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Full Length Research Paper

Does shore length influence population size and density distribution of hippopotamus?

Chansa Chomba[1]*, Rhamadhani Senzota[2], Harry Chabwela[3] and Vincent Nyirenda[1]

[1]Disaster Management Training Centre, Mulungushi University, P.O. Box 80415, Kabwe, Zambia.
[2]Department of Zoology and Wildlife Conservation, University of Dar es Salaam, Dar es Salaam Tanzania.
[3]Department of Biological Sciences, University of Zambia, Lusaka, Zambia.

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Population surveys of common hippopotamus *(Hippopotamus amphibius)* in Zambia were carried out between 2005 and 2008 to estimate population size and density distribution patterns against shore length. River bank foot counts were used in the Luangwa River system while boat/canoe counts were used to collect population data from lakes, dams and rivers. Population estimate was 40,060 hippopotami distributed over shore length of 11, 892 km. Luangwa, Zambezi and Kafue Rivers had shore length of 4,150 km which was only 35% of total shore length. The three rivers with only 35% of shore length had 35,000 individuals which was 87.36% of total population estimate, distributed as follows; Luangwa 25,000 (62% of total), Zambezi 6,500 (16% of total) and Kafue 4,000 (10% of total). Chi-square test showed a significant difference in population estimates in Luangwa, Zambezi and Kafue (χ^2, $P < 0.05$) being highest in the Luangwa (62%), Zambezi (16%) and Kafue (10%) respectively. It was found that shore length did not determine population density distribution. The Luangwa River which was not the longest had the largest number of hippopotamus supporting 62% of the national population estimate. More research is required to investigate other physical and anthropogenic factors determining hippopotamus population density distribution along shore length of water bodies.

Key words: Population status, Luangwa, Zambezi, Kafue, shore length, estimate.

INTRODUCTION

Population status of common hippopotamus *(Hippopotamus amphibius* Linnaeus 1758*)* was estimated to be about 157,000 individuals in Africa by Eltringham (1994). West Africa had the least population size totaling about 7,000 spread over 19 countries. East Africa held substantial numbers with 30,000 (now less than 20,000 (Anonymous, 2004) in Eastern Congo DRC and populations numbering tens of thousands in Ethiopia, Sudan and Tanzania. Several thousands were recorded in Kenya and Uganda bringing the total for East Africa to about 70,000 (Anonymous, 2004). Southern Africa had the highest population size with Zambia containing the biggest population (40,000) of any country in Africa (Eltringham, 1994). Other countries in the southern African sub region with large numbers were Mozambique (16,000 to 20,500), Malawi (10,000), Zimbabwe (6,900), and South Africa (5,000). The total in the whole region was estimated at 80,000. Angola was not covered during the survey. It was assumed that covering Angola would raise the population estimate for southern Africa to about 100,000. However, owing to loss of grazing land due to cultivation and poaching in some countries particularly those with civil strife suggests that the future of the species was relatively insecure. For that reason, the World Conservation Union (IUCN), hippopotamus specialist group re-evaluated and upgraded its status to vulnerable category on the International Red List of threatened species in 2006 (Lewison, 2007). The

*Corresponding author. E-mail: chansachomba@rocketmail.com. Tel: +260211278365, +260979324851.

population was reported to have further declined from 157,000 in 2004 to 125,000-148,000 in 2008 (CITES, 2012; Lewison and Oliver, 2008). It was found that populations most at risk were those in West Africa, where the distribution was particularly fragmented (Lewison, 2007). Identification of populations that were at particular risk or which are of special significance in conservation terms were considered to be a priority by IUCN. It was for this reason that this study focused its attention on Zambia to determine whether shore length determines hippopotamus population density distribution. Such information would assist the law enforcement agencies to apportion resources in such a manner that would be more effective and efficient to yield the best results. For Zambia, which has the largest population in Africa (Lewison, 2007; CITES, 2012; Chansa and Milanzi, 2010), it would imply allocating substantial amounts of money for monitoring and surveillance. If on the other hand, it was found that density distribution was determined by other factors, law enforcement agencies would focus their attention on only those areas of the shore length that is most critical to the growth and survival of the hippopotamus population.

In terms of security of the species in Zambia, the Zambia Wildlife Act No. 12 of 1998 provides sufficient legislative framework for the protection of fauna and flora, in which species are classified as either game or protected. Hippopotamus is classified under the protected category which receives the highest level of protection in terms of law enforcement and sentences passed by the courts of law. Under the Convention on International Trade in Endangered species of Wild Fauna and Flora (CITES), hippopotamus is placed in Appendix II where international trade is regulated through issuance of CITES permits and conducting non detriment findings which facilitates setting of sustainable quotas. At the international level, Zambia is a signatory to the Lusaka Agreement on cooperative enforcement operations directed at the international illegal trade in wild fauna and flora and CITES. These instruments have been implemented in Zambia and may have contributed to the effective protection of the hippopotamus.

MATERIALS AND METHODS

Study area location and description

The location of the study area was rivers and lakes in the Republic of Zambia (Figure 1), which is located at 8° and 18° south and 22° and 34° east in southern Africa. The study covered a total of nine lakes and dams and 18 rivers with a total shore length of 11, 892 km.

Climate

Zambia's climate is relatively mild, with three distinct seasons. The warm rainy season is between November and April. This is followed by a cool dry season between May and August and hot dry season from September to November. Annual rainfall averages between 600 and 1,300 mm decreasing southwards and in the major low lying river valleys. In some dry years, areas in the south may receive less than 500 mm of rainfall and in high rainfall areas of Northwestern, Luapula and Northern Provinces rainfall may exceed 1,500 mm with rains extending from about October to May in good years. In the hot season day time maximum temperatures average 27 to 38°C and minimum temperature average 2 to 15°C in the cool season. All the rivers are perennial and provide a suitable habitat for hippopotamus.

Data collection and analysis

River bank total counts along the Luangwa River

The river bank total foot count method involved six members of the research team walking along the bank of the river. Of the six, two were recorders one recording on data sheets and the other on the map. Two were observers using a pair of binoculars each and the other two carried firearms to protect the team from dangerous wild game. A maximum of 30 min was spent observing a school, which provided sufficient time to count all individuals in a school including those submerged under water as they come above water surface to breathe.

Boat counts along Kafue and Zambezi Rivers

Counts along the Kafue and Zambezi rivers were done by motor boat (Table 1). This method was used because the two rivers are deeper and fast running than the Luangwa River, thus providing easy passage by boat. The survey team comprised six members; two observers, one was the left observer and the other as right observer. The third member of the team recorded data from both observers on one data sheet. The fourth member carried a fire arm for security of the team from dangerous game including hippopotamus. The fifth member was the coxswain and the sixth member of the team was on stand-by to replace any member of the team that may for one reason or the other fail to carry on with the survey. Each observer used a pair of binoculars to count hippopotamus and called the number seen to the recorder. The speed of the boat did not exceed 10 km/h to give sufficient time to observers to scan the river thoroughly. In areas with large schools, the boat stopped for about 10 min to give observers adequate time to count, take photographs and establish Global Positioning System (GPS) coordinates of hippopotamus schools (Chansa and Milanzi, 2010).

Counts in other water bodies

In other water bodies (Table 2), information on hippopotamus population status was collected by Wildlife Police Officers, Tour Operators, Tourists and members of the Community Resource Boards (CRBs). Area Management Units (AMU) of Zambia Wildlife Authority (ZAWA) compiled the data. AMUs are managed by officers of the rank of Park Ranger and above. The rank of Park Ranger and above is held by a person with a minimum of Grade 12 high school leaver's certificate or basic degree and was found to be suitable in order to maintain credibility of the data.

Zambia Wildlife Authority officers derived population data from patrol sighting records. Data on hippopotamus population estimates for Lusiwasi, Mita hills, Mulungushi, Luapula, Kalungwishi and Chambeshi were about 10 years old. For Lusiwashi, Mita hills, and Mulungushi the last survey was carried out in 1996, while Luapula, Kalungwishi and chambeshi data collection ended in 1995. Data

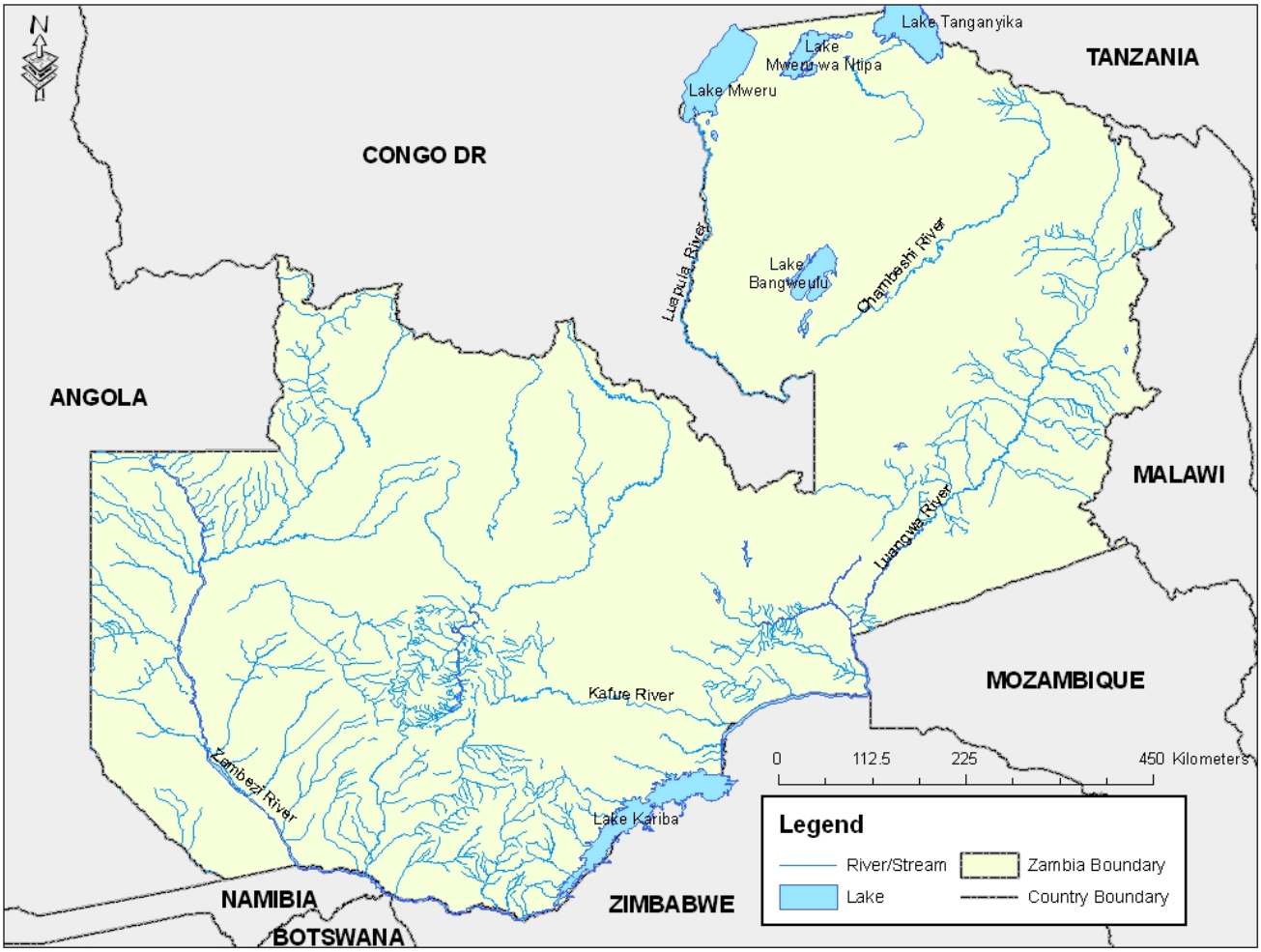

Figure 1. Location of the hippopotamus study area in Zambia.

Table 1. Major rivers where hippopotamus population surveys were conducted in Zambia.

Name	Shore length (km)	Method of survey	Number of hippopotamus	Year surveyed
Luangwa River	1,250	River bank counts by walking	25,000	2008
Zambezi River	1,400	Boat counts	6,500	2007
Kafue River	1,500	Boat counts	4,000	2007
Total	4,150		35,000	
SE	126		11,471	

for Kalungwishi and Luapula rivers, however, were collected by walking along river banks (Table 2).

Using Minitab Release 14, Statistical software programme, version 14, we conducted goodness of fit test based on the Null Hypothesis that hippopotami were distributed at random along the shore length. By recording all observations, it was assumed that if the hippopotami distributed themselves along the shore length at random, they will follow a poisson distribution (e.g. Dytham, 2004). The calculation was based on the formula by Fowler et al. (1998) and Dytham (2004):

$$\chi^2 = \Sigma \frac{(0 - E)^2}{E}$$

where *0*, represented the observed estimate of population or shore length and *E* was the expected estimate or shore length. Thus if there was no significant difference in population distribution per unit of shore length, longer shore lengths would have a higher number of hippopotami and vice versa. We further calculated and compared shore length between different water bodies. Shore length was calculated on Google maps by selecting a ruler symbol as unit of

Table 2. Major rivers, dams and lakes where information on hippopotamus population status was obtained by questionnaire survey in Zambia.

Name	Shore length (km)	Patrol method	Number of hippopotamus	Year recorded
Chambeshi	800	Boat/canoe	100	1996
Kabompo	600		50	2007
Kalungwishi	350	Walking along banks	20	1996
Luapula	1,040	Boat/canoe	50	1996
Lufubu				
Lufupa	180	Walking along banks	1,580	2007
Lunga	200	Boat/canoe	100	2007
Lunsemfwa	300	Boat/canoe	150	1996
LushiwashiRiver	200	Boat/canoe	200	1996
Lushiwashi Dam	15	Boat	10	1996
Mulungushi Dam	12	Boat	20	1996
MulungushiRiver		Boat/canoe	10	1996
Bangweulu	1,300	Boat/canoe	100	2003
Itezhitezhi	65	Boat	250	2007
Kariba	500*	Boat	600	2006
Mita hills Dam	10	Boat	10	1996
Mweru waMuchanga	1,440		50	1996
Mweru waNtipa	740	Boat	50	2007
Tanganyika	540	Boat	600	2008
Other	500	Boat/canoe/Walking	500	2003
Total	7,742		4,550	
SE	404		370	

measure and dragging a pointer along the shoreline and the measurement was shown in the table displayed on the top leftcorner of the page.

To calculate mean population size and density the formula described by Onyango and Plews, (2005) was used as follows:

$$\overline{\chi} = \frac{\sum x}{n}$$

Hippopotamus density was calculated by dividing shore length by population size as follows:

$$D = \frac{N}{L}$$

where; D is density; N is the number of hippopotami and L is the shore length.

RESULTS

Total population estimate for the whole country was 40,060 and the total shore length of all rivers, lakes and dams was 11, 892 km.

Luangwa, Zambezi and Kafue Rivers

Results showed that hippopotamus population size and density distribution were not determined by shore length. Luangwa, Zambezi and Kafue Rivers which are all perennial had collective shore length of 4,150 km which was only 35 % of total, but had 35,000 hippopotami which was 87.36% of total hippopotamus population in the country. Distribution of the estimated population of 35,000 individuals among the three rivers with 87.36% did not follow shore length; Luangwa had 25,000 hippopotami, Zambezi 6,500and Kafue which was the longest of the three had 4, 000 hippopotami (Table 1; Figure 2). These estimates were significantly different ($\chi 2$, $P > 0.05$) being highest in Luangwa which was also the shortest of the three with 62 %, followed by the second shortest Zambezi 16% and least in the longest Kafue which had 10 % of the population respectively (Figure 2).

Shore length between, Luangwa, Zambezi and Kafue rivers were significantly different (χ^2, $P < 0.05$), Kafue being the longest (1, 500 km) but with only 10 % population estimate of total, followed by Zambezi which was the second longest (1, 400km) but with 16 % population estimate of total and Luangwa the shortest (1, 250 km) of the three rivers but with the highest 62 % population size of total (Table 1, 2) suggesting that population size and density distribution were not determined by shore length (Figures 2, 3 and 4).

Population estimates in other water bodies

Other water bodies which included lakes and dams had

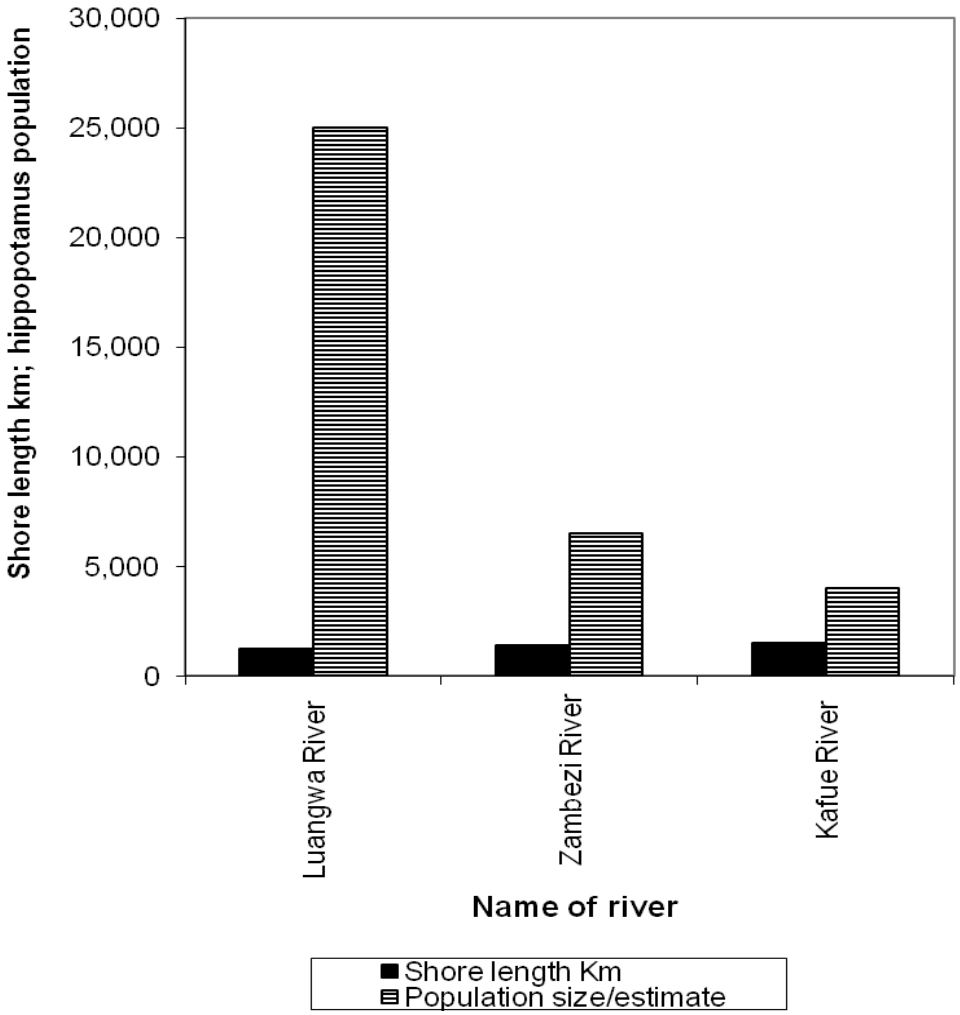

Figure 2. Shore lengths of and density distribution in Luangwa, Zambezi and Kafue Rivers which had the highest hippopotamus population estimates, Zambia.

the longest shore length 7,742 km which was 65 % of total but had a total hippopotamus population of 4, 550 individuals or 12.64 % of total which varied between water bodies (χ^2, $P < 0.001$), being highest in Lufupa River (1,580 hippopotami), and the rest had less than 1,000 individuals each (Figure 3). Shore length also varied significantly between rivers, lakes and dams (χ^2, $P < 0.001$). Lake Bangweulu had the longest shore length (1,300 km) but with a population estimate of only 100 hippopotami, followed by Lake Mweru wa Muchanga which had 1,140 km shore length with a population estimate of 50 and Luapula River had 1,040 km with population estimate of 50 respectively. Lufupa which had a shorter shore length of only 180 km had the highest number of 1, 580 hippopotami (Table 2, Figure 4), implying that other factors other than shore length determined population size and density distribution patterns. Factors, such as the security for water bodies which are located in National Parks and Game Management Areas, and those in open areas where the habitat may be exposed to human encroachment may also determine density distribution.

Results suggest that the Luangwa River system was the most important hippopotamus habitat in Zambia supporting 62 % of the national population size (Figure 2, Tables 1 and 2).

DISCUSSION

Luangwa, Zambezi, Kafue and Lufupa rivers contain the highest densities of hippopotamus in Zambia. The pattern of hippopotamus population density distribution did not follow shore length (Figures 2, 3 and 4) which suggested that there were other attributes determining hippopotamus density distribution. Chansa et al. (2010) suggested geomorphologic features such as river bends, lagoons, and confluences as being critical in determining the pattern of hippopotamus density distribution.

They further suggested that such geomorphologic

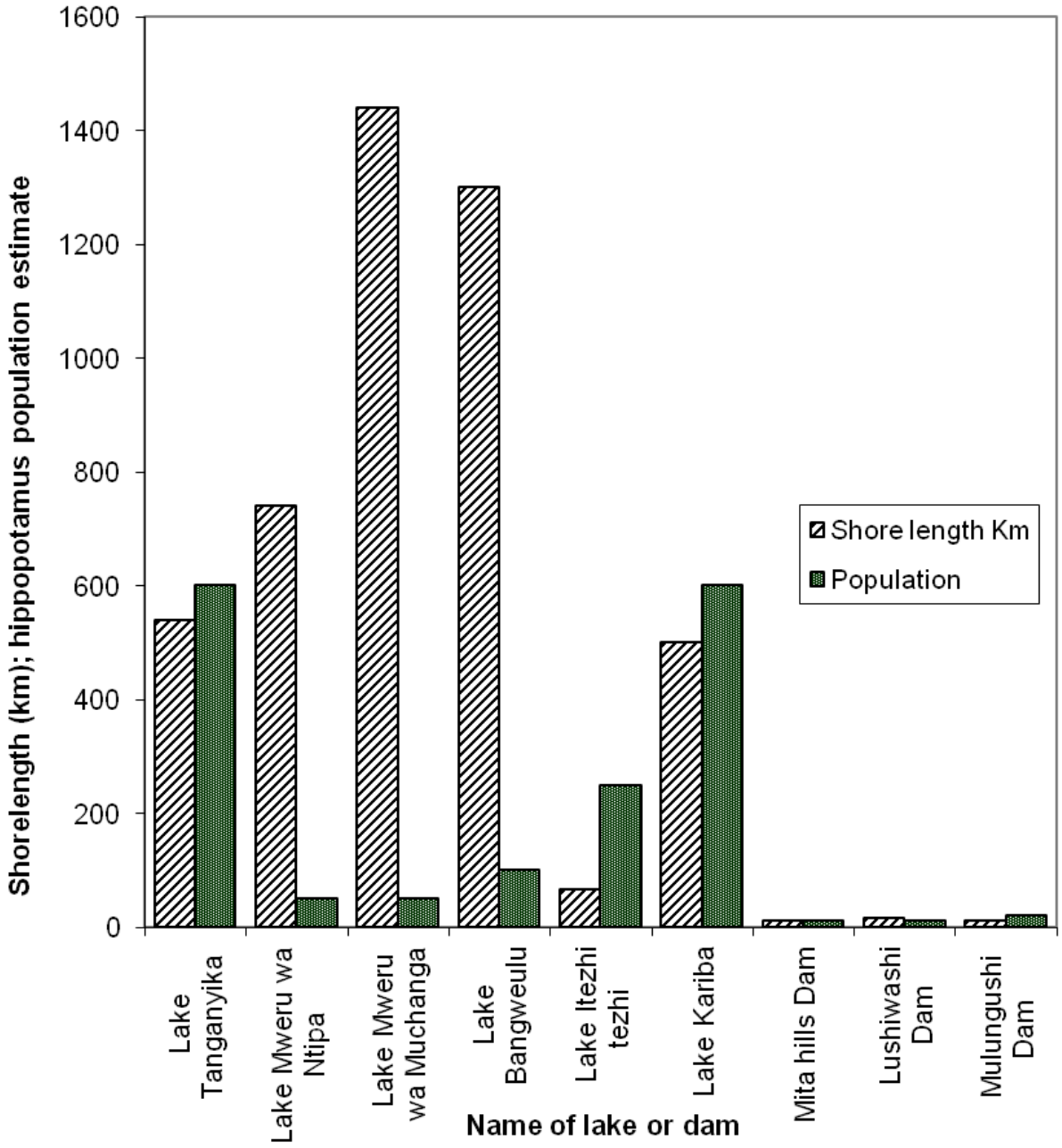

Figure 3. Shore lengths of Lakes and dams and hippopotamus population size and density distribution, Zambia.

attributes combined with open grassland plains provided food for hippopotamus and were responsible for higher densities in certain water bodies such as the Luangwa River in Zambia where densities of up to 42 km stretch of river bank were recorded (Chansa and Milanzi, 2010). Harrison et al. (2007) in describing the wet season distribution of hippopotamus along the Shire River in Malawi noted that in wet season when the Shire River main channel was full, deep and fast flowing, it was less habitable for hippopotamus. The hippopotamus retracted into lagoons and upper reaches and only returned to the main channel in the dry season. Attwell (1963) and Chansa et al. (2011) also noted that areas with river meanders and extensive grasslands with palatable grass species such as *Cynodon dactylon* would carry high densities. Attwell (1963) further gave an example of the Lufupa River a tributary of the Kafue River particularly in respect of its upper reaches where the hippopotamus populations were higher than the main Kafue River on account of the slow water flow and increased amount of flood plain habitat with aquatic grasslands of the Busanga plains (Now a Ramsar Site) offering rich feed, particularly *Echinocloa* spp. Darling (1960) however wondered why the great extent of flood plains along the Kafue and

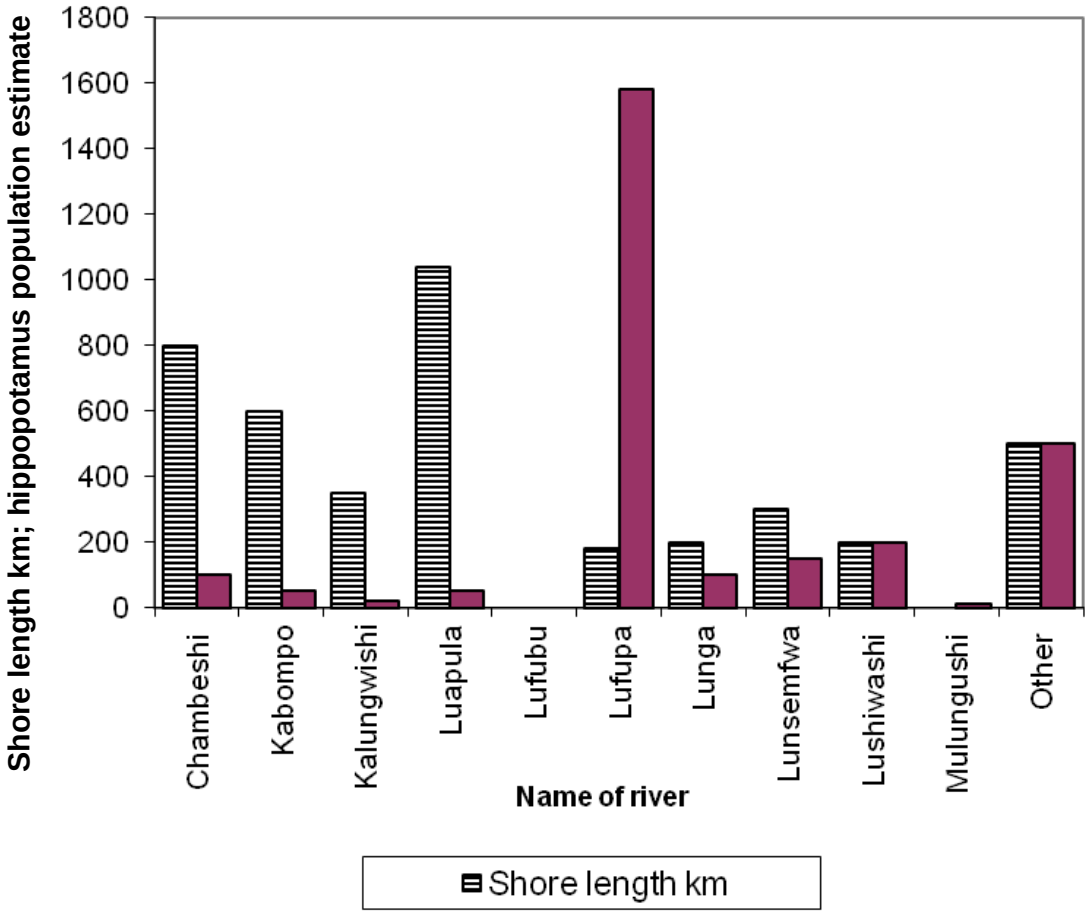

Figure 4. Shore lengths of other Rivers and hippopotamus population size and density distribution, Zambia.

Zambezi did not carry high numbers. He noted poaching and poor fire management as major reasons that had contributed to low populations in these areas. The aspect of poaching was however, discounted by Attwell (1963) for the Luangwa Valley, because hippopotamus was not a popular species for meat. Tribes in the Luangwa Valley did not eat hippopotamus meat as they suspected hippopotamus to cause leprosy (Chabwela personnal comm.). Similar observations were recorded by James (2007) in the Katavi – Rukwa – Lukwati ecosystem of Tanzania. The local tribes there also believe that hippopotamus is the reservoir for the leprosy causing bacteria (*Mycobacterium leprae*) and on that account would not eat hippopotamus meat. However, this belief of not eating hippopotamus meat may be restricted to the tribes bonafide in the Luangwa Valley. Based on the results obtained during this study, it is assumed that consumption and trade in hippopotamus meat may be restricted to areas outside the Luangwa Valley, otherwise the only valuable part of hippopotamus to the valley bonafides would be the teeth which are sold as ivory (Anonymous, 2011), but the CITES restrictions prohibit commercial trade in poached hippopotamus teeth.

The quality of the habitat of expansive grasslands and the river course changes of the Luangwa River and presence of lagoons were assumed to be responsible for such high hippopotamus densities and not shore length (Figures 2, 3 and 4, Table 1). Furthermore, the Kafue River is longer than the Luangwa River but it is a reservoir river which is more static ecologically and consequently the beneficial qualities provided by the continuous plant production in lagoons like in the Luangwa River are lacking. This fact was also acknowledged by Darling (1960) who commented that it was possibly the factor of habitat quality, which made an important contribution to the quick recovery of the hippopotamus in the Luangwa Valley after the near extermination in the late 1800s and early 1900s. Darling (1960) assessed the meandering of the river which in his view enhanced the quality of ecological dynamism and connectivity of the riverine areas of the habitat along the Luangwa River giving it a resilience and flexibility. Thus the river course changes of the Luangwa River appears to be the most important factor in hippopotamus density considerations as earlier on observed by Attwell (1963) and not shore length.

In comparing hippopotamus densities with other water bodies in Zambia, the hippopotamus count on the

Zambezi River system appears to be limited by hunting pressure because no other environmental factors appeared to be limiting. The Zambezi River habitat corresponded to the upper Luangwa River but on a vaster scale. A long the Zambezi River, we surmised that poaching was the primary population limitation. The Lozi - speaking tribes of the Western Province of Zambia where the Zambezi River passes through find hippopotamus meat a delicacy there-by keeping the hippopotamus numbers restricted through subsistence harvesting and commercial poaching. Other limitations may apply to the Kafue River. Kafue River has numerous reaches and rapids interspaced with pools which are all favourable habitat attributes for high hippopotamus density. We further speculate that uncontrolled fires, which fragment foraging patches, require greater hippopotamus travel time as well as lowering average vegetation height that favours other ungulate grazing styles other than hippopotamus. The issue of wild fire was also recorded to have a negative impact on the hippopotamus impact in the Luangwa Valley as well (Anonymous, 2010). For instance, in September of 2008, hippopotamus spoors were seen as far as 15 km from the river in the Lusangazi sector (lower study blocks) as most of the grazing areas had been burnt (Shawa, personal comm.). Uys (1959) also reported the effects of early burning of the aquatic grassland and adjoining savannah of the Busanga Swamp in Kafue National Park, where hippopotamus were concentrated in pools near available food and ten animals were found dead either killed by lion or in intra-specific fights. He concluded that loss of food supplies due to human caused fires during the dry season was a major factor in controlling hippopotamus population density, as vast areas of grassy dambos were burned and pasture denied to the species when most required. There was circumstantial evidence pointing to habitat quality and poaching as being factors responsible for low numbers in the Kafue and Zambezi River. Studies conducted by Zisadza et al. (2010) on the abundance, distribution and population trends of hippopotamus in Gonarezhou National Park, Zimbabwe also attributed the high density of hippopotamus in the Runde River not to shore length but presence of larger pools, sandbanks and higher volume of water in comparison to other rivers in the same area. They concluded that hippopotamus were more abundant in wide and slow moving reaches of rivers a fact which was also recorded in Malawi by Harrison et al. (2007).

Conclusion

From the results obtained during this study, Zambia had an estimated 40,060 individuals and still the largest population of the common hippopotamus than any other single country in Africa (Eltringham, 1994; Lewison, 2007; Chansa and Milanzi, 2010). The Luangwa River is the most important hippopotamus habitat in Zambia supporting 62% of the national population estimate. The Luangwa also had the largest hippopotamus population size of any water body in Africa.

This study showed that hippopotamus population size and density distribution may not be effectively estimated by shore length but other river attributes and contextual settings such as geomorphologic features which create micro environments suitable for hippopotamus feeding, resting, sun bathing, and survival of calves. Hippopotami were found to be widespread on the Zambezi and Kafue River systems including Lakes Kariba and Itezhi-tezhi. Lake Mweru wa Ntipa and southern shores of Lake Tanganyika located in Nsumbu National Park had stable populations (Kashitu and Kasempa, personal comm.), but such distribution was not determined by shore length but geomorphologic features, such as; sandbanks, confluence, pools and meanders with slow moving water. Anthropogenic attributes such as encroachment, late fires, and competition with livestock for pasture require further investigation to determine their impact on hippopotamus population dynamics.

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