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Monitoring the endangered population of the antelope *Kobus leche smithemani* (Artiodactyla: Bovidae), in the Bangweulu ecosystem, Zambia

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Abstract: Black lechwe (*Kobus leche smithemani*) is a semi-aquatic medium sized antelope currently enlisted on the IUCN red list of endangered species and is only endemic to the Bangweulu basin of Zambia. Its population has significantly decreased due to floods that took place during the period 1930-1940 from over 250 000-15 000 leading the Zambian government to gazette all habitats of Black lechwe into state protected areas, and to establish urgent management strategies needed to save the remaining population from extinction. Using retrospective data, our findings show that the population has increased from 15 000 animals in 1954 to 55 632 in 2009. The current population is estimated at 34.77% (55 632/160 000) of the carrying capacity of the Bangweulu basin. Although the Black lechwe is one of the 42 species offered for consumptive utilization by the Zambia Wildlife Authority (ZAWA), only 0.12% and 0.08% of the current stock was offered for safari and resident hunting annually for the period 2005-2009, respectively. Annual quota utilization were estimated at 67% (n=37) and 81% (n=37) for safari and resident hunting, respectively. Hence, overall income obtained from utilization of Black lechwe is very low accounting for only 2.1% of the total revenue earned from wildlife utilization. Although the current population trend is showing a unit increase of 639 animals per year, it is still far below levels ideal for the lucrative utilization. In this study, we demonstrate that adverse ecological changes on wildlife species, can lead to their vulnerability and danger of extinction, and that their recovery to full carrying capacity may demand a considerable amount of time. Rev. Biol. Trop. 60 (4): 1631-1639. Epub 2012 December 01.

Key words: Bangweulu, Black lechwe, conservation, ecosystem, utilization.

The Black lechwe (*Kobus leche smithemani*) is a semi-aquatic medium sized antelope endemic to Zambia's Bangweulu swamps. It is one of the three *Kobus leche* sub-species found in Zambia together with the Kafue lechwe (*Kobus leche kafuensis*) endemic to the Kafue flats and red lechwe (*Kobus leche leche*) in Liuwa National Park (NP) in Western Zambia. The Kafue and Black lechwe are endangered and are currently enlisted on the International Union for Conservation of Nature (IUCN) red list of threatened species (IUCN 2010). The Black lechwe population used to cover a large area, extending from the Bangweulu swamps of Zambia into the Katanga Province in Southern Democratic Republic of Congo

(Pitman 1934, Vesey-Fitzgerald 1955). The 1930-40s flooding caused the Black lechwe population to decline tremendously leaving only a small proportion of animals remaining in the Bangweulu swamps of Zambia (Pitman 1934, Vesey-Fitzgerald 1955). Current efforts by the Zambia Wildlife Authority (ZAWA) are directed to save the remaining population and avoid extinction (ZAWA 2010, unpublished). After major ecological changes, it is important for ecologists to effectively monitor the rate of recovery of animal species that are adversely affected by changes in ecological habitats. This is particularly important in animal species that are endemic to habitats vulnerable to ecological changes, because such animals are likely to go into extinction if the changes in the ecosystem are severe and prolonged. Monitoring the recovery process, serves as a guideline on the proportion of animals to be allocated for consumptive utilization, and helps in developing measures aimed at increasing the population of endangered species at risk of extinction. In addition, population studies are helpful in understanding how the decline or increase of one species affects the survival of others in an ecosystem.

Historical background shows that the livelihoods of local inhabitants around the Bangweulu swamps were heavily dependent on hunting the Black lechwe, although the population was so high that the impact of hunting was very low (Pitman 1934, Vesey-Fitzgerald 1955). Besides, a switch from poaching to fishing occurred during the 1930s – 1940s, following major flooding events which resulted in a significant decline in the Black lechwe population (Pitman 1934, Vesey-Fitzgerald 1955). Government efforts to preserve the remaining population were followed by gazetting the Bangweulu swamps into a game management area (GMA) and the surrounding areas into National Parks (NP) in 1972. This was done in order to save the remaining population from further decline due to poaching. Given the existing scenario in the Bangweulu GMA, where there is absence of most sought-after species for wildlife utilization such as the Black rhinoceros (*Diceros bicornis*), a balance has to be struck between consumptive utilization of a threatened Black lechwe antelope and conserving it to levels which allow a healthy recovery of the population from the danger of extinction. Thus we undertook this study to assess the recovery rate of the Black lechwe after the 1930-40 flooding, in relation to the carrying capacity as determined by ZAWA whilst allowing light off take rates for consumptive utilization. We wanted to find out whether the Black lechwe population is increasing or reducing in the Bangweulu basin. We also wanted to determine the increase or reduction unit of animals per annum. Furthermore, we wanted to determine the influence of the current Black lechwe population trend on utilization of this species on the Bangweulu basin. Using this study we document a classical example on how a change in an ecosystem can endanger one species almost to a point of extinction, leading to a very long recovery time that could take several decades to regain the animal population to its original status.

MATERIALS AND METHODS

Study area: The Bangweulu basin covers an estimated area of 30 000km^2 which includes three GMAs namely the Bangweulu GMA 3 600km^2, Chikuni GMA 2 500km^2 and Kalaso-Mukoso GMA 1 900km^2 making it one of the largest wetlands in Southern Africa. Game Management Areas (GMAs) are livestock-wildlife interface areas around NPs in which rearing of domestic animals is permitted (Balakrishnan & Ndhlovu 1992). The Bangweulu basin is an important ecosystem designated as Ramsar site 531 (RIS 2008). Black lechwe contribute significantly to the ecological balance of the Bangweulu basin by providing faecal nutrients to the various fish species that spawn in the basin. Annual fish production is estimated at about 7 000metric tons. The Bangweulu swamps are critical to regulating floods and are therefore important in the context of climate change. Annual rainfall averages 1 380mm and occurs between November and March while

mean temperatures vary between 6.5ºC in July and 40ºC in October. The area is underlain by a shallow depression of about 160km in diameter fed by several rivers. The seasonally flooded plain covers about 68 000km^2 while the permanent flooded area covers about 5 000km^2 which influences the distribution of animals and plants (Chabwela 1987).

The area comprises several mammals, reptiles, fish and avifauna species. Mammals in the GMA and their population estimates are: African Buffalo (*Syncerus caffer*) – 161; African Elephant (*Loxodonta Africana*) – 8; Black Lechwe (*K. lechwe smithemani*) – 87 000; Oribi (*Ourebia ourebi*) – 30; Sitatunga (*Tragelaphus spekei*) – 75; Tsessebe Tsessebe (*Damaliscus lunatus*) – 500; Zebra (*Equus burchelli*) – 45. Bird species in the area include the globally threatened Shoebill stork (*Balaeniceps rex*), and a large population of Wattled crane (*Grus carunculatus*). The area has 86 species of fish of which 33 are of commercial value. In addition the GMA is the only area where the threatened slender-nose crocodile (*Crocodylus cataphracus*) is found in Zambia.

Data collection and analysis: Retrospective data on the Black lechwe population in the Bangweulu GMA was collected from records obtained from ZAWA, formerly called National Parks and Wildlife Services, who are the custodian of wildlife in Zambia. Data was collected for the period 1930 - 2009 and was analysed in 2011. Aerial survey data on counts of the Black lechwe population for the period 1950 - 2009 was collected. This was based on reports submitted to ZAWA by different experts contracted to do the aerial population counts in the Bangweulu basin. Plotting of human inhabited areas and distribution of the Black lechwe was based on georeference (GIS) data obtained from the aerial surveys using ArcView GIS™ version 10. Utilization data on quota allocation for safari and resident hunting, revenue earnings from animal sales and other relevant details were also collected for data analysis for the period 2005-2009. Estimates of the carrying capacity of the Bangweulu basin for Black lechwe were based on ecological data provided by ZAWA. Population data was entered in Microsoft™ Excel and transferred to STATA™ version 10 for analysis. To determine the unit increase of animals per annum, we used two univariate time series analytical models namely the Prais-Winsten and Newey-West regression models (Prais & Winsten 1954, Newey & West 1987).

RESULTS

Population trend of Black lechwe on the Bangweulu ecosystem: Figure 1 shows the distribution of Black lechwe overlapping with human settlement in the Bangweulu basin. Table 1 shows the population trend of Black lechwe on the Bangweulu swamps from the 1930s-2009. The population was at its lowest between the period of 1954 and 1971, while the increase was observed in 1973 and stabilized until 1996.

The current population was estimated in 55 632 animals, based on the last aerial surveys carried out in 2009, which is about 22.25% of the earlier population estimated before the flooding in the 1930-1940s. Figure 2a shows the population trend since 1930s while A_1 shows the estimated carrying capacity of the Bangweulu basin, and A_2 the mean estimate for the study period. The current population was estimated to be 34.77% of the estimated carrying capacity (n=160 000) of the Bangweulu GMA. Taking the population trend from 1954 after the 1930s-1940s flooding to 2009, our estimates using the Newey-West regression model, indicated that there is a unit increase of 639 ($p<0.000$, 95%CI 403.86-873.56) animals per year, as shown in figure 2b. This gives an intake rate of 1.15% (639/55 632) of the current population estimate. Similarly, the Prais-Winsten regression model showed an estimate of 639 animals ($p<0.000$, 95%CI 417.49 -859.42). This unit increase of 639 animals per year gives a forecast of another 38 years for the Black lechwe population to reach half (80 000) of the estimated carrying capacity of the Bangweulu basin, and another 163 years to reach the full

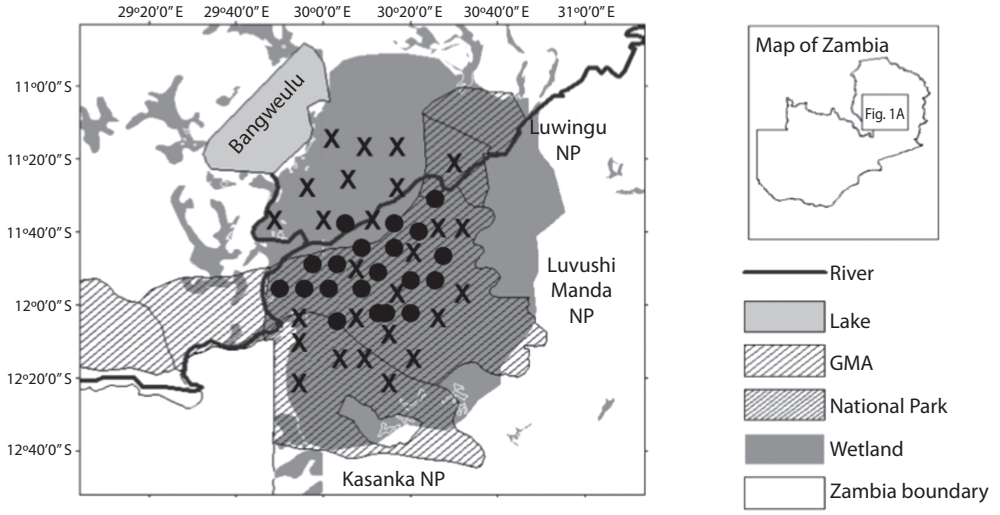

Fig. 1. Bangweulu basin with black dots showing the distribution of black lechwe in 2009 and X showing human inhabited areas. Map of Zambia shows the location of the Bangweulu basin reflected as Figure 1A.

TABLE 1
Population of the *Kobus leche smithemani* Black lechwe on the Bangweulu swamps

Year	Population estimate	Reference	Expected overall mean	Difference between estimated population & overall mean	% after 1930 population estimate
1930	250 000	Pitman 1934 (Pitman 1934)	44 472.31	205 527.69	100.00
1940	50 000	Bredsford 1944 (unpublished)	44 472.31	5 527.69	20.00
1954	15 000	Vesey-Fitzgerald (1955)	44 472.31	-29 472.31	6.00
1959	16 000	ZAWA (unpublished, 1959)	44 472.31	-28 472.31	6.40
1969	16 000	Bell & Grimsdell (unpublished)	44 472.31	-28 472.31	6.40
1971	16 500	Bell & Grimsdell (unpublished)	44 472.31	-27 972.31	6.60
1973	25 254	Grimsdell & Bell (unpublished)	44 472.31	-19 218.31	10.10
1983	41 041	Grimsdell & Bell (unpublished)	44 472.31	-3 431.31	16.42
1988	33 843	Howard *et al.* 1988 (unpublished)	44 472.31	-10 629.31	13.54
1989	32 336	Jefferey *et al.* 1989 (Unpublished)	44 472.31	-12 136.31	12.93
1990	32 085	Jefferey *et al.* 1990 (Unpublished)	44 472.31	-12 387.31	12.83
1991	29 600	Jefferey *et al.* 1991 (Unpublished)	44 472.31	-14 872.31	11.84
1993	33 700	Kamweneshe 1993 (Unpublished)	44 472.31	-10 772.31	13.48
1994	32 200	Kamweneshe 1994 (Unpublished)	44 472.31	-12 272.31	12.88
1996	32 366	Kamweneshe 1996 (Unpublished)	44 472.31	-12 106.31	12.95
2009	55 632	Kamweneshe 2009 (Unpublished)	44 472.31	11 159.69	22.25

carrying capacity (160 000) from the current population estimates (n=55 632). Although we did not determine the population increase of people living in the Bangweulu basin, before and shortly after the 1930-1940 floods, the number of people living in the surrounding district, including people living in the Bangweulu GMA, has steadily increased from 9 692 in 1980 to 12 728 in 1990, followed by an increase of 17 624 in 2000 to 20 321 in 2010 (CSO 2010). Although this expansion of the human population poses a significant danger to

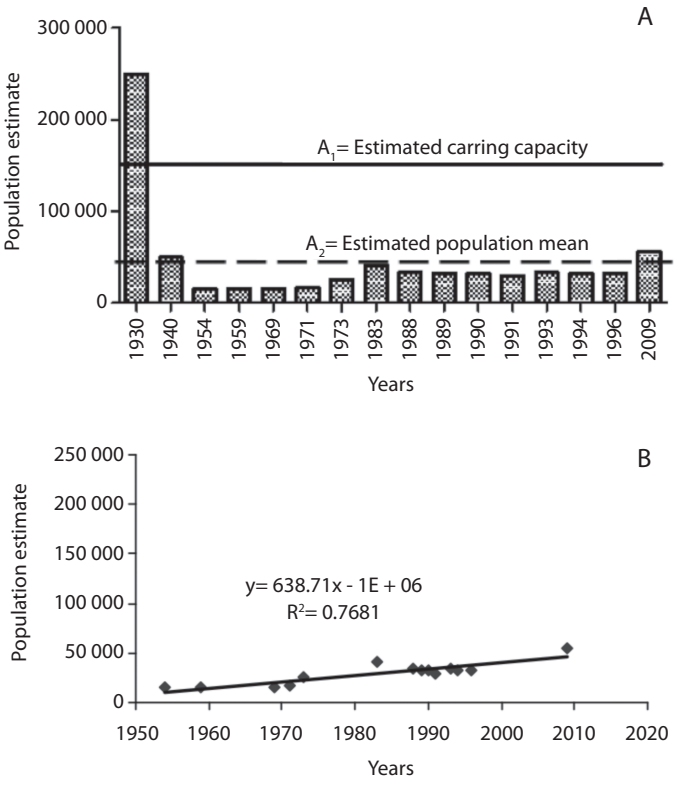

Fig. 2A. Black lechwe population trend since 1930s. A1 shows the estimated carrying capacity of the Bangweulu game management area while A2 shows the population mean between 1930 and 2009. **B.** Black lechwe population trend on the Bangweulu game management area for the period 1954 to 2009.

the survival of Black lechwe, considering that most illegal hunters come from people living within and surrounding areas of the Bangweulu GMA, the exact impact of human population growth on Black lechwe has not yet been evaluated and was not assessed in this study.

Utilization of black lechwe: During the period 2005-2009, ZAWA offered a total of 527 *Kobus leche smithemani* for hunting disaggregated as 295 and 232 animals for safari and resident hunting, respectively. The annual quota for each of the market segments was 59 animals for safari and 46 animals under resident hunting. On average, safari hunting comprises 53% of the *K. lechwe smithemani* allocated on quota compared to resident hunting which comprises 47%. The quota utilization percentage by the two market segments is on average 62% (n=37 animals) by safari hunting and 81% (n=37 animals) by resident hunters (Table 2). Records of animal quotas at the ZAWA licensing office showed that the annual quotas for *K. leche kafuensis* for the same study period (2005-2009) averaged around 106 and 571 animals for safari and resident hunting with quota utilization percentages of 42.0% (n=44 animals) under safari hunting and 98.7% (n=564 animals) under resident hunting. Indicative earnings by ZAWA from the consumptive use of the species are given in table 2. Safari hunting of the species remains the most lucrative as it is highly priced at about 15 times more expensive compared to resident hunting: on average, ZAWA earned

TABLE 2
Quota allocation, utilization and income earned from utilization of the *Kobus leche smithemani* Black lechwe antelope between 2005 and 2009

Hunting category	2005	2006	2007	2008	2009	Total	Average
Quota allocation safari hunting	55	60	60	60	60	295	59.0
Quota allocation resident hunting	50	40	30	41	71	232	46.4
Quota utilization safari hunting	54	29	47	24	29	183	36.6
Quota utilization resident hunting	32	40	23	39	53	187	37.4
Safari Hunting annual income (US$)	59 400	31 900	79 900	40 800	49 300	261 300	52 260
Resident Hunting annual income (US$)	1 234	1 256	3 599	4 866	6 796	17 751	3 550
Total hunting annual income (US$)	60 634	33 156	83 499	45 666	56 096	279 051	55 810

Notes: 1. Revenue earnings used are based on the animal fees charged by ZAWA 2. The Zambian Kwacha (ZMK): 1 US$ Exchange Rates Used by ZAWA for the Years are: 2005 – ZMK 3 500; 2006 – ZMK 4 300; 2007 – ZMK 3 835; 2008 – ZMK 4 810 and 2009 – ZMK 4 680 US = United States of America.

US$ 52 260 annually from safari hunting and a paltry US$ 3 500 from resident hunting for the period 2005-2009.

DISCUSSION

Monitoring animal population after adverse ecological changes is important for the purpose of determining the exact reduction on the animal population and the rate of recovery after the change in the ecosystem. This is particularly important in animal species that are naturally endemic to particular ecosystems. When these ecosystems are subjected to adverse ecological changes, vulnerable species inhabiting these places are bound to undergo severe population reductions, which might take a long time to return to full carrying capacity of the affected habitat. Reports from ZAWA indicate that the population of Black lechwe at the turn of the last century numbered approximately 250 000. However, after the 1930-1940 flooding which rose several meters high, the Bangweulu swamps never returned to its original levels thereby displacing a lot of animals (Pitman 1934, Vesey-Fitzgerald 1955). This created a major change in the Bangweulu ecosystem. As a result, the Black lechwe population decreased tremendously to 15 000 animals by 1954 (Vesey-Fitzgerald 1955). By 1969, there were only 16 000 animals left on the Bangweulu basin. In 1972 this prompted government to turn the ecological habitat of Black lechwe into GMAs and NPs which became state protected areas.

As shown in table 2, animal counts in the Bangweulu basin were not obtained at regular intervals because of financial constraints experienced by the Zambian government to carry out aerial counts at regular intervals over the last 60 years. However, use of time series statistical models, such as the Newey-West and Prais-Winsten regression models, makes it possible to estimate the population increase per annum based on existing data collected at different time points. Time series models have been widely used to calculate the unit increase over time as well as to forecast the performance of different parameters for different time periods (Box & Jenkins 1994). The Newey-West model has been shown to be consistent even when there are serial correlations and conditional heteroskedasticity of unknown forms while the Prais Winsten model has the advantage of being more reliable for small sample sizes especially in cases where losing one observation might seriously affect the outcome of results (Box & Jenkins 1994, McQuarrie & Tsai CL 1998). However, both models have been shown to be suitable for all sample sizes and, hence, they are widely used for multiple time series studies (McQuarrie & Tsai CL

1998, Chang *et al.* 2010, Huy *et al.* 2010). It is interesting to note that both models gave the same unit increase of 639 animals per annum.

Based on ecological surveys carried out by ZAWA in the last decade (ZAWA 2010, unpublished), the Bangweulu ecosystem can sustain a population of about 160 000 animals if adequate protection and management were provided. Grimsdell & Bell in 1975 (unpublished reports 1975) estimated that it would take approximately 29 years for the population to gain this carrying capacity at 10% annual growth rate of the 16 000 animals that existed on the basin in 1972. Similarly, Kamweneshe in 1996 (Kamweneshe 2000) estimated a growth rate of 6 000 animals per annum for a population of 32 000 animals that existed on the basin in 1996. However, 30 years after Grimsdell & Bell's, and 15 years after Kamweneshe's estimates the population has not reached half of the estimated carrying capacity. Hence, the current population growth rate of 639 animals per annum is too low to increase the animal population to the expected carrying capacity. Our forecasts indicate that at the current growth rate, it will take another 38 years for the population to reach half of the estimated carrying capacity and another 163 years to reach a full carrying capacity. This entails that recovery from the 1930-1940s flooding will not be attained soon unless there is a change in conservation strategies.

Based on the aforementioned reasons, cropping of Black lechwe is not foreseeable as a population control strategy in the near future. This is in line with recommendations made by other scientists (Bell & Grimsdell 1973) who pointed out that no lechwe should be cropped until the population reaches a minimum of 100 000 with an off-take rate of 10% per annum. At 100 000, an off-take of 10% would yield a minimum of 400 metric tonnes of meat and more animals would be allocated for safari hunting. Hence, for ZAWA to attain substantial revenue earnings from utilization of the Black lechwe it is imperative that the population is increased to full carrying capacity. The current population is far too low to implement consumptive utilization activities that are lucrative. It is likely that this trend might apply to utilization of other endangered species in situations where population growth is low and as such allocation of animals for utilization is bound to be low.

Thus far, there has been no major disease outbreak linked to high mortality in Black lechwe and there has been no major ecological change linked to population reduction after the 1930-1940 floods. Hence, the only possible cause of high off-take rates is illegal hunting of animals. This has been exacerbated by the increase in human encroachment into the Bangweulu swamps engaged in fishing activities. As shown in figure 1, the distribution of the human population in the GMA covers the lechwe populated areas. The increase in human population in the area poses a danger such that illegal hunting of wildlife might continue for a long time. Previous studies (Thirgood *et al.* 1992) have shown that approximately 3 000 Black lechwe are hunted illegally every year although it is likely that this number might be an underestimation. Hence there is an urgent need to improve the patrols of law enforcement officers in the GMA/NP, in order to reduce illegal hunting of Black lechwe. Current efforts based on the ZAWA annual reports in the last decade (ZAWA 2010, unpublished) have been directed at involving local communities in the ownership of wildlife as a way of sensitizing the public and putting joint efforts with the general public and government law enforcement agents in curbing down illegal hunting of wildlife. Given the current population estimate at 55 632, which is at one third of the carrying capacity of what the Bangweulu ecosystem can sustain, hunting quotas should be kept at minimal levels of 0.12% (59/55 652) for safari hunting and 0.08% (46/55 632) for resident hunting per annum. Although the human population within the Bangweulu GMA and the surrounding areas is showing an increase, most people are engaged on fishing on Lake Bangweulu and not in land tillage or ownership of livestock which often comes in direct conflict with wildlife. Hence, anthropogenic pressure is

perceived not to have reached alarming levels likely to cause significant adverse effects on expansion of the Black lechwe population apart from illegal hunting which can be controlled by law enforcement officers. However, there is need for detailed quantitative studies to verify these assertions. Another important factor that could adversely affect the carrying capacity of Black lechwe on the Bangweulu basin is global climate change. Thus far, there has been no study carried out to determine the effect of climate change on the Bangweulu basin. It is imperative that an assessment of the impact of climate change is carried out, and effective monitoring of climate factors, that would adversely affect the expansion of wildlife, are closely monitored in order to develop timely mitigation measures that would prevent the loss of threatened species from extinction.

In this study we provide a classical example of how a change in an ecosystem can endanger the survival of vulnerable species as shown in the flooding that took place on the Bangweulu basin in the 1930-1940s which led to the significant reduction of the Black lechwe in subsequent years. Although the flooding caused a drastic reduction in the population, suffice to mention that the low rate of recovery after the flooding has been exacerbated by poaching (Thirgood *et al*. 1992). As shown in this study, the recovery rate of 639 animals per year over a period of 60 years has been very slow by only increasing the number of animals to a third of the carrying capacity of the Bangweulu ecosystem. Put together, the estimated loss of 3 000 animal due to poaching (Thirgood *et al.* 1992) and the estimated unit increase of 639 animals per annum, the Black lechwe population would increase by 3 639 animals per year. Hence, our findings show that one major catastrophic change in an ecosystem can take a long time to regain the loss incurred for vulnerable species endemic to that ecosystem especially when the situation is exacerbated by negative anthropogenic pressure. It is imperative that disaster management should be an integral part of conservation plans aimed at preventing the loss of species vulnerable to major ecological changes. Thus, from this assessment, ZAWA needs to device methods that will increase intake rates of Black lechwe on the Bangweulu basin as a way of expediting the recovery process to regain the lost population of Black lechwe to full carrying capacity the Bangweulu ecosystem is able to sustain. There is urgent need to reduce illegal hunting while closely monitoring the consumptive utilization levels by allocating only a few animals for safari and trophy hunting in order to enhance the population growth. Subsequent aerial surveys will be vital in determining sustainable yield basis of these proposed measures and consumptive utilization quotas may be calculated from the deduced data.

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RESUMEN

El lechwe negro (*Kobus leche smithemani*) es un antílope semi-acuático de tamaño medio que en la actualidad se encuentra en la lista roja de la UICN de especies en peligro de extinción y sólo es endémica de la cuenca del Bangweulu de Zambia. Su población ha disminuido considerablemente, de más de 250 000 a 15 000, debido a las inundaciones que se dieron durante el período 1930-1940, lo que llevó al gobierno de Zambia a declarar todos los hábitats del lechwe negro en áreas protegidas estatales, y a establecer estrategias de administración urgentes necesarias para salvar el resto de la población de la extinción. Utilizando los datos retrospectivos, nuestros resultados muestran que la población ha aumentado de 15 000 animales en 1954 a 55 632 en 2009. La población actual se estima en 34.77% (55 632/160 000) de la capacidad de carga de la cuenca del Bangweulu. Aunque el lechwe Negro es una de las 42 especies que se ofrecen para su utilización consuntiva por la Autoridad de Vida Silvestre de Zambia (ZAWA), sólo el 0.12% y 0.08% de la población actual se ha ofrecido para el safari y la caza residente anual para el período 2005-2009, respectivamente. La utilización de la cuota anual se estima en 67% (n=67) y 81% (n=37) para safari de caza y residente, respectivamente. Por lo tanto, los ingresos totales obtenidos de la utilización del lechwe negro son muy bajos contando sólo el 2.1% de los ingresos totales obtenidos de la utilización de la fauna silvestre. Aunque la tendencia actual de la población está mostrando

un incremento unitario de 639 animales por año, está todavía muy por debajo de los niveles ideales para la utilización lucrativa. En este estudio, se demuestra que los cambios ecológicos perjudiciales sobre especies de fauna silvestre, puede conducir a su vulnerabilidad y peligro de extinción, y que la recuperación de su capacidad de carga completa puede exigir una cantidad considerable de tiempo.

Palabras clave: Bangweulu, Lechwe negro, conservación, ecosistema, utilización.

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