Journal of Ecology and the Natural Environment Vol. 4(9), pp. 247-257, June 2012
Available online at http://www.academicjournals.org/JENE
DOI: 10.5897/JENE11.141
ISSN 2006-9847 ©2012 Academic Journals

Full Length Research Paper

Population status of the common hippopotamus (*Hippopotamus amphibius*) in Luangwa River, Zambia

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Accepted 28 March, 2012

The population size of common hippopotamus, *Hippopotamus amphibious* in the Luangwa valley, Zambia was assessed for the period of 1976 to 2008. A comparison of historical data on population size for the period of 1952 to1975 was also made. Ecological carrying capacity (K) and carrying capacity band were estimated from data on population size. The river bank foot count method was used, which involved the counting of individuals and taking Global Positioning System (GPS) locations of hippopotamus schools. Ecological Carrying capacity (K) was 6,000 hippopotami and density at K was 35/km. The population was found to be oscillating within carrying capacity band of 2,000 individuals in eight (8) irregular cycles. From K, annual population changes were small and insignificant. A weak correlation was found between population size against time, suggesting a slow down in population growth from 1976 to 2008 (R^2 = 0.22). The highest population size of 6,832 hippopotami and density of 42 was reached in 1984. The lowest was 4,765 hippopotami and density of 29/km recorded in 1978. Within the period of 1976 to 2008, the population oscillated between 5,000 and 7,000 individuals, which were symptomatic of a population at K. The slow down in population growth was attributed to environmental resistance. More studies are required to identify factors responsible for environmental resistance which is caused by the rise and fall in the hippopotamus population of the Luangwa River.

Key words: Hippopotamus, ecological carrying capacity, oscillation.

INTRODUCTION

Common hippopotamus commonly called hippo (*Hippopotamus amphibius*) population size in Africa was estimated at 157,000 in 2004 (Anon, 2004). This number was compiled by IUCN based on information received from 34 sub-Saharan countries. West Africa had 7,000 split into small groups in over 19 countries. East Africa had about 70,000 with 30,000 in DRC (now less than 20,000), Ethiopia, Sudan and Tanzania, Kenya and Uganda had several thousands. Southern Africa had the largest population size of about 80,000 with Zambia containing the largest population (40,000) of any country in Africa (Lewison, 2007). 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).

In Zambia, current statistics show that 62% of hippopotamus population occurs in the Luangwa River in eastern Zambia (Chansa and Milanzi, 2011a). This population has consistently recorded high densities reaching 42 individuals/km (Tembo, 1987; Chansa and Milanzi, 2011a). Chansa et al. (2011c) showed that river meanders, extensive grasslands, sand bars and other geomorphologic features were critical habitat attributes responsible for the high hippopotamus density distribution

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along the Luangwa River. The population size in the Luangwa river has frequently risen above 6,000 individuals over the study area (Study blocks A-H), then falling below 6,000 individuals and recovering quickly to surpass 6,000. This rise and fall created oscillations centered around 6,000 over the last 32 years (1976 to 2008). Culling and anthrax outbreak that occurred during 1987 and 1988 season reduced the population below 5,000 individuals, but the population increased again to exceed 6,000 by 1989. The carrying capacity band of the hippopotamus population has not been estimated, although Zambia Wildlife Authority (ZAWA) has in the past, taken advantage of the population's quick recovery to conduct hippopotamus culling and cropping since the 1960s. Currently, there is a culling programme that started in 2005 and will continue beyond 2012 during which time more than 1,368 hippopotami will be culled. This study was therefore, carried out to estimate the ecological carrying capacity and carrying capacity band of the hippopotamus population. Data on population size for the previous surveys (1976 to 2004) and the current surveys (2005 to 2008) were collected and analysed. Data for the period of 1952 to 1975 were also collected from the ZAWA archives to compare with the population growth during the period of 1976 to 2008.

In this paper, carrying capacity band implied the difference in number of individuals between the lower and upper limits of the population size during the period 1976 to 2008. Knowing the ecological carrying capacity and carrying capacity band would help ZAWA to set sustainable trophy hunting quotas for resident and non-resident (Safari) hunting clients and other off-takes. In this study, it was assumed that mortality factors would have a negative impact on the population density if the total number killed through various forms of motarlity was greater than carrying capacity band and vice versa.

Further research to determine factors regulating the rise and fall of the hippopotamus population were recommended. Such assessments would further guide protected area managers on effective hippopotamus population and habitat management. Estimating the population's ecological carrying capacity would also aid management in decision-making regarding major causes of population fluctuation, impact on the habitat, other species and general river geomorphology. Detailed data on population size would also enable management to prepare a knowledge based hippopotamus management strategy.

MATERIALS AND METHODS

Study area

The study was conducted in the Luangwa Valley in eastern Zambia (Figure1). It covered 165 km strech of the Luangwa river starting from the Chibembe pontoon (12 48'S, 32° 03'E) to the Lusangazi-Luangwa confluence (13° 24' S, 31° 33' E). In 1976, the hippopotamus study area of 165 km was subdivided into study blocks A-H which was also further subdivided into two segments of the upper and lower study blocks (Table 1 and Figure 2). The subdivision was based on the convenience of management and delivery of field logistics and sleeping arrangements for the study team. In terms of management, the upper blocks belong to Nsefu sector and the lower blocks to Lusangazi sector.

Total counts along the Luangwa River

The river bank total foot count method was used during the dry season October-November each year for the period of 2005 to 2008 when the water levels were low and visibility was high. Data for the period of 1976 to 2004 were collected from ZAWA research data base at Chinzombo research centre located at the National Park headquarters. The survey team involved six members of the research team walking along one side of the river bank (Chansa and Milanzi, 2011b). Of the six, two were recorders; one recording on data sheets and the other on the map which was used to verify river geomorphologic features in the field. The other two were observers using a pair of binoculars each and the last two carried firearms to protect the team from dangerous animals such as lion and elephant. A maximum of 30 min was spent observing a school, which provided sufficient time to count all individuals in a school. Global positioning system (GPS) locations of all schools counted were taken which enabled plotting of density distribution along study blocks A-H (Figure 1) of the 165 km river stretch. Double counting of individuals was prevented by covering each river segment on each day and counts ending at points where there were no hippopotamus schools. GPS locations were taken for each end point to ensure that there was no overlap the following day.This method described earlier was adopted in 1976 as a standard method for counting hippopotami in the Luangwa Valley (Tembo, 1987) which has made data comparable over the last 32 years. This was also the main reason why the study period of 1976 to 2008, was chosen. This method has also proved to be the most practicable as it provides adequate time to scan the river, and the extent of the hippopotamus schools is more visible from the riverbank which is above water level. It is also the safest method compared with the other methods such as boat count method which involves use of the boat with observers and recorders sitting inside the boat while the coxswain drives the boat. Using boat count in the Luangwa River presents a risk of capsizing because the river erodes its banks and submerges many trees which cannot be seen from the water surface. Using an aircraft is unreliable due to the meandering nature of the river and the numerous turns and manouvres the pilot would be required to make (Tembo, 1987).

The main drawbacks of this method are that it takes long, almost a month to complete the 165 km stretch of the river which increases fatique, requires a minimum of six researchers which draws staff from other duties, increases transportation costs of delivering fresh food supplies to the research team at least once every two days and has the potential to expose research team members to dangerous animals such as lion, crocodile and elephant as they walk along the banks of the river.

Calculating population's mean size and density

To calculate population mean size and density, a summary table of the population size and density was prepared from the information collected from previous and current population surveys. The total figure of population size recorded each year from 1976 to 2008 were added up and divided by the total number of years to obtain overall mean. Density was obtained by dividing population by river length as defined by Onyango and Plews (2005) as follows:

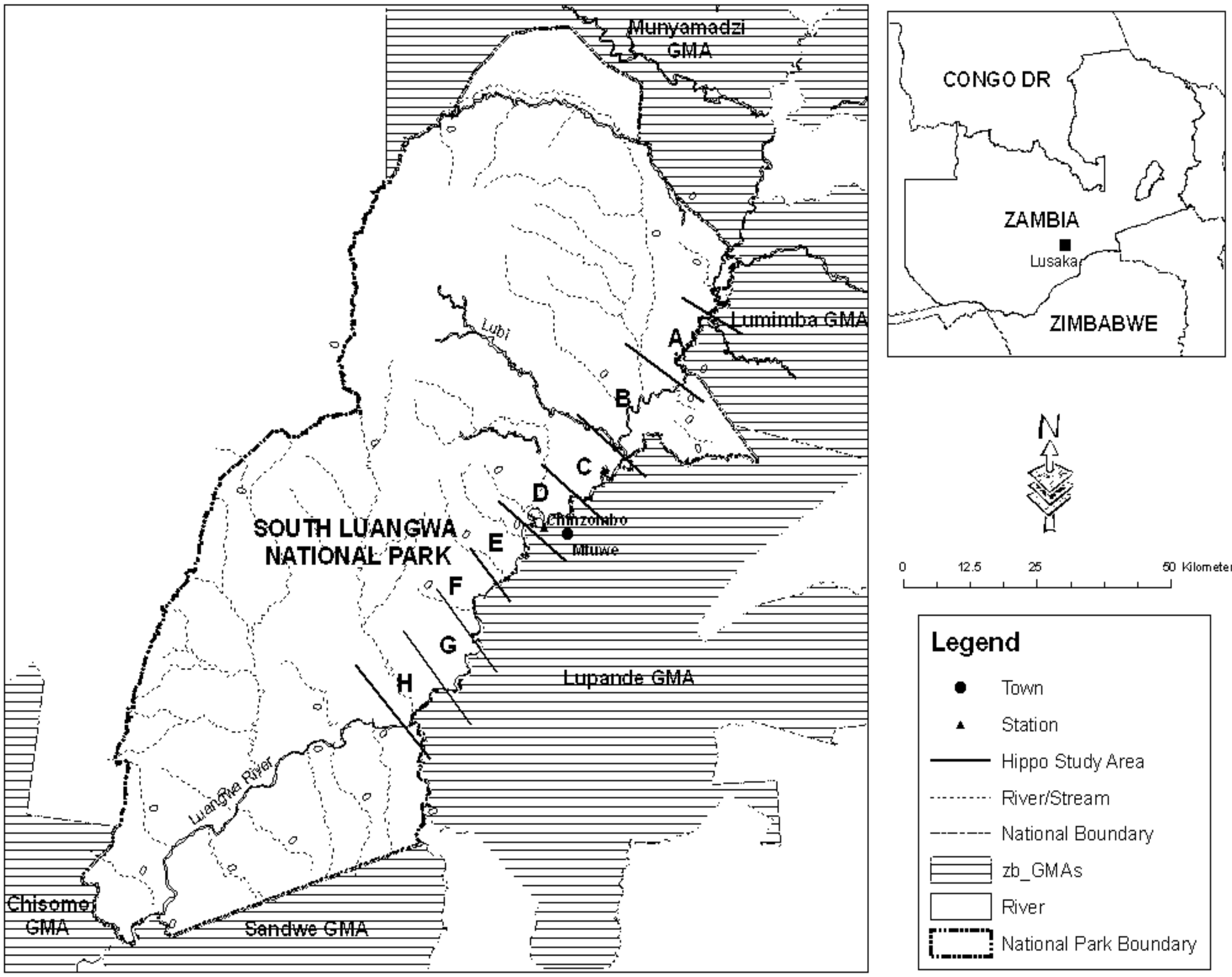


Figure 1. Location of Luangwa River and South Luangwa National Park in Zambia.

Table 1. Common hippopotamus population size for the period of 1976 to 2008 in Luangwa Valley, Zambia (Chomba, 2010).

Year	Total	Density/km river stretch	Year	Total	Density/km river stretch
1976	4,919	30	1992	5,500	33
1977	5,147	31	1993	5,353	32
1978	4,765	29	1994	6,449	39
1979	5,151	31	1995	5,886	36
1981	4,884	30	1996	5,226	33
1982	6,293	38	1997	5,330	32
1983	6,544	39	1998	4,904	30
1984	6,832	42	1999	5,189	31
1985	6,580	40	2000	5,938	36
1986	6,741	40	2001	6,169	37
1987	5,522	33	2002	6,272	38
1988	5,289	32	2004	6,350	38
1989	6,321	38	2005	6,130	37
1990	6,495	39	2006	6,369	38
1991	5,651	34	2008	6,318	38
Mean				5,775 (6,000)	35

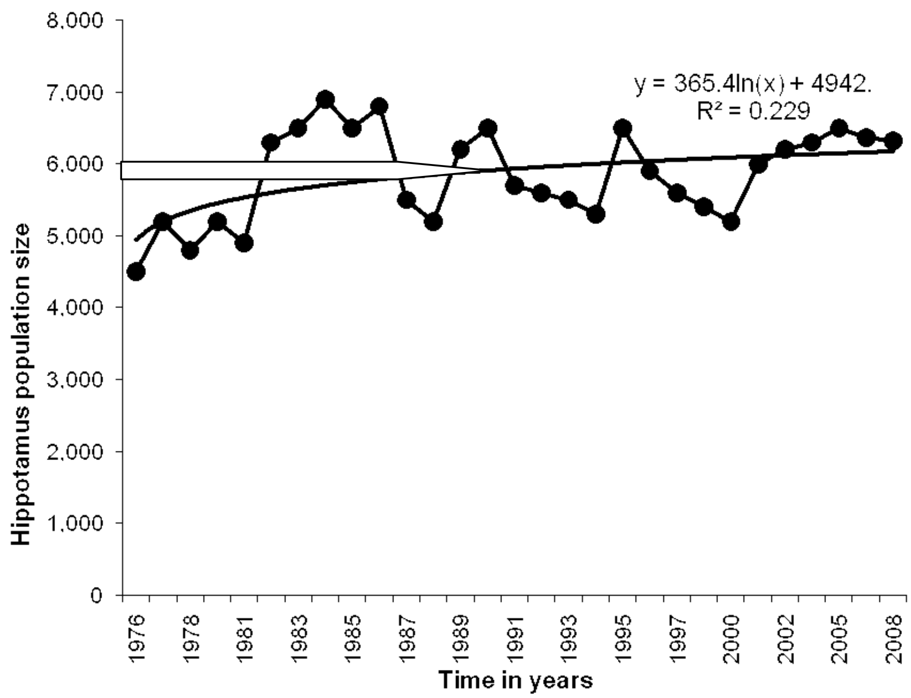


Figure 2. Hippopotamus population for the study period 1976 to 2008. Note how the population oscillated around K, in Luangwa Valley, Zambia.
= Block arrow line represents mean population size and point of stability for the period 1976 to 2008.

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

Where *D* is density, *N* is the number of hippopotami, and *L* is the river length.

Information on mean population size and density was entered into Minitab Release 14 Statistical software package and mean was calculated based on the formula:

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

Where mean ∑*x* is the sum of values divided by the number of values *n* (Onyango and Plews, 2005). A horizontal line representing mean population size K on the graph was generated from the *Y* axis to represent population mean for the period 1976 to 2008. The line K would end at the point of the curve where the population size leveled off. This point represented the point of stability in the population growth curve (Chapman and Reiss, 1999).

RESULTS

Population status

Mean population size and density/km for the period of 1976 to 2008 were 6,000 and 35/km for the 165 km river stretch respectively. A plot of population size against time for the period of 1976 to 2008 showed that 6,000 was the population's point of stability (Figures 2 and 3) and was taken to be *K* for the Luangwa hippopotamus. From this point of stability, annual population change for both population size and density were low. The correlation coefficient (y = 365.4 ln (x) + 4942, R^2= 0.229) was low suggesting a slowed down population growth. During the period of 1976 to 2008, the highest population size reached was 6,832 and density of 42 in 1984, and the lowest was 4,765 and density of 29/km in 1978. In the last 32 years, the population remained within the range of 5,000 to 7,000 individuals (Figure 4).

Historical data for the period of 1952 to 1975 showed that population's growth rate was initially slow from 1953 to about 1960 when the total population size was below 1,000 hippopotami, then rapidly increasing up to 1975 (Figure 5a). A plot of population size per year for the period of 1952 to 1975 showed a linear positive correlation between population size against time (y = 175.54x - 342979, R^2 = 0.7481) suggesting a rapid increase towards *K*. The point of stability *K* was therefore attained during the period of 1976 to 2008.

In the decade 1976 to 1986 (Figure 5b), the population maintained a steady increase and reached mean population size of 6,000 individuals and density of 35/km (R^2 = 0.8280), suggesting that the relationship between

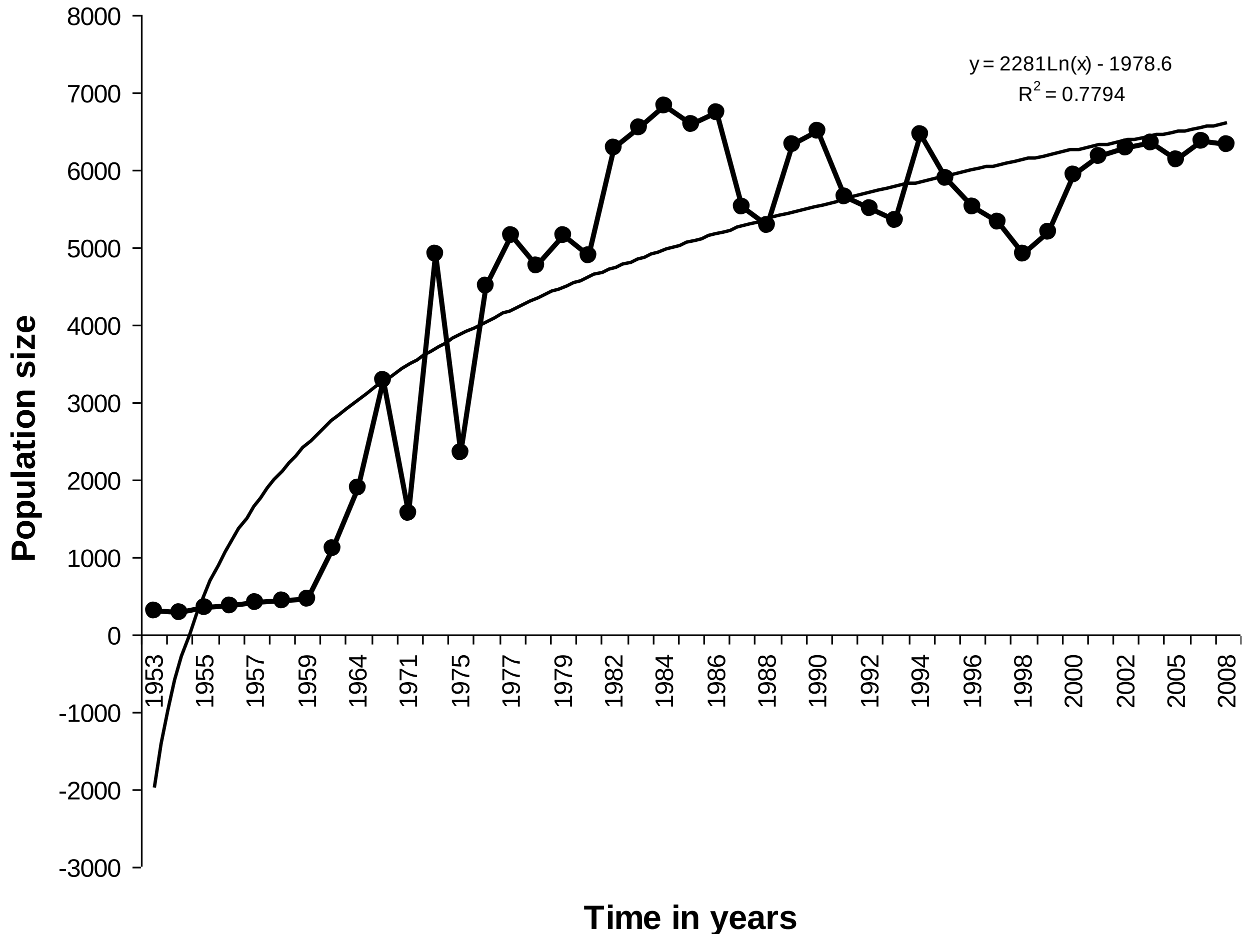


Figure 3. Hippopotamus population growth from 1953 to 1975 and 1976 to 2008, South Luangwa National Park, Zambia.

population size against time was linear (y = 243.05 x - 475764, R^2 = 0.8280). In the decade 1986 to 1996, the population declined (Figure 5c). A plot of population size against time suggested a weak negative correlation between population size and time (y = - 37x + 79552; R^2 = 0.0555) (Figure 5c). The decade 1996 to 2008 had an increase (y = 108.82 x -211926, R^2 = 0.6434) (Figure 5d).

Population oscillations

Hippopotamus population size varied from year to year for the period of 1976 to 2008 creating oscillations. Population size and density fluctuated between 5,000 and 7,000 individuals and density between 29 and 42/km respectively (Table 2). The difference between the lower limit 5,000 and upper limit 7,000 was 2,000 individuals and was taken to be the carrying capacity band for the period of 1976 to 2008 (Figure 4).

The hippopotamus population oscillated in four irregular cycles of about 8 years. Four years (range 2 to 7 years) above K and 3.5 years (range 2 to 5 years) below K before rising again to exceed it. Table 2 shows the population size and years when the population was above *K* and when it was below K. The highest increase was 1,409 in 1982 and the lowest decrease was -1,219 in 1987 (Table 2).

DISCUSSION

Population status

At the time of concluding this study in 2008, the hippopotamus population along the 165 km stretch of the Luangwa River had reached ecological carrying capacity *K* at 6 000 hippopotami and was oscillating within the carrying capacity band of 2000 hippopotami. Population stability was achieved after a period of more than 100 years from the late 1890s when the population was almost decimated (Attwell, 1963) to the current decade. This assertion is derived from comprehensive studies of the Luangwa hippopotamus population status which began in the 1950s, initially covering study blocks A-D of

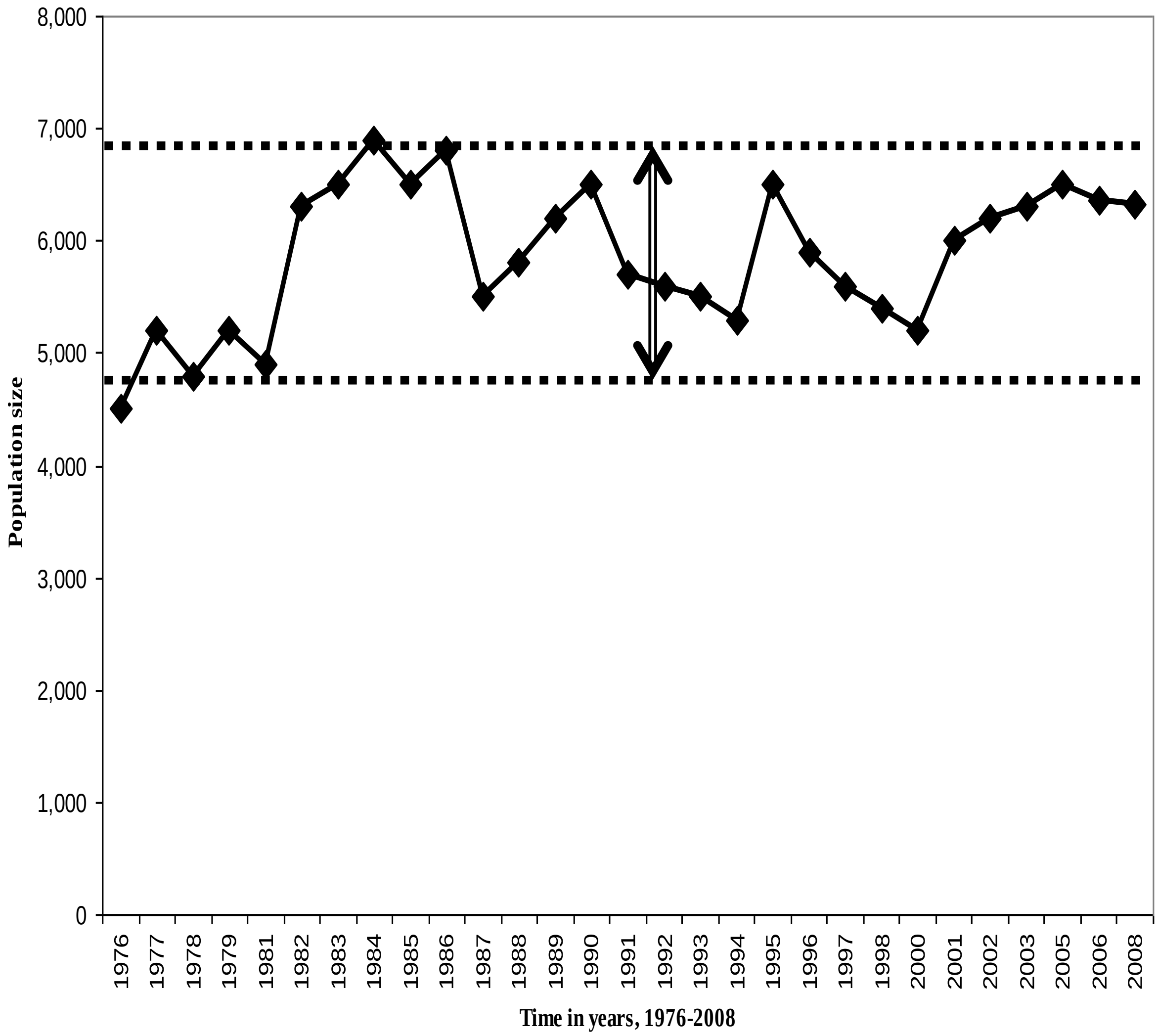
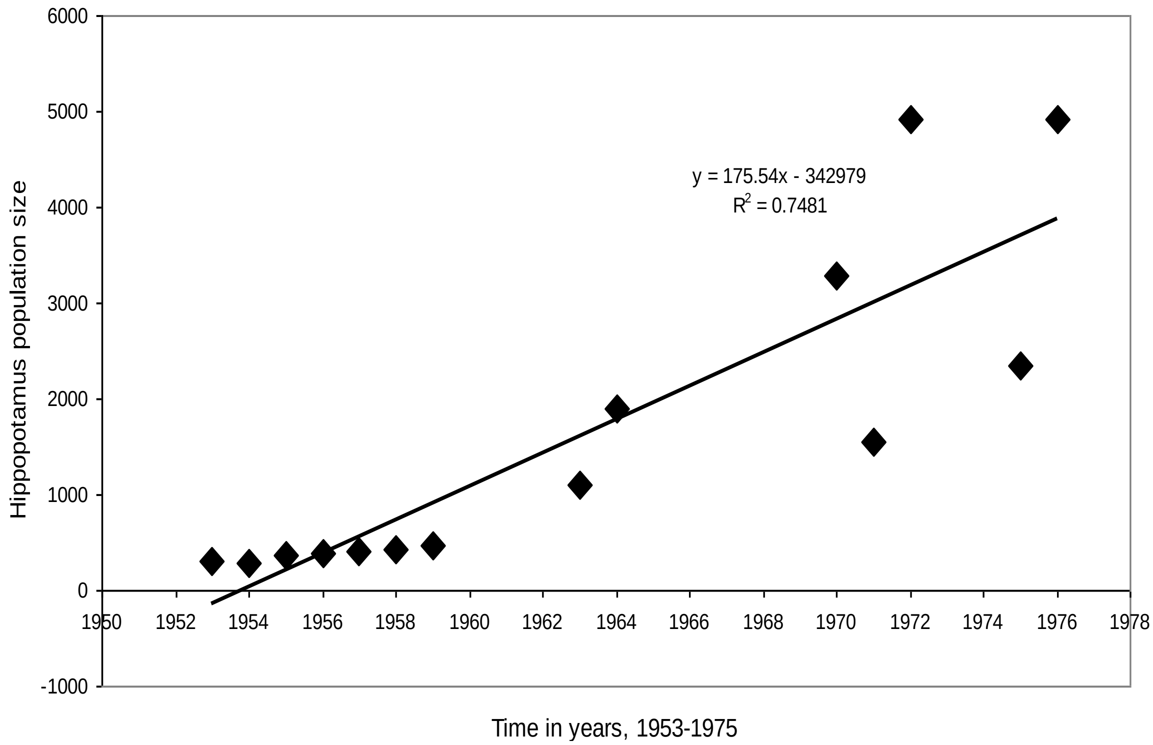


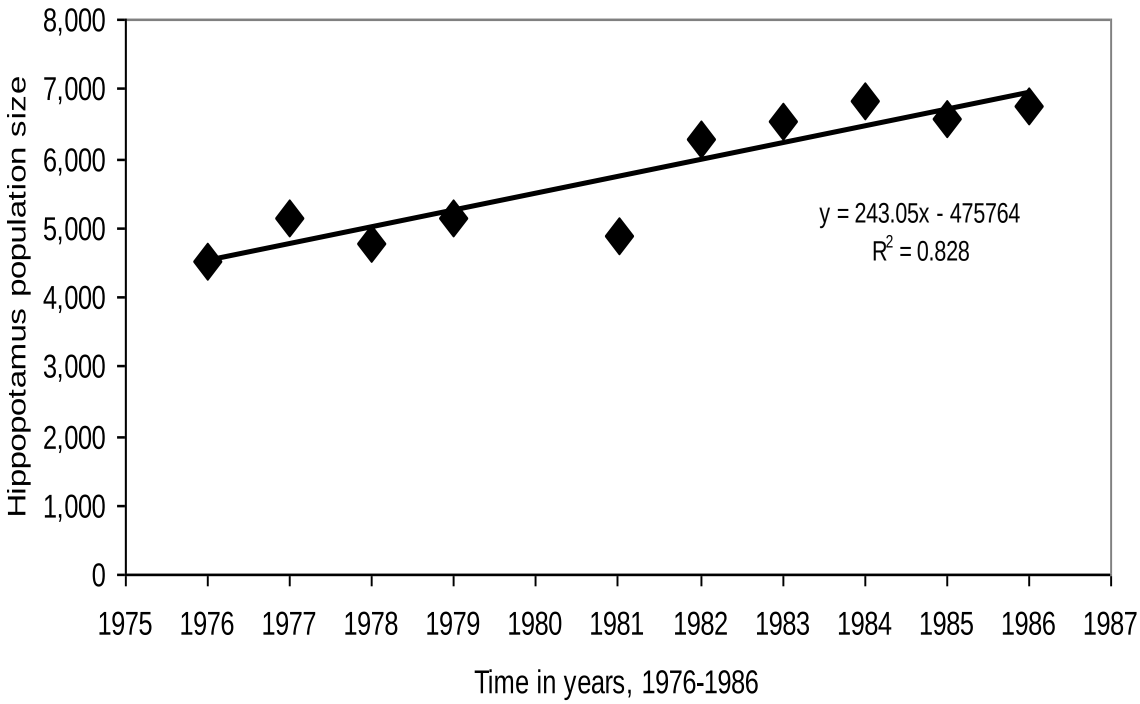
Figure 4 Plot of population size generated in Ms Excel programme showing population oscillations within the lower and upper limits of the population size for the period of 1976 to 2008 in Luangwa Valley, Zambia. ⟺ Is amplitude (carrying capacity band) of the rise and fall; ■■■■■■■■ dotted lines represent upper and lower limits of population size.

the study area (Attwell, 1963), but in 1976, five years after the area was established as South Luangwa National Park, annual counts were standardized to cover an area of 165 km along the Luangwa River marked A-H (Figure 1).

Based on the additional information on hippopotamus population collected from the ZAWA archives for the period of 1952 to 1975, the population increased rapidly when it was below 6,000 individuals following a sigmoid curve then slowed down after reaching K and started to fluctuate about K. The population growth rate was inititaially slow between 1952 and 1960 because the population was small at ≤ 1,000 individuals until after 1960 when it picked up again towards K. The line K in Figure 2 shows that the hippopotamus population size was at ecological carrying capacity K. This was the maximum number of hippopotami that the area could hold in terms of food supply, places to live and other habitat welfare factors. At very low density as was the case before the mid 1970s, the population growth was rapid because the food resources were abundant when population size was below K, but as the population size started to approach K in the mid 1970s, the rate of increase progressively declined, sometimes registering negative growth rate. The rise during years of population increase and decline in other years generated oscillations around K. Such fluctuation was also related to rainfall which determined the amount of food produced (Chansa et al., 2011c). The vertical amplitude of 2000 hippopotami was caused by interactions between the hippopotamus

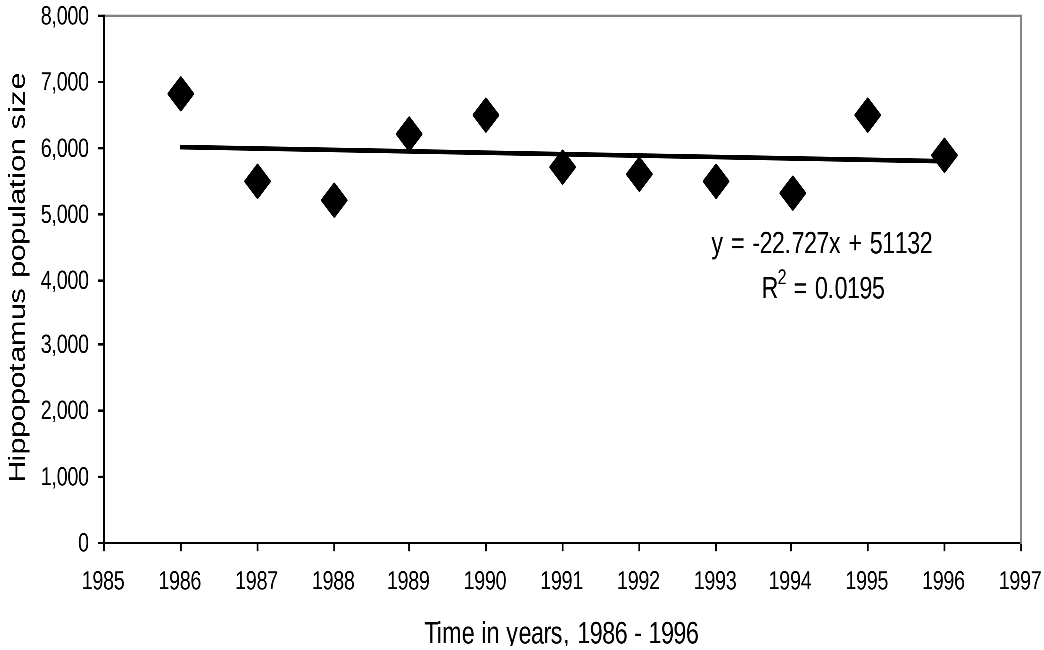


(a)

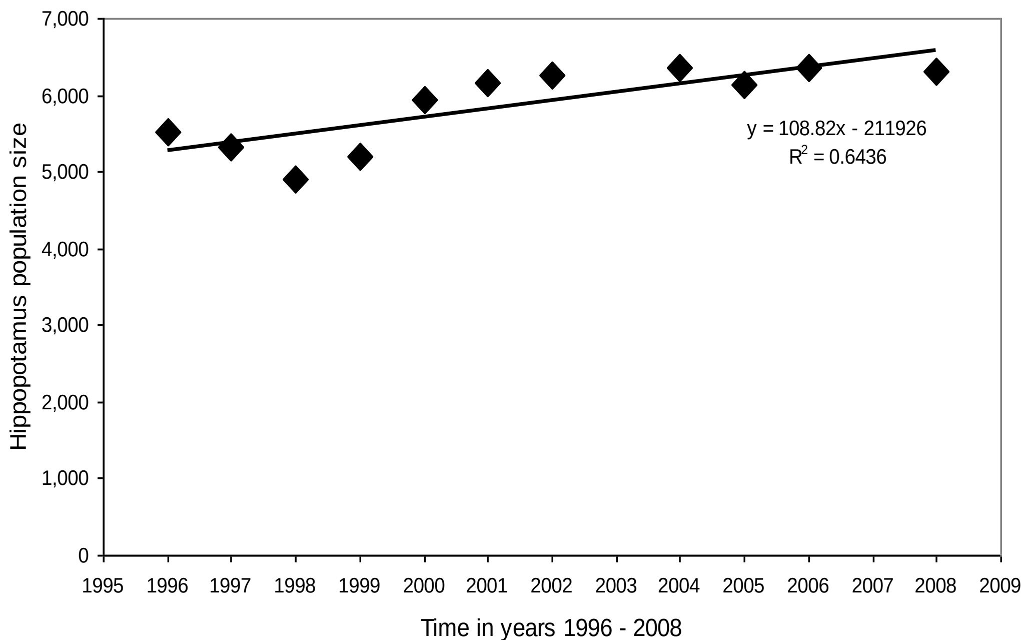


(b)

Figure 5. (a) Plot of the hippopotamus population showing rapid increase during the period of 1952 to 1976, in Luangwa Valley, Zambia, (b) plot of the hippopotamus population showing increase during the period of 1976 to 1986, in Luangwa Valley, Zambia, **(c)** plot of the hippopotamus population showing marginal decrease during the period of 1986 to 1996, in Luangwa Valley, Zambia, (d) plot of the hippopotamus population showing marginal increase during the period of 1996 of 2008, in Luangwa Valley, Zambia.



(c)



(d)

Figure 5. Continued.

population and plant food supply.

Population oscillations

Results on the hippopotamus population oscillations are consistent with Mduma et al. (1999) regarding the 40-year study of the wildebeest in Serengeti National Park, Tanzania. The Wildebeest population estimate reached its peak in the mid 1970s after which it started oscillating, in which Mduma et al. (1999) concluded was an indication of a reduction of food availability. Klein (1970) in his study of the reindeer population provided another example of the value of body condition indices in

Table 2. Rise and fall of hippo population from 1976 to 2008, in Luangwa Valley, Zambia (Chomba, 2010).

Year	Population size	Annual change	Density	
			Above K	Below K
1976	4,919	646	30	
1977	5,147	-382	31	
1978	4,765	386	29	
1979	5,151	-267	31	
1981	4,884	1,409	30	
1982	6,293	251		38
1983	6,544	288		39
1984	6,832	-252		42
1985	6,580	161		40
1986	6,741	-1,219		40
1987	5,522	-233	33	
1988	5,289	1,032	32	
1989	6,321	174		38
1990	6,495	-844		39
1991	5,651	-151	34	
1992	5,500	-147	33	
1993	5,353	1,096	32	
1994	6,449	-563		39
1995	5,886	-360		36
1996	5,226	-196	33	
1997	5,330	-426	32	
1998	4,904	285	30	
1999	5,189	749	31	
2000	5,938	231		36
2001	6,169	103		37
2002	6,272	78		38
2004	6,350	-220		38
2005	6,130	239		37
2006	6,369	-51		38
2008	6,318			38
Total			14	16
Range			2 to 5 yrs	2 to 7 yrs
Overall Mean			3.5	4
		Mean decrease (-379)		
		Mean increase (475)		

Variations in the number of years when the population was above K was significant (P < 0.05) and variations in the number of years when the population was below K was also significant (P < 0.05), implying that the cyles were irregular.

describing the role of food supply. He demonstrated that in 1957, a total number of 1,350 reindeer were introduced on St' Mathews Island in the pacific. At the time of their introduction on the island, their average body weights were found to exceed those of reindeer in domesticated herds by 24 to 53% among females and 46 to 61% among males. By 1963, the population had increased to 6,000 by which time average body weights had declined from the 1957 values by 38% for adult females and 48% for adult males. He concluded that the reduced body growth was almost certainly related to qualitative and quantitative changes in the food supply. A massive population crash followed soon after determination of the 1963 values and Klein (1970) suggested that food supply, through interaction with climatic factors, was the dominant population regulating mechanism for reindeer on the island. Such results demonstrate that food is an important factor in regulating population size and density of animals whether in temperate or savannah ecosystems.

Population oscillations obtained in the Luangwa hippopotamus population was a response to fluctuations in food supply. This pattern of rise and fall in population is coherent with the results obtained by Mduma et al. (1999) on the Serengeti wildebeest, suggesting that although the two populations live in different ecological settings and display different patterns of feeding behavior, their response to food supply is similar. Thus the Luangwa hippopotamus which is resident in a unimodal rainfall regime and does not migrate and the Serengeti wildebeests which migrate in response to bimodal rainfall regime both respond to food availability by regulating population size. Therefore, notwithstanding the variation in ecosystems where the Luangwa hippopotamus and the Serengeti wildebeest are found, the role that food plays in regulating the two population's growth rate is similar.

The carrying capacity obtained in this study of 6,000 individuals therefore, referred to the density of animal population at which growth stabilized and started to fluctuate in response to food availability as influenced by rainfall fluctuation (Bell, 1986; Child, 1999). This level would also be described as an equilibrium point at which the rate of production of edible forage equals the rate at which the forage is consumed by the hippopotamus and other herbivores sharing the same range. This equilibrium point was also referred to as the saturation density or ecolo-gical carrying capacity by Caughley and Gunn (1996). At K, the animals are not necessarily in very good condition and their death rate equals their birth rate and recruitment rate is low. This is also in other words, the point of stability in the density of an undisturbed population, and is designated as K in the conventional logistic equation (Sinclair and Grimsdell, 1982). Bell (1986), Mentis and Duke (1976), Mentis (1977) and Caughley (1977) similarly defined the carrying capacity as the density of an animal population at which growth stabilizes in the absence of illegal and legal off-takes, predation, immigration or emigration, inter-specific competition, or fluctuation in population density in response to rainfall fluctuation. However, carrying capacity explained above is given as if it were a fixed point. In fact, it is not, as the population is subject to mortality factors and variations in food supply. The equilibrium point tends to fluctuate between years depending upon the availability of high quality forage (Chomba 2010). Bell (1986) based the rise and fall of an animal population at "K" on quality forage and assumed that in the absence of illegal and legal off-takes, predation, immigration or emigration, inter-specific competition, the population would stabilize at "K" but this is not the case in the natural environment where there are fluctuations in food production and various forms of mortality. Chapman and Reiss (1999) additionally indicated that the amount of rainfall received per year (or severity of drought) between 'fat' and 'lean' years, disease, illegal and legal off takes, predation, emigration and immigration determine the amplitude of the rise and fall of large mammal populations. Similarly, Mduma et al. (1999) attributed population regulation of the wildebeest to food supply, which is determined by rainfall. In the Luangwa Valley, the rise and fall of the population between lean and fat years generated a carrying capacity band of 2,000 individuals which was indicative of the difference between "lean" and "fat years".

Conclusion

From this study, it can be concluded that firstly, the population had reached K of 6,000 individuals and density of 35/km and was oscillating within the carrying capacity band of 2,000 hippopotami. Secondly, the population oscillated in four (4) irregular cycles in the last 32 years (1976 to 2008); the lower limit of the carrying capacity band being the "lean years" and upper limit being "fat years" and mid-point of 6,000 being K.

From the results obtained, it can be assumed that in lean years, the 165 km stretch of the Luangwa River would hold about 5,000 individuals and fat years up to 7,000 individuals, while the average years would hold 6,000 individuals. Rainfall was assumed to be an important factor in determining the common hippopotamus population in the Luangwa valley by influencing primary production (Chansa et al., 2011c).

ACKNOWLEDGEMENTS

We wish to thank Prince Benard Scholarship Fund for supporting the study. Mr. Chaka Kaumba prepared the location map. The research assistants at Mfuwe and Chinzombo Research Centre in particular put in their best during field surveys. Mr. Trevor Silwamba actively participated in the survey and helped to organize other field assistants. Several other people provided their input in different ways and we thank them all for their support.

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