only outlet of Lake Malawi is the Shire River along the western boundary of the park. Although elephants spend many long hours in the floodplain on the eastern bank, they never crossed the river until 1991/92 during the worst southern African drought in living memory. This study investigated the impact of the river on the floodplain and inferred the influence on elephant movements. Waterflow of the Shire River at Liwonde since 1972 was reviewed and influences of water level variations were inferred from aerial photographs and geomorphic maps. Elephants crossing the river were also observed. The period 1972–1975 had low waterflow, reaching a minimum of 180 cumecs. Elephants did not cross then, probably because the population was small (below 200) and therefore had no incentive to do so. In contrast, the period 1976–1990 was characterised by high river waterflow of up to 1050 cumecs, leading to extensive flooding. This provided water and good forage. During the drought between 1991 and 1995 little flooding occurred. The elephants overutilised the eastern floodplain. Some crossed the river for better forage. The population had then increased to 400.

Key words: Liwonde National Park, Malawi, Shire River, floodplain, elephants *Loxodonta africana*, Liwonde Barrage, drought.

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Introduction

Liwonde National Park, southern Malawi, Central Africa, is a riverine-lacustrine park that is hydrologically connected to Lake Malawi. The only outlet of the lake, the Shire River, follows the western boundary of the park for about 35 kilometres. The floodplain along the river, characterised by river channels, levees, marshes and other wetlands, is influenced by changes in water level in the lake and the river. In the park, elephants *Loxodonta africana* spend most of their daytime in the eastern floodplain, particularly so in the dry season. However, there is no record of their crossing the river since the park was established in 1972, until the worst southern African drought from 1991 to 1995 (Hulme *et al.* 1994; Magadza 1994; Braack 1995; Zambatis & Biggs 1995). To date, they continue to cross the river.

Other records of elephants crossing rivers have been reported for the Luangwa River during the dry season (Lewis 1986), the Zambezi River during drought (Dunham 1986) and Lake Tanganyika (Anon. referee *pers. comm.*). In Liwonde National Park, it is possible that the influence of the Shire River on the floodplain, enhanced by waterflow control at Liwonde Barrage 4 km south of the southern boundary of the park, may have affected the elephant behaviour. The objective of the present study, therefore, was to

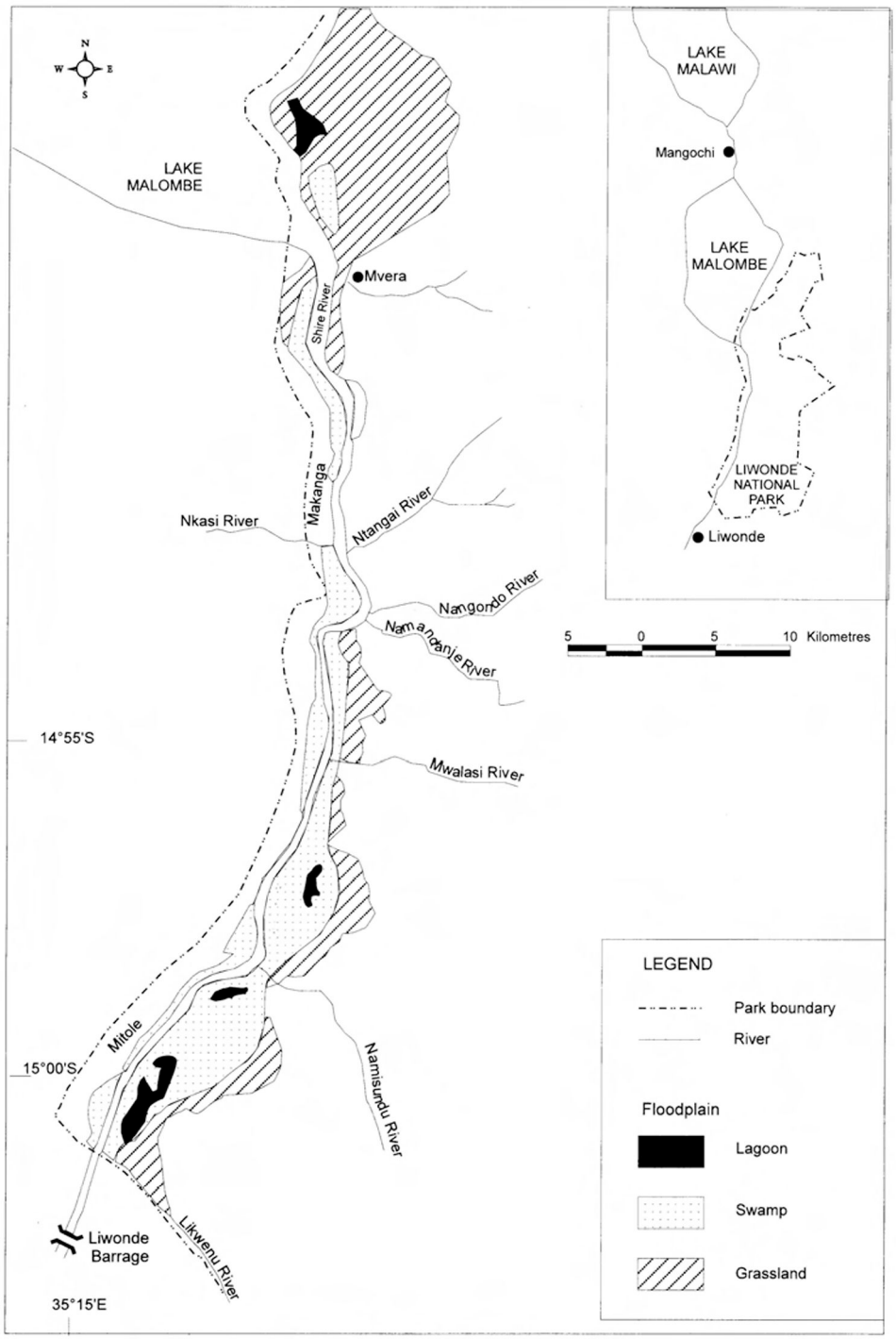

Fig. 1. Map of the Shire River segment in Liwonde National Park showing major geomorphic features along the river and the Liwonde National Park in relation to Lake Malawi and Lake Malombe.

investigate the impact of the river, together with waterflow control, since the park was established, and to infer how these parameters may have influenced elephant movements.

The elephant population in the park was estimated at about 400 in 1995 (Bhima 1996), having increased from 200 in 1977, when the first aerial count was conducted (Stead & Dudley 1977). When the park was established in 1972, the population was probably in the region of 170 animals.

Study area

Liwonde National Park (538 km²), Malawi, is located between 35°15'–35°26'E and 14°36'–15°03'S in the Upper Shire River Valley, 30 km south of the southernmost reach of Lake Malawi. The park is generally flat (mean elevation 500 m above sea level) with a mean east-west gradient of 4 m/km and a north-south gradient of 0.015 m/km (Crossley 1980). The Shire River flows into Lake Malombe (surface area ca.400 km²) adjacent to the northwestern boundary of the park and then flows along the park's western edge, leaving the park near Liwonde Town, a further 35 km to the south. The western park boundary runs parallel to the river, 1 km from away from the western bank, forming a 35 km² stretch of land west of the upper Shire River.

The park has extensive marsh and floodplain areas. Most (61.7 %) of the marshes and lagoons occur in the southern half of the east bank, between the Mwalasi and the Likwenu River confluences (12 km south of the lake) where the Shire River is generally wide (300–400 m) with low banks. Most flooding occurs in this area and it is a preferred elephant habitat in the dry season (Bhima *pers. obs.*). On the west bank, tall *Phragmites mauritianus* and patches of tall *Borassus aethiopum* palms occur. The drier higher lands on the eastern section are largely savanna woodland dominated by *Colophospermum mopane* and other vegetation communities are of much smaller extent (Dudley 1994).

The park has a wet season from November to April and a dry season from May to October. The mean annual rainfall for the period 1977 to 1995 was 998.8 mm. In the 1991/92 wet season, only 401.1 mm of rainfall, or 40.2 % of the long-term mean, was recorded. The subsequent years of 1992/93, 1993/94 and 1994/95 all had rainfall below the long-term mean, i.e. 803.8 mm, 637.8 mm and 886.5 mm respectively. Temperatures range from mean lows and highs of 12–28 °C in the cool season (June - July) to 20–41 °C in the hot season (September - October).

The Shire River and Liwonde Barrage

The Shire River flows south from Lake Malawi to the Zambezi River, crossing a sand bar at the Nkasi River confluence (Fig. 1), then runs through a wide and deep channel of reduced cross-section but steeper gradient to Liwonde Town. It flows strongly throughout the year with a maximum mean (1940–1970 free waterflow rate (412 cumecs) occurring in April or May and a minimum (253 cumecs) in November or December (UNDP/WMO 1976). In 1980, when Lake Malawi reached the highest recorded water level, the maximum waterflow of the Shire was 1050 cumecs (Govt. of Malawi 1991).

The Liwonde Barrage, 80 km south of Lake Malawi, was constructed in 1965 and spans the full width of the river with 14 radial gates, each 9 m wide. When the gates are fully open, there is little hindrance to the waterflow. Gate controls are set relative to the lake levels and the river flow rates. The first gate control procedures established in 1966 were rather crude, causing quick build up and recession of the water upstream when

closed and opened, respectively. Subsequent control procedures introduced in 1976 were more sensitive and did not induce such rapid changes in the upstream river levels (UNDP/ WMO 1976; A. Mandeville *in litt.*). The main function of the barrage is to reduce drops in the lake level and yet maintain a minimum river flow for various downstream users, particularly for the generation of hydroelectric power.

Methods

Variations of river levels and impacts on the park

We undertook a review of the Shire River waterflow and water levels at Liwonde from various reports and publications for the period 1972 to 1995 to obtain the long-term mean waterflow and pattern of fluctuation. A more detailed analysis of the fluctuations was done for the last, nearly 10-year period (January 1986 to October 1995) to obtain the actual level at Liwonde when the elephants crossed, and to see if it was lower then than during the rest of the period. This was based upon daily recorded data of river level collected at the barrage by the Electricity Supply Commission of Malawi (ESCOM) from a permanent stake located 50 m above the barrage and calibrated in metres. This gave an indication of variations in water levels immediately above the barrage, which includes the river in the park up to the Nkasi River sand bar. The levels for July 1992, the month when the first crossing occurred, were compared to the long-term levels using the Kolmogorov-Smirnov two-sample test (Siegal & Castellan 1988).

The influence of the Shire River water level variations and impacts of the barrage on the park were studied by estimating changes in the total flooded areas at different times. Values were calculated from aerial photographs and geomorphic maps, paying particular attention to features such as raised beaches, alluvial islands, high river banks and terraces, old river channels, levees and marshes and other wet lands. Comparisons were made between the extent of the minimum and maximum flooded areas for the years when waterflow in the Shire River was low (1972–1975, see results) and for the years of "normal" to high discharge (1976–1990). Flooded area size during the drought period was estimated from aerial photographs of July 1995 (photographs for the area during drought peak in 1991/1992 could not be found) and were compared to the flooded area size in September 1982. Paired comparisons were made for the different segments of the Shire River, using the *t*-test.

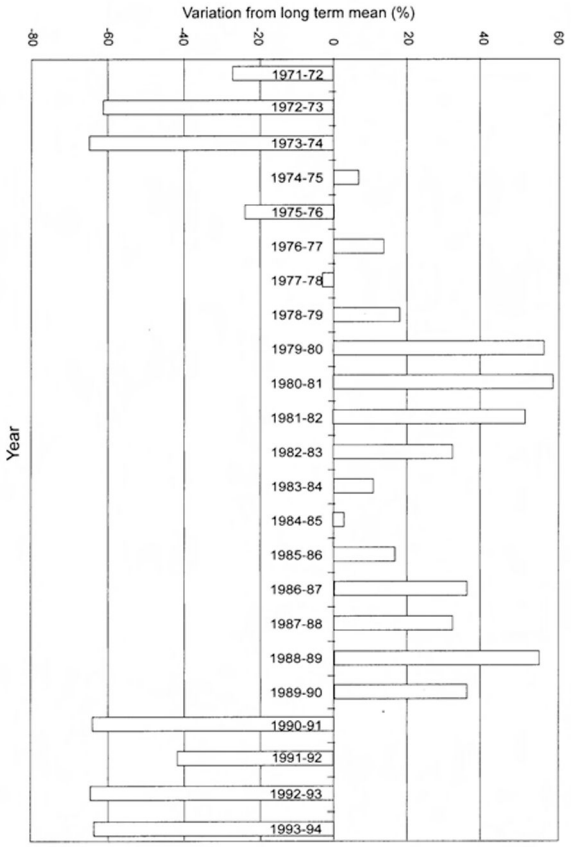

Fig. 2. Percent mean annual waterflow variations of the Shire River at Liwonde for the period 1974/75 to 1994/95, with a long term mean waterflow rate of 552 cumecs (Govt. of Malawi 1991; unpubl. data)

Elephant activity on the western bank

Observations and records of elephants crossing the Shire River were made from 1992 through to 1995 and augmented by frequent reports from safari boat operators. Data recorded includ-

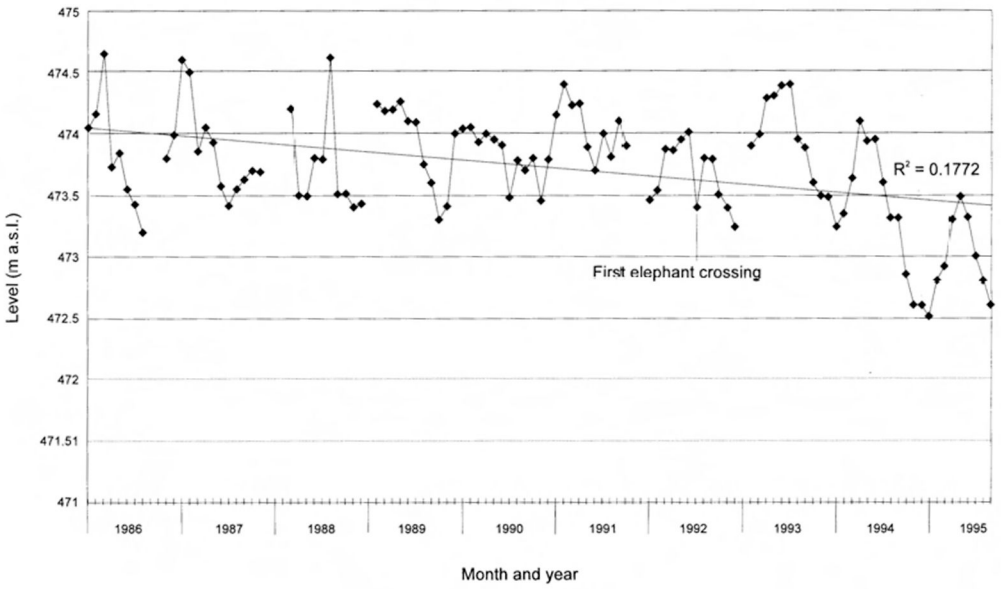

Fig. 3. Mean monthly levels of the Shire River, 50 m above the Liwonde Barrage in Malawi from January 1986 to September 1995, with a long-term mean level of 473.66 m a.s.l. to show a declining trend.

ed date, place, number and direction of crossing. Where possible, groups were identified to determine the frequency of crossing and to estimate the numbers of individuals on the west bank at any one time. Total numbers were estimated from annual aerial counts done by the Wildlife Research Unit.

Results

Review of Shire River waterflow and levels

Variations in the Shire River waterflow at Liwonde from the long-term mean are given in Fig. 2 for the period 1974/75–1993/94 (based on Govt. of Malawi 1991; Dept. of Water Development unpubl. data). The long-term mean rate for this period was calculated as 557.5 cumecs. From 1976/77 to 1989/90, waterflow was generally high with peaks during the periods 1979/80 to 1982/83 and 1986/87 to 1989/90. A low waterflow period occurred between 1990/91 and 1993/94, reaching a minimum of 180 cumecs, with decreasing flow continuing through the dry season of 1995.

Fluctuations in water height, as recorded 50 m upstream of the barrage for the period 1986–1995, are given in Fig. 3. The long-term mean water level above sea level was 473.66 m. The fitted straight line shows a significant decline of water level with time ($R^2 = 0.1772$; $df = 108$; $P < 0.01$). The seasonal pattern was one of high levels (above the long-term mean) in December to April (wet season) and lower levels (below the long-term mean) in July to November (dry season). In 1992, when elephants first crossed, the levels were low most of the year, but still within the range of observed levels of the past 10 years. There was no significant difference between the long-term mean level for July and the mean level for July 1992 ($P > 0.05$). In 1993, the levels were normal, but below the long-term mean from August 1994. The lowest levels since 1986 occurred in August 1994 and were below the long-term mean through to the late dry season of 1995 (September - October). These levels were significantly lower than the monthly long-term mean levels ($P < 0.05$), and so too were the means for June, July and August 1995.

Table 1

Estimated surface area (km²) flooded of the Shire River when the Liwonde Barrage operated under the 1966 control procedures. Flooded areas consist of marshes, lagoons, some floodplains and grasslands. The estimates are based on long-term seasonal variation of water levels for the years 1940-1970 (471.1–472.2 m above sea level at Liwonde)

Shire River section	Length (km)	Max. flooded area	Min. flooded area	Difference	% Flooded Area	% Increase in flooded area
Likwenu/ Namisundu	8.00	10.36	7.42	2.94	46.3	39.6
Namisundu/Mwalasi	5.75	7.14	4.72	2.42	31.9	51.3
Mwalasi/Nkasi	8.50	4.88	2.62	2.25	21.8	85.9
River total	22.25	22.38	14.77	7.61	100.0	51.5

Flooded areas under different waterflow regimes and the influence of the barrage

While the barrage operated under the 1966 control procedures, the flooded area in the park alongside the Shire River was mainly below the Nkasi-Shire confluence (Table 1). The area is 22.3 km long and includes 73.6 % of the Shire's riparian habitat. The influence of flooding was greatest in the southern section. The barrage was activated twice each year (February and July) causing sudden altered water levels. Some floodplain/grassland areas were inundated by the rise in the water level, but the area involved was unlikely to ever have been more than 22.4 km², mostly on the east bank. More important were the sudden fluctuations caused by the flooding.

The total seasonal park flooding during the unusually high water level period in 1979–1980 is shown in Table 2. Waterflow was not regulated by the barrage. Compared to the low waterflow period of 1972–1975, an additional 22 km² of the floodplain or grassland was flooded in 1979–1980. Flooding in the southern sections of the park was proportionally worse than in the north. Under the 1976 control procedures of the barrage, maximum water levels would be a little higher than the maximum for a 'normal' unregulated flow. Therefore it would remain within the major river terrace and flood channels. More serious would be the unseasonal flooding caused by the gate closures during the late dry season. A comparison of flooded areas in September 1982 (late dry season) and July 1995 (early dry season) (Table 3), shows that the surface area flooded in July 1995 was significantly less than that flooded in September 1982 ($t = 45.6$; $df = 7$; $P < 0.001$).

Elephants on the west bank

A herd of at least 32 elephants was first seen crossing the Shire River in July 1992 near the confluence of the Ntangai River when the water level in the river was within the normal range of fluctuation. The herd was subsequently sighted between Makanga and Lake Malombe (Fig. 1) where 44 individuals were recorded in an aerial total count on 11 October 1992.

In 1993, the group continued to be active between Makanga and Lake Malombe, but no crossings were reported. An aerial count on 13 October, 1993 recorded two herds under 1 km apart consisting of seven and 39 individuals respectively.

Table 2

Estimated surface area (km²) flooded by the Shire River under free flow and unregulated by the Liwonde Barrage in Malawi for the high water level years of 1979 and 1980. The area flooded consists of marshes, lagoons, alluvial islands, and floodplain/grasslands. Water levels at Liwonde Barrage were 472.8–475.0 m a.s.l.

Shire River section	Length (km)	Max. flooded area	Min. flooded area	Difference	% Flooded area[a]	% Increase in flooded area[b]
Likwenu/ Namisundu	8.00	14.43	10.36	4.07	34.8	39.3
Namisundu/ Mwalasi	5.75	8.99	7.14	1.85	21.7	25.9
Mwalasi/Nkasi	8.50	7.25	4.88	2.37	17.5	48.6
Nkasi/Mvera	8.25	10.76	7.27	3.49	26.0	48.0
River total	30.50	41.43	29.65	11.78	100.0	39.7
Lake Malombe	11.00	8.38	6.31	2.07	-	32.8
Park total	41.50	49.81	35.96	13.85	-	38.51

[a] Maximum flooded area per section as a percent of total maximum flooded area for river portion of the park.
[b] Percent increase in flood area at seasonally high river levels.

In 1994, the elephants continued to utilise the same area. In October, a woman collecting firewood was attacked and injured by an elephant in the Mitole area on the west bank. Apparently more elephants had crossed to the west bank. An aerial count on 28 October, 1994 recorded 67 elephants in herds of 2, 12, 12, 17 and 24 individuals between Nkasi River and Lake Malombe.

From November 1994, 3 months after the river levels had gone below the normal fluctuation range, elephants began to cross the river freely. In the first half of 1995, the herd between Makanga and Lake Malombe was in excess of 80 individuals, straying out of the park several times in March, April, June and July. Similarly, a herd of 30–38 was observed crossing in January, April, May

Table 3

Estimated flooded surface area (km²) in the Shire River floodplain in Liwonde National Park of Malawi from aerial photographs taken in September 1982 (late dry season) and in July 1995 (early dry season). Area flooded in September 1982 was significantly larger than area flooded in July 1995 ($t = 45.6$; $df = 7$; $P < 0.001$)

Shire River section	Area flooded in September 1982	Area flooded in July 1995	Difference
Likwenu/Namisundu	9.44	6.13	3.31
Namisundu/Mwalasi	6.25	4.12	2.13
Mwalasi/Nkasi	5.08	3.36	1.72
Nkasi/Mvera	6.81	4.52	2.29
Totals	27.58	18.13	9.44

and August. In July and August another herd of nine individuals also crossed the river regularly near the Likwenu River confluence on the southern border of the park. Several groups of two to four were also seen regularly. The time spent on the west bank by these herds ranged from a few hours (i.e. returning the same day) to several days. The maximum time recorded for a herd was eight days. In the annual aerial count on 2 October 1995, 49 individuals were counted in herds of six at Makanga and 43 in the Mitole area. Several other crossing points were noted, all close to various river confluences.

Discussion

River systems fluctuate naturally in daily, seasonal and annual cycles in response to cyclic environmental and biotic processes (Buermann *et al.* 1995). The multi-year and monthly fluctuations observed in the Shire River are two examples of such cycles. Elephant movements across the Shire River are influenced by this cycle. For most of the years in the park's existence, the river flow has gone through the high phase of the cycle, causing flooding of the riparian habitat. When the first elephants crossed the river in 1992, the water level in the river was within the normal fluctuation range. From 1972 to 1975, the levels were low, but the elephants did not cross. It seems, therefore, that it was not just the drop in water level but also the impact on the floodplain that has influenced elephants to cross.

During the low waterflow period of 1972 to 1975, an estimated maximum area of 23 km² and a minimum of 15 km² were flooded. During these years, flooding could be related more to run-off from high ground during the rains than to rising river levels. Generally, water would remain within established marshes, old river terraces and channels because of the small gradient in the floodplain. As levels drop, water would be expected to recede from these terraces and peripheral marshes but remain in the older flood channels as well as the main river course. Elephants did not cross the river then probably because the population was small (< 200). Although most of the floodplain probably was dry, the elephants could still survive on the available vegetation.

In years of normal and high waterflow (1976 to 1990) even more area was inundated. High water levels in the Shire River overflow into lagoons and marshes. In 1979/80, for example, an additional 22 km² of floodplain were inundated. This water remains available to animals much later in the dry season. This action is enhanced by the transient flooding, caused by actions of the barrage. Elephants tend to prefer peripheral water sources to the main river channel for their drinking, and they only utilise the main river channel when water is scarce (Jarman 1972; Wyatt & Eltringham 1974). Elephants in the park therefore utilised the lagoons and marshes in these years. In addition, the vegetation in these flooded areas, which is the major food source for these elephants, has been adequate for the numbers of elephants then present in the park, suggesting a lack of incentive to cross the Shire River.

Waterflow declined sharply in 1991/1992 because of the drought. Based on classifications by Hulme *et al.* (1994) and Zambatis & Biggs (1995), the drought in the upper Shire River catchment could be considered moderately severe (45 % of long-term mean annual rainfall was recorded in the park). The rainfall season was shorter than normal and could have prevented lagoons and other wallows from filling up from direct rainfall and surface run-off as they normally would do as was observed in July 1995 (early dry season), when less area was flooded than in September 1982 (late dry season). In addition, temperatures in the rainy season in the park were higher than usual (unpubl. data) probably leading to the drying up of most peripheral wallows much earlier in the year. This is due to increased evaporation as has been observed in the Okavango swamp (Magadza 1990) and in reservoirs in northeastern Zimbabwe (Kapetsky 1994). Furthermore, the action of the barrage did

not cause any transient flooding despite consistent control of waterflow. The vegetation in the floodplain, already a in poor state, may then have been quickly depleted by the elephants and other wild animals, inducing the elephants to cross to the west bank where vegetation was in a better state.

After the first elephants crossed the Shire River in July 1992, there was a lapse of 27 months before the next recorded crossing. No crossing occurred in 1992/93 because the drought was mild. The water levels in the river returned to normal, water in the lagoons was available and the vegetation on the east bank may have been normal. However, the cumulative effects of the three consecutive droughts from 1992/93 to 1994/95 led to further crossing in late 1994. In August 1994, the water level in the Shire River reached its lowest level since 1986, but elephant crossings occurred in October and then regularly from November onwards. This is a further indication that it is not the water level in the river *per se* that lead to elephant crossings, but its impact on the floodplain vegetation.

The west bank is now part of the range used by the elephants in the park, as crossing the Shire River has continued even after the drought. Many elephant groups that cross to the west bank since October 1994 return to the east bank and it seems that the herd that first crossed in 1992 is the only permanent one on the west bank. This new elephant range in the park has management implications that may need attention. Conflict with humans, such as damage to crops and injuries, should become a problem as already noted in April-May 1995. Elephant movements out of the park may be controlled by maintaining the currently dilapidated electric fence on the western boundary. These fences have proved to be effective elsewhere (Bell 1984; Thouless 1994), but if not possible, an increase in control shooting might be necessary.

Having been without elephant activity for many years, the west bank has well-developed woodlands and riverine forests. An *Acacia xanthophloea* woodland and extensive stands of *Borassus* palms are present. They are the only examples of their type in the park. They have an aesthetic appeal in a park which is otherwise mostly mopane woodland (ca.74.0 %). With elephant densities reaching as high as 3–4 elephants/km² at certain times in this small area of the park, their impact on the vegetation is already notable. Elephants can fell mature *Acacia xanthophloea* trees (Spinage & Guiness 1971). The *Borassus* palms on the west side of the Shire River are 15–20 m tall. On the eastern side, however, they only coppice probably due to elephant browsing activity (Shorter 1989). There is need to investigate the impact of the elephants on the vegetation of the west bank.

Conclusions

Elephants in Liwonde National Park never crossed the Shire River since the establishment of the park because there was no incentive to do so until 1992. Although the Shire River waterflow was low from 1972 to 1975, the elephants could survive on the available resources because the population was small. The years 1976 through to 1990 were generally 'normal' to high rainfall years, with waterflow in the Shire River following suit. Flooding of the riparian habitat in these years provided readily accessible water and ensured that the forage in this most preferred habitat was green until late in the dry season. In the drought years of 1991/92–1994/95, no flooding occurred, likely causing the elephants that had now increased significantly, to deplete the available resources and cross over to the west bank where the vegetation could have been in better condition due to elephant absence for many years.

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