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Population Structure of the Common Hippopotamus (*Hippopotamus amphibius*) in the Luangwa River, Zambia

Chansa Chomba

School of Agriculture and Natural Resources, Disaster Management Training Centre,
Mulungushi University, P. O. Box 80415, Kabwe, Zambia.
chansachomba@rocketmail.com

Abstract

Population structure of the common hippopotamus *(Hippopotamus amphibius* Linnaeus 1758*)* in the Luangwa Valley, eastern Zambia was assessed during the period 2005-2008. Field observations and laboratory examinations were used to classify hippos in age groups. Chi-square Test of age group composition showed a significant difference in the percent proportion of age groups in the population (χ^2 = 57.98, DF = 6, $\propto$ = 0.05, P< 0.001). Calves one year old and less were not represented. Younger groups 'iii' and 'v' comprised only 15 percent of the population. The remaining 75 percent were older age groups vii - xix mainly comprising mature and senescent individuals. The age structure was biased towards older age groups. Skewed age distribution in favour of older age groups was an indication of a declining population growth rate. More research is required to investigate factors responsible for the decline in population growth rates.

Keywords: *Common hippopotamus, age structure, calves, sub adults, adults, declining*

1. Introduction

Animal populations vary in their proportion of young and old individuals. Age groups can be assigned to qualitative age classes such as such as calf, juvenile, sub adult and adult (Brower and Zar, 1977). The proportions of individuals belonging to the various age groups are collectively referred to as age structure or age distribution of the population. Brower and Zar (1977) recognized three methods of obtaining data on population structure. The first being the vertical approach where the researcher follows a cohort. Thus by knowing the age of cohort members, the researcher can follow their survival until all have died. Secondly, is the horizontal approach where information on all ages within a given population is obtained at one time, thus all cohorts in a population are examined at the same time. In this method, one assumes a stable age structure and that birth and death rates remain constant. The third is where the researcher knows the age at death for members of the population.

In studying the hippopotamus population structure, it was assumed that hippopotamus birth rates and death rates were constant and therefore age classes were proportionately equal. The samples collected from the culled specimens were examined at the same time as unbiased samples from a population.

Knowledge of hippopotamus age structure is important for knowing age distribution in the population as this affects hippopotamus population dynamics. From this knowledge of age distribution, population growth rates may be estimated. Such knowledge would enable the researcher to know whether the population is declining, stable or increasing. For most species, recruitment rate in any population is determined by the proportion of age groups. If the number of calves and sub adults are more than older age groups the population would be rapidly increasing. The number of individuals in each age class can be plotted as a horizontal histogram forming a pyramid. If there are an almost equal proportion of age groups the population stabilizes or is stationary and when the older age groups are more than the younger age groups the population declines.

To determine age group composition in a population requires taking random samples of a population unless the population under study is small that all individuals can be counted. Chapman and Reiss (2000) outlined ways of determining age in animals and trees. Different methods are used ranging from field observation of live specimens to laboratory methods. In this study, a combination of methods was used. Field observations of live specimens and laboratory examination of skulls based on Laws (1967) obtained from culling were used. To ensure credibility of the age groups obtained from body and skull measurements, a comparison was made with measurements made during the 1970 - 1972 culling programme. During the period 1970 - 1972 skull measurements were taken and animals were placed in age groups based on body size measurements, skull measurements and the teeth eruption and wear.

The culling programme was designed in such a way that the whole hippopotamus school was removed in a day and this prevented sampling error arising from under representation of some age groups in the sample.

2. Materials and Methods

2.1 Study area Location and description

The study was carried along a 165 km Luangwa river stretch in eastern Zambia (Figure 1).

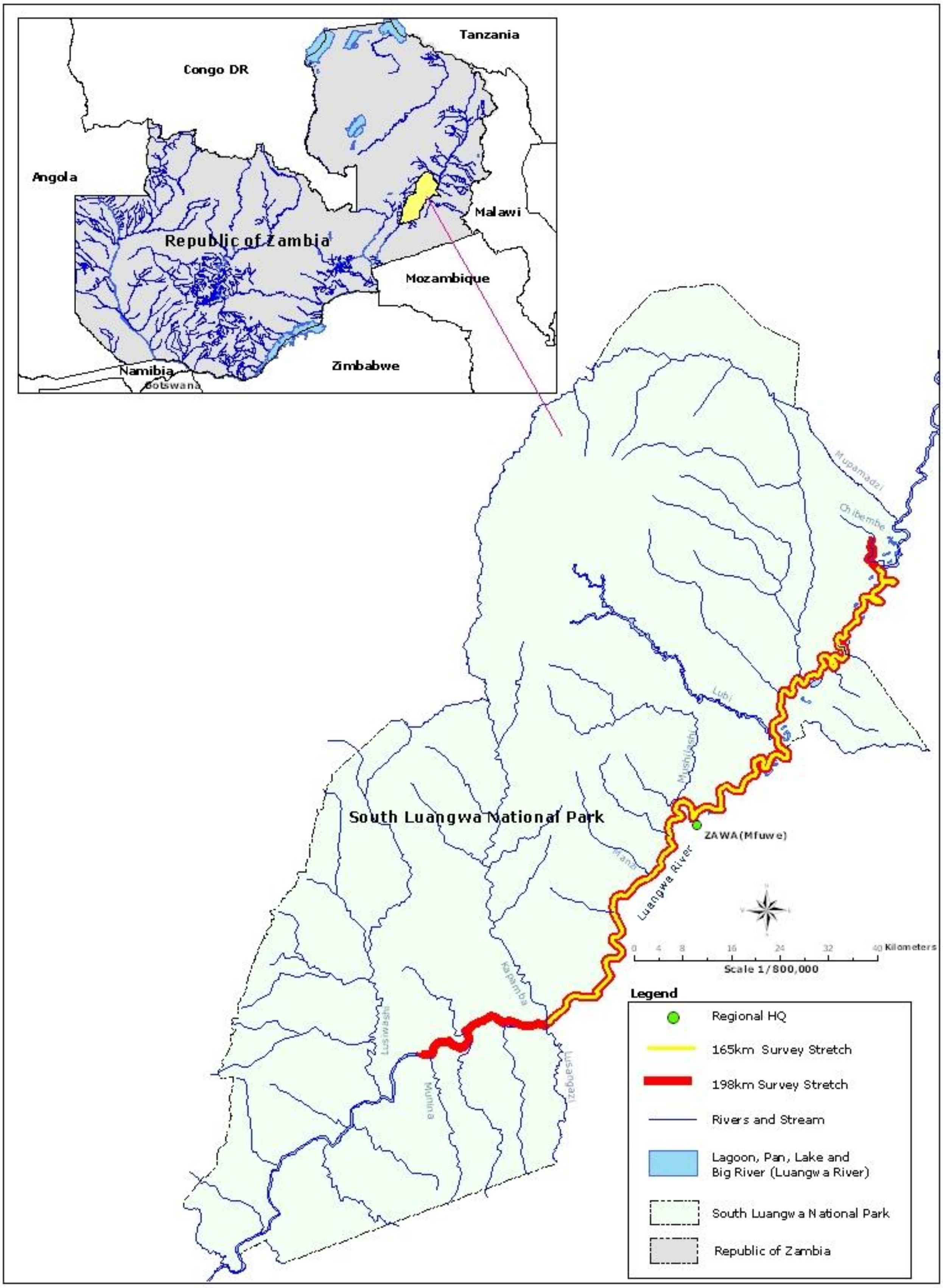

Figure 1: Location of the study area along the Luangwa River, eastern Zambia.

2.1.1 Climate

The annual rainfall ranges from 400 - 800 mm and minimum and maximum temperatures are 10^{o}C (June - July) and 38^{o} C (October) respectively. The hot rainy season is from late November to April, a cool dry season is from May to August, and a hot dry season from September to early November.

2.1.2 Population structure

Data on hippopotamus age class composition were obtained from observations carried out on live specimens during the river bank total count (Figure 2a, b) and measurements from dead specimens obtained from culled specimens (Figure 3).

The field observations of hippo to classify individuals in age groups involved six members of the research team walking along the bank and recording hippos observed on a data sheet. A maximum of 30 minutes was spent to examine a school and to classify individuals into age groups and sex using a pair of binoculars. Photographs of schools exceeding 20 were taken using a digital camera with a high resolution zoom lens. Pictures from the camera were downloaded into a computer at the base station in Mfuwe and individuals scrutinized. Age groups were calves, sub adults and adults. Age classification was based on body size, while sex was based on external genitalia and body size for adults. This classification followed earlier field methods used by Marshall and Sayer (1976). Calves are individuals usually one year and below and are of the smallest size and usually by the mother's side or accompanying the mother in water and on land (Figure 2a and 1b). Sub adults are young ones that have not yet reached sexual maturity and will usually be in proximity of the mother. These individuals sometimes accompany the mother but can also be with other young ones or alone. The body size is such that when standing by the mother's side its height is usually more than half the height of the mother but still smaller than her and larger than calves. Sex determination was carried out by observing body size and where possible external genitalia. In addition, sexual dimorphic features were used where males had broader fore heads than females (Figure 2a and 2b) and also most of the males stayed in isolation and in peripherals possibly to guard and defend the territory against intruders. Also the sides of the male heads (around the ears) are darker; in females they are brownish (Skinner and Smithers, 1990). Calves mostly appear on the sides of the adult females and their heads are smaller. Males appear to have a much bigger body size than females even when on the surface of the water (Jackmann, 1994).

(a)

(b)

Figure 2: a)Age and sex differences based on body size when animals are standing. Calf with the small body size is on the left, adult female in the centre and adult male which is also larger that the female is on the right. Nsefu area of South Luangwa National Park, b) Age and sex differences based on body size when animals are lying down, calf with the small body size female is on the left, and calf is in the middle and male which is also larger that the female is on the right. Nsefu area of South Luangwa National Park, Zambia.

Figure 3: Skull measurements being taken by field assistants. Mfuwe base camp, Luangwa Valley Zambia.

The classification of individuals as calves, sub adults and adults was verified in this study by comparing body measurements and lower jaw measurements from culled specimens. This method was also used in the 1970 - 1972 culling programme as recorded by Marshall and Sayer (1976) where body length was measured from the tip of the snout to the base of the tail and used to place carcasses in respective age groups. Lower jaws were also measured in centimeters from the rear end to the front end of the skull and also used to place animals into age groups (Figure 3). The same approach was used in the 2005 - 2008 culling programme. Age determination from skulls was done by examining tooth eruption and degree of wear of molar teeth (Sensu Laws, 1967).

2.1.3 Age and Sex Determination from Dead Specimens

Sex determination on dead specimens was based on external genitalia and was conducted for each carcass and classified as male or female. Body length measurements were taken for each carcass using a measuring tape from base of tail to tip of snout. A handling bay, handling and processing facilities were provided at Mfuwe to receive carcasses from the field and taking weight and body length measurements while the carcass was suspended from a steel column (Figure 4). Based on body measurements taken as described above, age groups were classified as calves up to 150 cm, sub adults from 151 cm to 230 cm and adults above 230 cm. These cut off points have been used in the previous culling schemes for Luangwa hippo.

Measurements from skulls were done by collecting and soaking them in water or burying them under ground for at least one week to facilitate easy removal of the flesh. After about one week, skulls had all flesh removed and washed in clean water using a wire brush. Removal of flesh was important in order to expose the erupting teeth which are often hidden under the gum. Skulls were then exposed to sun shine to dry and later put in a lockable store room where they could not be stolen or taken by hyaenas (Figure 5a, b). Age determination from skulls was then done by measuring with a steel tape taking measurements in centimeters from the rear to the front end of the lower jaw (Figure 3). Teeth eruption and the degree of tear and wear were examined using a table developed by Laws (1967). Other measurements of the skull proportions were also taken (see Figure 3). The measurements were then recorded on a data sheet on which specimens were classified in age groups I to XIX which is the oldest age group of 43 years (*Sensu* Laws, 1967).

Figure 4: Steel column from which hippo carcasses were suspended to take weight and other measurements before skinning, Luangwa Valley, Zambia.

Figure 5: Cleaned hippo skulls stored in a safe room ready to be taken for measurements, Luangwa Valley, Zambia.

3. Results

3.1 Population structure

There were seven (7) age groups recorded in this study (Table 1 and 2; Figure 6). The difference in age group proportions in the population was significantly different (χ^2 = 57.98, DF = 6, $\propto$ = 0.05, P< 0.001). Calves one year old and less were not represented in the population. Younger groups 'iii' and 'v were only 15 percent of the population (Table 1; Figure 2). Older age groups vii - xix comprising mature and senescent individuals were the majority being 75 percent of the population. The age structure was biased towards older age groups.

Table 1: Hippopotamus age distribution based on the three culling programmes conducted so far in the Luangwa Valley, Zambia

Age group	Estimated Age in years	Year			Percentage (%) composition of population 2005 - 2008
		1970	1971	2005-2008	
i	< 1	7	0	0	
iii	1 - 2	5	4	2	2.2
v	3-5	16	16	13	13.26
vii	6 -11	67	69	31	31.63
ix	12 -17	82	34	25	25.51
xi	18 - 26	59	26	15	15.30
xv	27 - 34	125	54	9	9.18
xix	36 - 41	15	7	3	3

(Data for 1970 and 1971 from Marshall and Sayer, 1976)

Table 2: Measurements from hippopotamus specimens culled in 2005, Luangwa Valley, Zambia

Age group	Jaw length (mm)	Estimated age in years	Age group	Jaw length (mm)	Estimated age in years
ix	39	15	xi	41	22
ix	38	17	xi	40	21
ix	41	17	xi	41	23
ix	40	11	xi	39	20
ix	40	18	xi	43	25
ix	39	17	xi	42	20
ix	39	16	xi	43	25
ix	35	15	xi	42	25
ix	38	17	xi	39	25
ix	38	18	xi	39	25
ix	39	18	xi	43	25
ix	39	15	xi	39	20
ix	40	17	xi	38	20
ix	38	14	xi	41	20
ix	39	17	xi	36	19
ix	39	15	xi	38	20
ix	39	16	xi	40	20
ix	37	15	xi	43	26
ix	42	20	xi	34	20
ix	39	18	xi	37	18
ix	38	15	xv	40	30
ix	38	15	xv	39	30
ix	38	15	xv	39	30
ix	40	18	xv	40	30
ix	40	18	xv	39	30
ix	39	12	xv	41	32
ix	38	15	Xv	37	30
ix	40	18	xv	37	30
ix	39	18	xv	38	32
ix	39	15			
ix	39	17			

xix	40	35	vii	36	10
xix	41	35	vii	37	11
xix	44	35	vii	35	10
vii	37	10	vii	37	11
vii	30	8	vii	36	9
vii	32	8	v	33	5
vii	30	6	v	28	5
vii	30	6	v	26	4
vii	35	8	v	25	4
vii	35	8	V	28	5
vii	35	10	v	26	5
vii	35	10	v	28	5
vii	35	8	v	29	4
vii	30	6	v	22	3
vii	35	8	v	23	4
vii	36	9	v	25	4
vii	35	8	v	32	3
vii	36	8	v	29	5
vii	34	10	v	28	5
vii	34	10	iii	15	2
vii	37	10	Iii	15	2
vii	37	10			
vii	36	8			
vii	36	10			
vii	36	10			
vii	32	8			
vii	33	8			
vii	33	8			
vii	38	11			

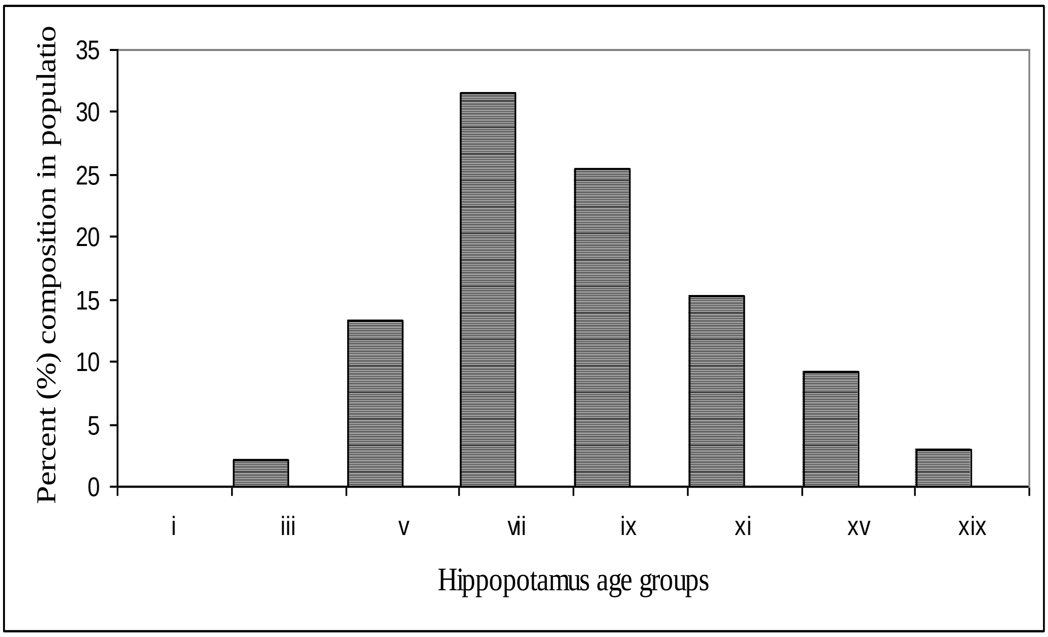

Figure 6: Hippopotamus age structure, showing percent composition of different age classes in the population. Luangwa Valley, Zambia.

The skewed age distribution in favour of older age groups (Table 1; Figure 2) was an indication of a population at *K* when recruitment rate declines. The 1970 - 1972 culling programme data (Table 3a, 3b, 3c and 3d) also showed an underrepresentation of younger groups.

Table 3a: Sample size, average weight and shoulder height of 189 male hippopotamus culled in 1970 (After Marshall and Sayer, 1976)

Age class	Approximate age (years)	Number in sample	Mean weight (Kg)	Mean shoulder height (cm)
I	0 – 0	2	123	70
II	0 – 5	4	202	79
III	1 – 0	3	460	103
IV	3	3	508	105
V	4	7	579	112
VI	7	15	782	123
VII	8	8	861	128
VIII	11	22	1027	130
IX	15	24	1267	138
X	17	22	1353	140
XI	20	8	1473	145
XII	22	6	1469	141
XIII	24	13	1489	142
XIV	27	18	1598	144
XV	30	18	1646	150
XVI	33	12	1757	147
XVII	35	4	1799	147
XVIII	38	0	-	-

Table 3b Sample size, average weight and shoulder height and breeding status of 186 female hippopotamus culled in 1970 (After Marshall and Sayer, 1976)

Age class	Approximate age (years)	Number in sample	Mean weight (Kg)	Mean shoulder height (cm)	Percent (%) Lactating	Percent (%) Pregnant*
I	0 - 0	0				
II	0 - 5	1	342	0	0	0
II	1 – 0	2	513	103	0	0
IV	3	0	0	0	-	-
V	4	6	673	111	0	0
VI	7	7	819	117	20	-
VII	8	5	891	123	-	20
VIII	11	10	1085	125	12	-
IX	15	16	1246	133	20	36
X	17	20	1312	135	65	39
XI	20	5	1320	134	40	0
XII	22	20	1348	135	79	50
XIII	24	7	1458	140	100	30
XIV	27	13	1484	139	80	23
XV	30	45	1453	138	76	35
XVI	33	19	1507	140	65	42
XVII	35	9	1389	137	88	42
XVIII	38	2	1536	137	50	100

A small number of individuals were not examined for pregnancy and lactation, the percent figures refer only to individuals for which the data were available.

Table 3c: Sample size, average weight and shoulder height of 82 male hippopotamus culled in 1971

Age class	Approximate age (years)	Number in sample	Mean weight (kg)	Mean shoulder height (cm)
I	0 - 0	0	-	-
II	0 - 5	0	-	-
II	1 – 0	1	318	100
IV	3	2	454	107
V	4	4	556	105
VI	7	9	743	122
VII	8	4	1051	130
VIII	11	10	1091	141
IX	15	7	1245	141
X	17	9	1194	145
XI	20	3	1293	145
XII	22	3	1289	147
XIII	24	4	1435	148
XIV	27	11	1516	151
XV	30	8	1597	153
XVI	33	5	1527	149
XVII	35	2	1587	145
XVIII	38	0	-	-

Table 3d: Sample size, average weight and shoulder height and breeding status of 128 female hippopotamus culled in 1971

Age class	Approximate age (years)	Number in sample	Mean weight (Kg)	Mean shoulder height (cm)	Percent (%) Lactating	Percent (%) Pregnant*
I	0 - 0	0	-	-	-	-
II	0 - 5	0	-	-	-	-
II	1 – 0	3	422	100	0	0
IV	3	3	531	109	0	0
V	4	7	617	114	0	0
VI	7	19	831	124	5	11
VII	8	13	1056	128	15	15
VIII	11	14	1124	137	7	36
IX	15	12	1134	139	25	42
X	17	6	1276	138	50	33
XI	20	4	1247	141	25	50
XII	22	9	1333	138	78	11
XIII	24	3	1293	140	100	0
XIV	27	10	1270	140	70	30
XV	30	11	1376	140	64	45
XVI	33	9	1324	140	56	33
XVII	35	4	1304	142	75	0
XVIII	38	1	1565	151	100	0

4. Discussion

4.1 Population status

The hippopotamus population size in the Luangwa River was at ecological carrying capacity K of 6,000 individuals as recorded by Chomba et al. (2013). At *K* recruitment rate declines and the composition of calves and sub adults in the population also declines. Similar results were obtained during the 1970-1972 culling programme where there was an under representation of younger age classes (Marshall and Sayer, 1976) which is a true reflection of the population structure, at *K* (*Sensu* Chomba et al. 2013).

Concern was however, raised during this study regarding the accuracy of age structure results obtained based on Laws (1967) method which has shortcomings particularly accuracy regarding patterns of tooth eruption for animals after seventeen years of age. It is recorded that after 17 years of age accuracy becomes intricate mainly arising from the degree of wear of teeth influenced by nature of grass, rainfall regime and others which in turn also influence wear of molars and premolars as also acknowledged by Marshall and Sayer (1976). Despite the short comings highlighted, the variations based on the age at which tooth wear becomes significant cannot alter the results and secondly, this is so far the best method available and the results obtained are therefore reliable. Healy and Ludwig, (1965) however, found that the rate of wear of sheep's teeth was directly proportional to the amount of soil ingested by the sheep, this in turn was a function of soil type and vegetation. Ludwig, Healey and Cutress (1966) found that tooth wear was related to the seasonal distribution of rainfall being greatest where there were wet winters and dry summers, and least where rainfall was more evenly distributed. Viewed from this angle one would contemplate that seasonal distribution of rainfall in Uganda where the method was developed is much more even (Figure 4.7) than in Zambia and therefore tooth wear is likely to start slightly later in life than the Luangwa hippopotamus population. It is therefore concluded that the results obtained in this study were accurate and indicative of reduced recruitment rate in the hippopotamus population of the Luangwa valley.

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