1. 1. Is the supply of trophy elephants to the Botswana hunting market sustainable? CHERYL-SAMANTHA OWEN 24th March 2005 Submitted in partial fulfilment of a masters degree in Conservation Biology, Percy FitzPatrick Institute, University of Cape Town, South Africa. Percy FitzPatrick Institute Department ofZoology University ofCape Town Private Bag 7701 South Africa cowen({iJ,botzoo. lICt. aC.za
2. [2.](https://image.slidesharecdn.com/b2cf288c-5ffb-4db2-aac3-0c115465eba7-150612075258-lva1-app6891/95/owencherylsamantha2005msccbthesis-2-638.jpg?cb=1434095639)The copyright of this thesis rests with the University of Cape Town. No quotation from it or information derived from it is to be published without full acknowledgement of the source. The thesis is to be used for private study or non-commercial research purposes only. U niversity ofC ape Tow n
3. [3.](https://image.slidesharecdn.com/b2cf288c-5ffb-4db2-aac3-0c115465eba7-150612075258-lva1-app6891/95/owencherylsamantha2005msccbthesis-3-638.jpg?cb=1434095639)Is the supply of trophy elephants to the Botswana hunting market sustainable? Cheryl-Samantha Owen, Percy FitzPatrick Institute ofAfrican Ornithology, University of Cape Town. Rondebosch 7701 Abstract Botswana hosts the world's largest population of African elephants Loxodonta africana, and in northern Botswana, populations are increasing at a rate of 6% per annum, The greatest cash return on a single elephant is from trophy hunting, and hunting is an important foreign income generator. Hunting does, however, risk the sustainability of both the elephant population and the supply of males with trophy-quality tusks. A model utilising a Leslie matrix was developed to simulate the population dynamics of the elephants in northern Botswana under different levels of hunting pressure, with different calf survival rates and with or without a carrying capacity imposed. The age structure of a pristine population, and the proportion of elephants of each age with trophy-quality tusks was developed from tusk measurements and ages of elephants culled over 25 years from Kruger National Park. The model suggests that the current level of hunting pressure is sustainable and unlikely to threaten the availability of trophy-quality tusks in the future. Simulations of increased hunting pressures indicated that doubling the current hunting take-off would result in very few large trophy animals, but would not compromise the supply of males suitable for trophy hunting. A decrease in the current survival rate of calves in their first year of life would, however, greatly reduce the supply of trophy- quality elephants.
4. [4.](https://image.slidesharecdn.com/b2cf288c-5ffb-4db2-aac3-0c115465eba7-150612075258-lva1-app6891/95/owencherylsamantha2005msccbthesis-4-638.jpg?cb=1434095639)Introduction The continental estimate of African elephant Loxodonta africana numbers decreased from 1.3 million in 1979 to 609 000 in 1989 (ITRG 1989), proof that attempts to control the ivory trade during the 1970s and 80s failed. At the beginning of the 19th Century, Botswana alone may have supported as many as 400,000 elephants (Campbell, 1990). Subsequently, uncontrolled commercial hunting for ivory reduced numbers to a remnant population in the north. By the end of the 19th Century, hunting quotas had been imposed to halt the decrease, and by the 1930s numbers were increasing (Child, 1968). Aerial and ground surveys in northern Botswana (that started in the early 1970s (Gibson et al1998)) indicate that the population of elephants in northern Botswana has increased to its present level of 93,004-117,763 animals (Chase 2004) and that the population is increasing at a rate of 5-6% per annum (Chase 2004, Van Aarde et al 2004, Gibson et al 1998). The geographical range of elephants in northern Botswana is ca 107,500 km", indicating a population density of 0.86-1.09 elephants/krrr' (Chase 2004). This range includes ca 18,247 km2 of protected areas (Chobe and Nxai Pan National Parks and Moremi Game Reserve); the remaining area consists of forest reserves and proposed wildlife management areas (Chafota et al1993). In 1983, the Botswana Government banned elephant hunting because of an alleged decrease in tusk weight and perceptions that elephant populations were concentrating in protected areas. This decision, however, was not supported by empirical evidence, and Melton (1985) showed that the apparent decrease was within the range of normal statistical variability (Spinage 1990). Sport hunting does, however, playa role in the illegal ivory trade because most trophy ivory eventually enters the trade (Parker 2004). Strong opposition to the ivory ban from other countries, including India and Kenya where hunting is forbidden, originates from concern that any legal trade in ivory endangers their elephants. Due to their success in downgrading their elephants to CITES Appendix II, by 1997 Botswana, Namibia and Zimbabwe were selling ivory stockpiles gleaned from culling, siezures and natural deaths (Stiles and Martin 2001). Elephants in Botswana are still classified as CITES Appendix II and according to CITES regulations are subject to a 2
5. [5.](https://image.slidesharecdn.com/b2cf288c-5ffb-4db2-aac3-0c115465eba7-150612075258-lva1-app6891/95/owencherylsamantha2005msccbthesis-5-638.jpg?cb=1434095639)sport-hunting quota of 210 animals. Since the reintroduction of elephant hunting in Botswana (in 1996), there has been a consensus among hunting operators that the quota for trophy bulls could be increased without significantly reducing either the numbers of elephants or the quality of trophies (Peak 1996-2004). The number of elephants available on quota given by the Botswana government since 1996 has increased from 80 to 180. In spite of this increase, trophy quality has remained high, with the average weight for the heaviest tusk per year ranging from 24.6-27.2 kg; indeed, Botswana is now recognised as producing the best tusk weights in Africa (Peak 2002). Whether quotas were set to maximise returns is questionable, but what has emerged is the importance of setting quotas with an emphasis on the sustainability of trophy quality. Even though elephant numbers have increased, it is possible that the number oflarge trophy elephants has decreased. Adjusting annual offtakes up or down on the basis of the average age of the previous year's offtake may suffice to manage a population sustainably (Parker 2004). Simplistically, a rise in the average age of trophy elephants means that there are enough older bulls surviving to raise the average age and therefore, hunting quotas can be raised. Conversely, a drop in average age of the annual trophy bag indicates that too few bulls are surviving and the quota should be decreased. The consequences both to conservation and to the hunting industry are too high to risk a population crash and therefore more facts are needed in order to build on the simple theory outlined above for the management of northem Botswana's elephant population. An accurate assessment of the age structure and trophy quality of the population of elephants is necessary in order to set a justifiable quota, and a trophy management policy is needed that identifies offtake levels according to population, age, trophy-quality minimums and client needs. A certain minimum number of males must be allowed to reach the natural end of their lives in order to provide for good quality trophy elephant bulls. Caro et al. (1998) suggested (for Tanzania) that any offtake less than 10% of the local population size (of any hunted species) was unlikely to lead to overexploitation. However, specifically with 3
6. [6.](https://image.slidesharecdn.com/b2cf288c-5ffb-4db2-aac3-0c115465eba7-150612075258-lva1-app6891/95/owencherylsamantha2005msccbthesis-6-638.jpg?cb=1434095639)respect to elephants, Martin and Thomas (1991) state that the generally accepted hunting level for trophy bulls is 0.75% or less of the population annually. If this proportion is accurate, and assuming Botswana has ca III 760 elephants (Chase 2004), then the hunting quota could in theory be raised to 838 individuals. However, because poaching is not a problem in Botswana, if there is a trend of decreasing trophy quality in the face of a growing elephant population, then the cause can only be due to an unsustainable hunting quota. The African elephant is a long-lived species, characterized by deferred and intermittent breeding (seasonal breeding occurs annually and the gestation period is 22 months), relatively high adult survivorship, and correspondingly long lifespans (approximately 60 years) (Hanks 1979). The natural mortality of elephants in northern Botswana is low, and the availability of permanent surface water resources is the main factor restricting range expansion (Vandewalle 2003). For the past nine years, hunting has removed approximately 0.1% of the population annually. Since 1996, the tusk dimensions of elephants hunted by foreign clients in Botswana have been recorded (under the CITES permit system) in an extensive database held by Mochaba Trophy Handlers. These data form a basis for evaluating trends in sport hunting from 1996 to 2004 and can be used to support the Botswana Department of Wildlife and National Park's efforts in allocating trophy-hunting quotas. The database of the tusk length, tusk weight and age of hunted elephants confirms what constitute trophy-quality bulls, and allows determination of the optimal ages for animals with trophy-quality tusks, described as the optimal trophy age window. The objective of this study is to model the demographics of elephants in . northern Botswana in order to predict the rate at which trophy elephants enter the population, and hence advise on sustainable hunting levels. The age distribution and the number of animals remaining after a hunting season are key factors in the dynamics of exploited populations (Silliman and Outsell 1958). The optimum yield of trophy hunted bulls will be determined by the maximum number of individuals that can be removed from the population in northern Botswana without 4
7. [7.](https://image.slidesharecdn.com/b2cf288c-5ffb-4db2-aac3-0c115465eba7-150612075258-lva1-app6891/95/owencherylsamantha2005msccbthesis-7-638.jpg?cb=1434095639)impairing the ability of the remainder to produce the maximum yield of trophy animals on a sustained basis (Anderson 1975). This study simulates various scenarios with different hunting bags for the elephants in northern Botswana through time. Hunting generates important foreign income, and with almost half of the region covered in hunting concession areas, effective management of hunting resources is required. To explore these issues a simple age-structured population model is constructed based on the KNP elephant population from 1975 to 2000, the estimates for the total population in northern Botswana, and the records of hunted elephants in Botswana from 1996 to 2004. Key questions: • How many elephants per year enter the trophy window in terms of 1) age (i .e. potential supply) and 2) carrying trophy-quality tusks (i.e. realised supply)? • How many elephants per year enter the optimal trophy age window still carrying trophy-quality tusks? . Methods Background data for the model Kruger National Park (KNP): age structure ofculled elephants The ages and heaviest tusk weights of 4 583 elephants culled randomly in Kruger National Park (KNP) from 1975-2000 were used to provide an age structure for a 'pristine' population of elephants, i.e. a population not affected by selective hunting. 5
8. [8.](https://image.slidesharecdn.com/b2cf288c-5ffb-4db2-aac3-0c115465eba7-150612075258-lva1-app6891/95/owencherylsamantha2005msccbthesis-8-638.jpg?cb=1434095639)Age-related tusk breakage In October 2004, 12 days of ground-based observations were conducted in Chobe National Park to determine the age structure of bachelor groups and the proportion of bulls of different ages with broken tusks. Sampling focused along the main rivers, Chobe and Khwai, but also across the Savute, Linyanti and Nagatsaa areas. The bulls were classed into three age classes: 10-19, 20-39 and 40-60 years. Ages were determined using Moss's (1996) ageing criteria. Bulls were classified into three categories: animals with trophy-quality tusks, animals with chipped tusks, and animals with no tusks or broken tusks. In the analyses, elephants with chipped tusks were included in the trophy- quality category as interviews with hunting operators revealed that clients were still prepared to accept chipped tusks as trophies (D. Dandridge pel's. comm.). The proportions of broken-tusked animals per age class were subjected to a linear regression in order to calculate the proportion ofbroken-tusked animals per year class. Age structure ofhunted elephants Data on the tusk length, tusk weight and age of hunted elephants in Botswana from 1996 to 2004 were extracted from the database collated by Mochaba Trophy Handlers, in Maun. In order to determine the age of the elephant when it was shot hunters are encouraged to send the lower jaw bones together with the corresponding tusks to the trophy handlers. For those trophies with matching lower jawbones, ages were estimated based on Laws' (1966) analysis of tooth eruption and wear. Elephant tusks grow throughout the animals lifetime (Laws 1969), and thus a relationship between age and tusk mass or length is therefore predictable, however Craig and Gibson (1993), based on hunting trophies from Zimbabwe, state that there is a broad spread of tusk masses for anyone age class. Pilgram and Western (1986), however, used regression analysis to evaluate measurement reliability and to develop mathematical models describing the relationship between sex, age and tusk measurements and found that the age of individual elephants can be determined from tusk dimensions at a useful 6
9. [9.](https://image.slidesharecdn.com/b2cf288c-5ffb-4db2-aac3-0c115465eba7-150612075258-lva1-app6891/95/owencherylsamantha2005msccbthesis-9-638.jpg?cb=1434095639)level of accuracy. The detailed tusk measurements in the Mochaba database were used to illustrate what constitute trophy-quality bulls, but it was necessary to find a con-elation between either tusk length or tusk weight and age because only 196 out of 995 recorded trophy bulls were aged. In the study by Pilgram and Westem (1986) weight was found to be statistically superior to measures of length. The heaviest tusk weight was therefore chosen as the independent variable and both model 1 and model 2 regressions were performed to correlate tusk weight with age. The model 1 regression did not fit the observed age structure as accurately as the model 2 regression, and the model 2 regression was therefore chosen to fit ages to the weight of the heaviest tusk for the entire database of 995 bulls. The model 2 regression takes into account that the independent variable may be measured with error, and the analysis makes far fewer assumptions about the data than the standard, model 1 regression (Dytham 2003). Hunting bag The average hunting bag per year (by age class) was calculated from the observed age structure of the hunted elephants from 1996 to 2004. Constructing and evaluating the model Determining the stable age distribution The Leslie Matrix model was first considered by Lewis (1942) and Leslie (1945) in their experiments of population mathematics and has since become the most common model used to account for the effects of age on birth and death rates. The number of live young after one time period is determined by the age-specific fertility rates adjusted for mortality, plus the number of females in each age group (Shiao-Yen and Botkin 1980). The purpose of building a Leslie matrix was to find the stable age distribution of the elephant population in northern Botswana and compare this to the observed age 7
10. [10.](https://image.slidesharecdn.com/b2cf288c-5ffb-4db2-aac3-0c115465eba7-150612075258-lva1-app6891/95/owencherylsamantha2005msccbthesis-10-638.jpg?cb=1434095639)distribution of the KNP population. The Leslie matrix assumed the population to be pristine, and not subject to trophy hunting (in order to compare it with the elephant population of KNP). The stable age distribution is reached when the population does not change in size and the age structure of the population is constant with time (Hanks and McIntosh 1973). The model stable age distribution adhered to Caughley's (1966) definition and resulted in a constant growth rate of 6% per annum and a constant survivorship and fecundity rate in each age class. The model growth rate of 6% fits well with the estimated growth rate of 5-6% from studies of the elephant population in northern Botswana by Chase (2004) and an estimate of the population growth rate for Chobe National Park as 5.31 % (Van Aarde et al. 2004). Databasefor the model Fixed values are used for each element of the matrix to describe the population (Table 1). The population parameters used in the model - fecundity, mortality and age structure - were drawn from several different sources. Birth rate, calving interval, age of first reproduction, sex ratio, calf survival rate from 0 to 1 year, survival rate from 1 to 4 years, 5 to 10 years, and 11 to 45 years were obtained from the study of the dynamics of elephants in Chobe National Park (Van Aarde et al 2004). Van Aarde et al (2004) estimated one single survival rate for adults >20 years old, but studies by Hanks (1971, ]972) separated the older age classes and estimated a range (low, medium and high) of survival rates for 46-55 and 56-60 year old elephants. In the model, Hank's (oPP. cit.) medium survival rates were selected as the survival rates for these two age classes. This was done in order to differentiate the mortality of older elephants to younger adults because there is an increase in mortality of elephants >45 years old as a result of tooth wear and a rapid decrease in the grinding area of the molars (Laws ]969). Van Aarde et al (2004) estimated the calving rate from the ratio of number of first-year calves to the number of reproductively active females. The birth rate for the model was taken as the inverse of this calving interval. Population sex ratio was calculated from the survey made in Chobe National Park (Van Aarde et al2004). 8
11. [11.](https://image.slidesharecdn.com/b2cf288c-5ffb-4db2-aac3-0c115465eba7-150612075258-lva1-app6891/95/owencherylsamantha2005msccbthesis-11-638.jpg?cb=1434095639)The model assumes that the calf mortality suggested by Van Aarde et al (2004) is correct because of the corresponding low standard deviations; however, first-year survivorship varies greatly in other studies of elephant population dynamics. Laws (1969), for example, suggested that first-year mortality was 36%. Due to the importance of calf survival on population dynamics, a series of simulations was run with different calf survival rates to assess the sensitivity of the model to this parameter. Table 1. Parameters used in the Leslie Matrix to determine stable age structure Parameter Rate Source Location Calf Survival Rate (0-12 months) 0.954 Van Aarde et al (2004) Chobe National Park Survival Rate (1-4) 0.987 Van Aarde et al (2004) Chobe National Park Survival Rate (5-10) 0.989 Van Aarde et at (2004) Chobe National Park Survival Rate (11-45) 0.989 Van Aarde et al (2004) Chobe National Park Survival Rate (46-55) 0.95 Hanks and McIntosh (1973) Zambia Survival Rate (56-60) 0.5 Hanks and McIntosh (1973) Zambia Birth rate 0.29 Van Aarde et at (2004) Chobe National Park Age of first reproduction 12 Van Aarde et at (2004) Chobe National Park Proportion of females 0.595 Van Aarde et at (2004) Chobe National Park Proportion of males 00405 Van Aarde et at (2004) Chobe National Park Building the life table The life table provides a table ofparameters for every age age class, and is linked directly to the calculations in the Leslie matrix. A life table with survivorship, mortality and fecundity values for each age class was created using the given population parameters. Survival was taken to equal the probability, given that an elephant reached a certain age, that it would survive to reach age x + 1. The mortality rate was equal to l-survival rate. The birth rate was multiplied by the proportion of females in the population in order to account for a population with both males and females (because the model was designed such that the output reflected only males). 9
12. [12.](https://image.slidesharecdn.com/b2cf288c-5ffb-4db2-aac3-0c115465eba7-150612075258-lva1-app6891/95/owencherylsamantha2005msccbthesis-12-638.jpg?cb=1434095639)Building the Leslie Matrix The top row of the matrix consists of age-specific fecundities, which are the number of young bom per individual that survive through the first time unit. The proportion of the corresponding age class that survives to become members of the next age class, the survival values, are the subdiagonal elements (Fowler and Smith 1973). Maximum longevity is considered to be 60 years (Hanks 1973) and in order to truncate the model so that all elephants died upon reaching their 6151 birthday the survival for age-class 60 was set at O. The first colunm to the right of the matrix contains the age distribution at time O. In year 0, a random figure of 20 was assigned to each age class; from this point on, age structure is calculated iteratively until the population reaches a stable age structure. The total population at time t + 1 divided by the total population at time t is the population growth rate (A, = Nt+1/ Nt). In time, A, reaches a constant (the eigenvalue). As population density approaches an equilibrium value, the principal eigenvalue of the matrix approaches unity and the corresponding eigenvector approaches the equilibrium age distribution. The Leslie matrix as used in this model simulated the dynamics of the elephant population and determined its equilibrium density and corresponding age structure (Fowler and Smith 1973); the latter can then be expressed as proportions. Outline of Leslie Matrix Set-Up 'EJesl' Matrix 0 to 60 Age distribution in time time HI Fo FI F2 F59 F600 #0 =MMULT(#o to #60) So 0 0 0 0 0 #1 0 Sl 0 0 0 0 #2 0 0 S2 0 0 0 #3 0 0 0 S59 0 0 #60 10
13. [13.](https://image.slidesharecdn.com/b2cf288c-5ffb-4db2-aac3-0c115465eba7-150612075258-lva1-app6891/95/owencherylsamantha2005msccbthesis-13-638.jpg?cb=1434095639)Comparison with KNP data With the stable age distribution calculated, it was possible to build an age-structured model that moved through time. In order to compare the age structure predicted by the model with the known age structure in KNP, the proportions of elephants in each age class (derived from the Leslie matrix) was multiplied by the total number of elephants in the KNP database (4 583). In order to simulate the behaviour of the northern Botswanan population, the same proportions were applied to the wet season estimate of the Botswanan population (111 763, Chase 2004). The model was then run for 20 years, using parameters in Table 1. The model outputs were multiplied by 0.405 (the proportion of males in the population) such that numbers refer only males. Running the model incorporating trophy and non-trophy males Still based on a pristine population of males, a second model was developed to distinguish between non-trophy and trophy individuals. The measurements of heaviest tusk weight from animals culled in KNP were used to calculate the proportion of elephants in each age class with tusks 2:11 kg (the legal minimum weight), and data from field observations in northern Botswana were used to calculate the proportion of elephants of different ages with broken tusks. These proportions were used to predict the number of trophy-quality tusks in each age class. Age classes 0-19 were calculated using the same formulas as used in the original model, but age classes 20-60 were split into three categories: 'non-trophy', 'trophy weight' and 'trophy quality, undamaged'. The proportion of individuals with non-trophy tusks that grow into trophy-weight tusks as they move into the next age class - the tusk growth ratio - was calculated as 1-(propo11ion of non-trophy tusks in the present age class/proportion of non-trophy tusks in the previous age class). Trophy availability in age classes 20-60 was calculated by multiplying the total number of males in the pristine population at age x by the proportion of elephants at age x with trophy tusks. The number of trophy-quality individuals with no broken tusks was 11
14. [14.](https://image.slidesharecdn.com/b2cf288c-5ffb-4db2-aac3-0c115465eba7-150612075258-lva1-app6891/95/owencherylsamantha2005msccbthesis-14-638.jpg?cb=1434095639)calculated by multiplying the number of trophy weight bulls by the proportion of bulls without broken tusks at that specific age class (derived from regression analysis (see above)). The numbers of non-trophy bulls in years 1-20 were calculated using the equation: Non-trophy (NT) year 1 - 20 = (NT ofprevious age class \* survival of previous age class) - (survival ofprevious age class \*(1- tusk growth ratio ofpresent age class) \*NT ofpresent age class). The potential numbers of trophy-weight bulls (assuming no tusk breakage) in years 1-20 were calculated using the equation: Trophy (1) year I - 20 = (T ofprevious age class \*survival ofprevious age class) + (survival ofprevious age class \* (l - tusk growth ratio ofpresent age class) \*NT of present age class). Capping thepopulation at carrying capacity Left to run for 20 years, the pristine population of males reaches 148 869, corresponding to a total population of 367 795. A ceiling cap was put on the model to stop the total population running over a carrying capacity of 140000, or 56 667 males. It was assumed that numbers of animals exceeding the carrying capacity did not contribute to reproduction as they either died or emigrated to neighbouring countries; the probability of emigration or death was considered equal in all age classes. A cap proportion was calculated for each year by dividing the carrying capacity (56 667) by the observed total of males for that year. The total number in each age class was multiplied by the corresponding cap proportion for that year; this held the total population of males at their maximum carrying capacity of 56 667. This calculation was done on a year-by-year basis, so as every year was capped, the number of individuals in each age class in the . following year was reduced. 12
15. [15.](https://image.slidesharecdn.com/b2cf288c-5ffb-4db2-aac3-0c115465eba7-150612075258-lva1-app6891/95/owencherylsamantha2005msccbthesis-15-638.jpg?cb=1434095639)Hunting bag scenarios This model incorporated different hunting scenarios by subtracting the absolute number of bulls removed from each age class from the total number in each trophy weight category. All formulae were replicated from the pristine males model, but the calculation for the number of trophy-weight individuals was adjusted for the hunting offtake. Three levels of hunting offtake were modelled: the average observed hunt bag from 1996 to 2004, and double and triple the observed hunt bag. Each model capped the population in the year it exceeded carrying capacity. The number of trophy-weight individuals in each age class from years 1 to 20 after the hunting offtake was calculated by the following equation: Trophy (T) year 1 - 20 = (T 0/previous age class \* survival previous age class) + (survival previous age class \*(1- tusk growth ratio a/present age class) \*NT a/present age class) - hunt bag a/present age class. Model sensitivity to calfsurvival Three different calf survival rates were used to test the sensitivity of the model to the survival of 0-1 year old calves. The survival based on Van Aarde (2004) was used as the high survival rate; the lower standard deviation of this rate was used as a medium survival rate; and the survival rate based on data presented in Hanks's (1972) study was used as the low calf survival rate (Table 2). Table 2. High, medium and low survival rates for calves 0-1 year old. Calf Survival Rate Source .954 Van Aarde et al (2004) .904 Van Aarde et al (2004) .64 Hanks (J 972) 13
16. [16.](https://image.slidesharecdn.com/b2cf288c-5ffb-4db2-aac3-0c115465eba7-150612075258-lva1-app6891/95/owencherylsamantha2005msccbthesis-16-638.jpg?cb=1434095639)Results Comparison of age structures: calibrating the model Of the 4 739 elephants culled from the Kruger National Park, 4 583 were aged (Fig. 1). The population is dominated by the youngest age classes, with almost 8% of the population being calves less than one year old, and each age class above 32 years old containing <1% of the population. 9 8 ,...., 7 '$. 6 '-" i7 5 @ 4 ::J C" 3 eII. o ~ ~ b q V ~ ~ v ~ v ~ ~ ~ ~ ¥ ~ ~ ~ ~ ~ ~ Age Class Figure 1. Age structure of elephants (both sexes combined) culled in Kruger National Park, 1975-2000. The stable age distribution predicted by the model (Fig. 2) is very similar to the observed elephant population age structure in KNP (Fig. 1). Just over 7% ofthe population is aged <1 year, and each age class>31 years old holds less than 1% of the population. The similarity between the two age distributions confirms that the model is predicting a realistic age structure. 14
17. [17.](https://image.slidesharecdn.com/b2cf288c-5ffb-4db2-aac3-0c115465eba7-150612075258-lva1-app6891/95/owencherylsamantha2005msccbthesis-17-638.jpg?cb=1434095639)8 ~ 6o...... ~ 4e Ql 6- 2Ql ..U. a :) ~ co ,,1- "co ~ ~ ~ ~'lt ~co ~:) ~ ~co ~1- ~co co:) Age clas: Figure 2. Age structure of the culled elephants from KNP as predicted by the model. Botswana: age structure of hunted elephants, 1996-2004. Two linear regressions were performed to predict age from observed tusk weights of elephants hunted in Botswana, 1996-2004 (Fig. 3). The model 2 regression produced the structure most similar to the observed age structure ofthe 196 trophy animals aged from analysis of lower jawbones (Figs. 4-6). I 70 60 50 ....... 40 ~ >...... 30Ql Cl < 20 10 0 0 10 20 30 .... 40 50 Weight (Kgs) Figure 3. Two Iinear regressions ofpredicted ages from observed weights of heaviest tusks 15
18. [18.](https://image.slidesharecdn.com/b2cf288c-5ffb-4db2-aac3-0c115465eba7-150612075258-lva1-app6891/95/owencherylsamantha2005msccbthesis-18-638.jpg?cb=1434095639)25 20 ....... 15~Q '-' ~ e 10<U ::J C" <U .. 5II. O+rrrrrTTTTTTTTTTTT""""'"'T"T"T''-r"r-r''Hr.,.,.,.,...,.,.,...,.,.,wr-H,.a,.y.,,..,..,.,...,.,.,...,...,,.,..,..,-rl <::> )< '0 ,,'l- ,,<0 ",<::> l' ~ ,,;>'" ,,;><0 )<<::> )<)< )<'0 ~'" ~<o <0<::> Age (Years) Figure 4. Age structure of the 196 trophy elephants hunted in Botswana, aged from the analysis oflower jawbones. r------ 18 - -~...-..\_-\_..-.~..\_-..--...----..--.-.-.-----. ------.--.,,-..-. -•.-,,--., 16 14 ....... 12 ~ 10 g 8 <U g. 6 <U ..II. 4 2 O+n-TTTTTT"TTTrrrTTT"rrrrrrTTTTTT.",..'M',w,wr'-M~"T'rr-rrr-rrr..,,-,..{ <::> )< '0 "", ,,<0 ",<::> l' ",'0 ";>,,, ,,;><0 )<<::> ~ )<'b ~'" ~<o <0<::> Age (years) Figure 5. Age structure of 995 trophy elephants hunted in Botswana, as predicted by the model 1 regression. 16
19. [19.](https://image.slidesharecdn.com/b2cf288c-5ffb-4db2-aac3-0c115465eba7-150612075258-lva1-app6891/95/owencherylsamantha2005msccbthesis-19-638.jpg?cb=1434095639)11111,1 ,I I.• ,I JII 9 8 7 ~ 6 ~ 5 ~ go 4 ..u. 3 2 1 o -h-r"""""''''''''''"TTTT'IT"rTTTWr''r'ffrWIWr'M'r'rIT o V 00 N ~ 0 v 00 N ~ 0 v 00 N ~ 0 ~ ~ N N N M M V V V ~ ~ ~ Age (years) Figure 6. Age structure of 995 trophy elephants hunted in Botswana, as predicted by the model 2 regression. Trophy-quality tusks KNP trophy-quality tusk proportions The youngest bulls with a tusk weight heavy enough to be regarded as trophy quality were 20 years old. The proportion of bulls with trophy-quality tusks increases in a linear fashion from age 20 until age 29, by which age all bulls carry trophy-weight tusks (although some may have one broken tusk) (Fig. 7). --------,-~'.\_-~----1.2 1 c 0.8 0 :e 0.60 c. 0 0.4..0. 0.2 V ",'0 {'> ,,'" "S ,,'0 t><'y tJ" ~ s<:) S" s'o sO) Age Class -----------------------------, Figure 7. Proportion of bulls in each age class in KNP that have trophy-quality tusks. 17
20. [20.](https://image.slidesharecdn.com/b2cf288c-5ffb-4db2-aac3-0c115465eba7-150612075258-lva1-app6891/95/owencherylsamantha2005msccbthesis-20-638.jpg?cb=1434095639)Age-related Tusk Breakage In Chobe National Park, 60 of 260 bulls had broken tusks, the proportion increasing with age (Table 3). Table 3. Proportion ofmale elephants in Chobe National Park with broken tusks. Age 0/0 class Total Broken Broken 10-19 58 7 12 20-39 162 40 25 40-60 40 13 33 The proportion of bulls with broken tusks increased linearly, but not significantly, with age (1'1 = 0.98, p>0.05; Fig. 8). The lack of significance is a consequence of the single degree of freedom, but predictions from the regression were nonetheless used in subsequent models. I>< '0 ,,'" "ro ",0 l' ",'0 ,,'" "ro 1><0 t>i" 1><'0 ~'" ~ro roO Age Figure 8. Regression relating the proportion of elephants with broken tusks to age. 18
21. [21.](https://image.slidesharecdn.com/b2cf288c-5ffb-4db2-aac3-0c115465eba7-150612075258-lva1-app6891/95/owencherylsamantha2005msccbthesis-21-638.jpg?cb=1434095639)Hunted elephants in Botswana, 1996-2000. HUllting bag On average, 110 elephants have been shot annually in Botswana over the nine years since the reintroduction of hunting in 1996. The government-allocated quota of elephants for tourist hunting has never been reached. The lowest percent of the quota used, 41%, was in the first year hunting was reintroduced, and the highest, 89%, was in 2000 (Table 4). Table 4. Botswanan elephant hunting quotas and realised hunting bags. Year Quota Number shot % of quota shot 1996 80 34 41 1997 78 50 65 1998 174 97 57 1999 174 122 64 2000 174 155 89 2001 180 133 74 2002 180 131 73 2003 180 138 76 2004 180 136 78 Total 1400 995 71 Age and tusk sizes oftrophy elephants in Botswana Between 1996 and 2004, the average heaviest tusk of hunted males weighed around 25 kg, corresponding to an average age for hunted elephants of 38 years (Table 5, Figs. 9 and 10). 19
22. [22.](https://image.slidesharecdn.com/b2cf288c-5ffb-4db2-aac3-0c115465eba7-150612075258-lva1-app6891/95/owencherylsamantha2005msccbthesis-22-638.jpg?cb=1434095639)60 Table 5. Weight-frequency distribution (heaviest tusk) of trophy elephants hunted in Botswana, 1996-2004. Tusk weight (kg) 1996 1997 1998 1999 2000 2001 2002 2003 2004 11-15 0 2 2 6 0 3 2 5 3 16-20 6 16 16 26 19 14 13 8 10 21-25 33 34 33 34 32 39 37 34 42 26-30 27 36 35 25 36 31 34 38 30 31-35 27 8 9 5 12 11 11 12 13 36-40 6 4 4 2 1 2 3 3 1 41-50 0 0 0 2 0 1 0 0 1 100 80 ~ C QI ~ go 40 ..u, 20 0--t-Lr.,....,~L,J-,J'"-;J-~'-r'"-r'"-;J-,-Lr"L,J-,J.......,...~'-rA-r..,....~'-r'"-ra.,-r-r'".,.a,--.,.-,,-,.....,.....,.-i VV~~~VV~V~o/y~~~~~~~~ Tusk Weight (Kg) Figure 9. Pooled weight-frequency distribution (heaviest tusk) of trophy elephants in Botswana over a nine year period. 20
23. [23.](https://image.slidesharecdn.com/b2cf288c-5ffb-4db2-aac3-0c115465eba7-150612075258-lva1-app6891/95/owencherylsamantha2005msccbthesis-23-638.jpg?cb=1434095639)..... 45Ul til 40.¥ ...... 35.... 30.c til 25'iii 3: 20 'tl 15 e 10 "' 5.....Ul 0... >- Plio PI" ...... PI'O PI"> RJ() RJ"" RJ"" RJ'? ~Ql ..,,0) ..,,"> ..,,0) ..,,0) ",,<::5 ",,<::5 ",,<::5 ",,<::5 ",,<::5til c:e Year • Average Age !IJg Average Heaviest Tusk Weight Figure 10. Trend in average age and average heaviest tusk weight of elephants hunted in Botswana, 1996-2004. Effects of hunting with no carrying capacity limitations Population trends under pristine conditions (no hunting) The pristine population of males, starting with 45 237 animals (from the stable age distribution) increases at 6% p.a. The population exceeds the estimated carrying capacity of 56 667 by year 4, and by year 20 it reaches a total of 148 869, with trophy-quality bulls accounting for 12% of the population (Table 6). Table 6. Predicted number of trophy-quality bulls, total population of 20-60 year olds and total number ofbulls in a pristine, uncapped population. Year 0 Year 4 Year 20 Total trophy-quality bulls 5425 6885 17853 Total 20-60 year-old bullss 10264 13 025 33777 Total bulls 45237 57406 148869 Under pristine conditions, the growth rate of the population of males with trophy-quality tusks equals that of the population growth rate, but the proportion of animals with at least one tusk weighing more than 31 kg is small (Fig 11). 21
24. [24.](https://image.slidesharecdn.com/b2cf288c-5ffb-4db2-aac3-0c115465eba7-150612075258-lva1-app6891/95/owencherylsamantha2005msccbthesis-24-638.jpg?cb=1434095639)- - - - - - - - - - - - - - - - - - - ~ - ---------- ------1 8000 7000 - 6000 > 5000 u c ~ 4000 tT CIl s: 3000 1000 o 11-15 16-20 21-25 26-30 31-35 36-40 41-45 Tusk Weight (kgs) .Year 0 II Year 4 Year 20 Figure 11. The frequency of trophy-quality tusks in various weight categories under uncapped, pristine conditions after 0, 4 and 20 years. Population trends with current hunting bag The population of males (starting with a total of 45237 with a stable age distribution and the observed hunting bag introduced in year 1) exceeds the estimated carrying capacity by year 4. By year 20 it reaches a total of 144523, when trophy-quality bulls account for 11.6% of the population (Table 7). Table 7. Predicted number of trophy-quality bulls, total population of 20-60 year olds and total number of bulls under the observed hunting bag (population uncapped). Year 0 Year 4 Year 20 Total trophy-quality bulls 5425 6579 16793 Total 20-60 year old bulls 10264 12600 32246 Total bulls 45237 56873 144523 The number of trophy-quality tusks in each weight category is similar to that of the pristine population, with most tusks weighing 16-20 kg, and only a few tusks >40 kg (Fig. 12). 22
25. [25.](https://image.slidesharecdn.com/b2cf288c-5ffb-4db2-aac3-0c115465eba7-150612075258-lva1-app6891/95/owencherylsamantha2005msccbthesis-25-638.jpg?cb=1434095639)7000 6000 5000 ~ 4000 e Ql ::l 3000 e-Ql ...u. 2000 1000 0 .Year 0 Year 4 Year 20 11-15 16-20 21-25 26-30 31-35 36-40 41-45 Tusk Weight (kg) Figure 12. The frequency of trophy-quality tusks in various weight categories under the observed hunting bag (population uncapped), at 0, 4 and 20 years. Population trends with double the current hunting bag The population of males (starting at a total of 45 237 with a stable age distribution) exceeds the estimated carrying capacity one year later than that of the pristine and observed hunting bag scenarios. By year 20, it reaches a total of 140 177, when trophy- quality bulls account for 11.2% of the population (Table 8). Table 8. Predicted number of trophy-quality bulls, total population of 20-60 year olds and total number of bulls under double the observed hunting bag (population uncapped). Year 0 Year 4 Year 20 Total trophy-quality bulls 5424 6273 15732 Total 20-60 year old bulls 10264 12 175 30715 Total bulls 45237 56341 140 177 23
26. [26.](https://image.slidesharecdn.com/b2cf288c-5ffb-4db2-aac3-0c115465eba7-150612075258-lva1-app6891/95/owencherylsamantha2005msccbthesis-26-638.jpg?cb=1434095639)The trend in trophy weights under double the hunting bag is similar to that of both the pristine and observed scenarios, but there are substantially fewer bulls in the heavier tusk weight categories (Fig. 13). 6000 5000 >- 4000 u c CII 3000::J e- CII .. 2000Ll. 1000 0 .Year 0 Year 4 Year 20 11-15 16-20 21-25 26-30 31-35 36-40 41-45 Tusk Weight (kg) Figure 13. The frequency of trophy-quality tusks in various weight categories under double the observed hunting bag (population uncapped). Population trends with triple the current hunting bag Under triple the current hunting bag, the population ofmales exceeds carrying capacity in year 5, resulting in a total population of 14671 trophy-quality bulls by year 20 (Table 9). Table 9. Predicted number of trophy-quality bulls, total population of 20-60 year olds and the total number of bulls under triple the observed hunting bag (population uncapped). Year 0 Year 4 Year 20 Total trophy-quality bulls 5425 5967 14671 Total 20-60 year old bulls 10264 11 751 29 184 Total bulls 45237 55808 135 830 The trend in trophy weights under triple the hunting bag starts with a similar pattern to the previous scenarios, with the number of trophy quality bulls increasing from year 0 to 24
27. [27.](https://image.slidesharecdn.com/b2cf288c-5ffb-4db2-aac3-0c115465eba7-150612075258-lva1-app6891/95/owencherylsamantha2005msccbthesis-27-638.jpg?cb=1434095639)year 20, but there is a marked decrease in the number of bulls with tusk weights exceeding 30 kg (Fig. 14). 6000 5000 2000 3000 ~ 4000 cQl :I 0" ~ II. 1000 o 11-15 16-20 21-25 26-30 31-35 36-40 41-45 Tusk Weight (kg) .Year 0 Year 4 Year 20 Figure 14. The frequency oftrophy-quality tusks in various weight categories under triple the observed hunting bag (population uncapped). Effects of hunting with carrying capacity superimposed The model was run starting with a population of 45 237 males, but with male numbers capped once they exceeded 56 667. Population trends under pristine conditions (no hunting) The age structure of the population remains static from the year capping is introduced, at which time trophy-quality bulls account for 12% of the total male population (Table 10). Table 10. Predicted number of trophy-quality bulls, total population of 20-60 year olds and the total number ofbulls in a capped pristine population. Year 0 Year 4 Year 20 Total trophy-quality bulls 5425 6796 6796 Total 20-60 year old bulls 10264 12857 12857 Total bulls 45237 56667 56667 25
28. [28.](https://image.slidesharecdn.com/b2cf288c-5ffb-4db2-aac3-0c115465eba7-150612075258-lva1-app6891/95/owencherylsamantha2005msccbthesis-28-638.jpg?cb=1434095639)The frequency of trophy-quality males remains constant from year four (Fig. 15). 3000 .- -- -- - .•...................................- - ..-- --.-- -- -.-.•'-'."'.' . 2500 2000 >-u C 1500QI j C' QI 1000..u, 500 o .Year 0 IilIYear4 "Year 20 11-15 16-20 21-25 26-30 31-35 36·40 41-45 Tusk Weight (Kg) Figure 15. Frequency of trophy-quality tusks under pristine conditions (population capped) in three different years.. Population trends under observed hunting bag Under the observed hunting bag, trophy-quality bulls in year 20 account for 11% of the male population (Table 11). Table 11. Predicted number of trophy-quality bulls, total population of 20-60 year olds and the total number of bulls in a capped population subjected to the observed hunting bag. Year 0 Year 4 Year 20 Total trophy-quality bulls 5425 6555 6395 Total 20-60 year old bulls 10264 12554 12414 Total bulls 45237 56667 56667 26
29. [29.](https://image.slidesharecdn.com/b2cf288c-5ffb-4db2-aac3-0c115465eba7-150612075258-lva1-app6891/95/owencherylsamantha2005msccbthesis-29-638.jpg?cb=1434095639)The supply of trophy-quality tusks increases from year 0 to year 4, but by year 20 only the supply of trophies of 11-25 kg continues to increase. Above 25 kg, the supply decreases with increasing tusk weight (Fig. 16). 2500 2000 ee ~ 1500 C' QI ..u, 1000 500 o 11-15 16-20 21-25 26-30 31-35 36-40 41-45 Tusk Weight (Kg) .Year 0 ~Year 4 Year 20 Figure 16. Frequency of trophy quality tusks subjected to the observed hunting bag in three different years (population capped). Population trends under double the current hunting bag In year 20, under double the observed hunting bag, trophy-quality bulls account for 10.5% of the total male population (Table 12). Table 12. Predicted number of trophy-quality bulls, total population of 20-60 year olds and the total number of bulls in a capped population subjected to double the observed hunting bag. Year 0 Year 4 Year 20 Total trophy-quality bulls 5425 6273 5988 Total 20-60 year old bulls 10264 12 175 11 966 Total bulls 45237 56341 56667 27
30. [30.](https://image.slidesharecdn.com/b2cf288c-5ffb-4db2-aac3-0c115465eba7-150612075258-lva1-app6891/95/owencherylsamantha2005msccbthesis-30-638.jpg?cb=1434095639)The frequency distribution of tusks in various weight categories is similar to that of the observed hunting bag, with the frequency increasing in the first three weight categories and decreasing above 25 kg. There is, however, a much smaller increase from year 4 to year 20 in the 2] -25 kg weight category - a sign that the availability of heavier tusks is about to decrease (Fig. ]7). 3000 2500 2000 >. u c QJ 1500:::I C" QJ ..u. 1000 500 0 .Year 0 Year 4 Year 20 11-15 16-20 21-25 26-30 31-35 36-40 41-45 Tusk Weight (Kg) L.-- \_ Figure 17. Frequency of trophy-quality tusks in a capped population subjected to double the observed hunting bag in three different years. Population trends under triple the current hunting bag With the introduction of triple the hunting bag, by year 20, trophy-quality bulls account for] 0% ofthe male population (Table] 3). 28
31. [31.](https://image.slidesharecdn.com/b2cf288c-5ffb-4db2-aac3-0c115465eba7-150612075258-lva1-app6891/95/owencherylsamantha2005msccbthesis-31-638.jpg?cb=1434095639)Table 13. Predicted number of trophy-quality bulls, total population of 20-60 year olds and the total number ofbulls in a capped population subjected to triple the observed hunting bag. Year 0 Year 4 Year 20 Total trophy-quality bulls 5425 5967 5633 Total 20-60 year old bulls 10264 11 751 11 597 Total bulls 45237 55808 56667 Although the pattem depicting the frequency of tusks in various trophy weight categories is similar to the previous scenarios, triple the hunting bag has a more severe impact on the frequency of heavier trophy weights. By year 20, the number of tusks weighing 31- 35 kg is only four, and there are no tusks heavier than this (Fig. 18). 3000 -.-.----.--.----~~-.----.-----.--.--.-.- 2500 2000 >- 1500u or:: Q) ::l C' 1000Q) ...u.. 500 o .Year 0 IlIlYear 4 Year 20 11-15 16-20 21-25 26-30 31-35 36-40 41-45 Tusk Weight (Kg) Figure 18. Frequency of trophy-quality tusks in a capped population subjected to triple the observed hunting bag in three different years. Effects of variable first-year survivorship The survival of 0-1 year old calves has a considerable effect on the population of trophy quality bulls by year 20. Under the observed hunting bag scenario (population 29
32. [32.](https://image.slidesharecdn.com/b2cf288c-5ffb-4db2-aac3-0c115465eba7-150612075258-lva1-app6891/95/owencherylsamantha2005msccbthesis-32-638.jpg?cb=1434095639)uncapped), and reducing first-year survival from 0.94 to 0.64 reduces the number of trophy-quality bulls by 40% after 50 years (Fig. 19). 120000 100000 ()' 80000 C CII g. 60000 CII ..II. 40000 20000 Survival - - - 95% -'- - -90% --64% O+-r-r-r-r--ro-,.--,--r-r-r--r-r.....-r-r-r--r-r,.--,--r-r-r-'--'''-'--'rrT...--r"-,-,--,,.--,--r-r-r--ro-,.--,--r-r-r ~ ~ ~ ~ V ~ ~ V ~ V ~ y ~ ~ ~ ~ ~ Years Figure 19. The effect of variable first-year survivorship on the supply of trophy-quality bulls (population uncapped). Discussion The 'elephant problem' in northem Botswana, first described by Caughley (1976), manifests itself in changes in vegetation and structure - mainly the disappearance of riverine Acacia woodlands on the elevated alluvial plains along the Chobe River (Skarpe et al2004) - caused by an overabundance of elephants. It has been described in terms of the density of elephants, focusing mainly on the sheer magnitude of their numbers (Ben- Shahar 1997). Decisions revolving around how best to manage these populations have been debated for the past 20 years, and whether the best solution is hunting, culling or redistribution (or a combination of all three), the age structure and ramifications of reducing numbers must be considered in addition to density (Fowler and Smith 1973). In 2003, Van Aarde et al (2004) conducted ground and aerial surveys to obtain data on the age-structure of elephant herds in part of the Okavango Delta, Chobe National Park 30
33. [33.](https://image.slidesharecdn.com/b2cf288c-5ffb-4db2-aac3-0c115465eba7-150612075258-lva1-app6891/95/owencherylsamantha2005msccbthesis-33-638.jpg?cb=1434095639)and Moremi Wildlife Reserve in northem Botswana. Van Aarde et at (2004) derived estimates of age of first calving, calving interval and age-specific survival rates in order to determine the trends in elephant population numbers. The total population number of elephants in these combined areas available for inclusion in the study was 13 918, but their estimated size of northern Botswana's elephant population in September 2002 ranged from 114 576 to 132000. The estimation by Chase (2004) of the total population numbers in Northem Botswana (107 500 krrr') is between 106 938 and 109392 in the dry season and 93 004-111 763 in the wet season. It is the latter of these estimates upon which the model's initial total population number was based. It is assumed that age-specific mortalities and fecundities are independent of population density, the environment or abiotic factors and, as such, remain constant. Elephants are assumed to have populations characteristic of equilibrium conditions, with stationary age distributions in habitats undisturbed by humans. Shiao-Yen and Botkin (1980) point out that this is not necessarily the case and that birth and calf mortality rates may vary due to annual variations in rainfall, producing an age structure affected by a time-varying process. The similarity, however, between the age distributions measured in Kruger National Park and derived in the model confirms that the model's parameters are realistic . and its age structure credible. Natural population regulation mechanisms based on density dependence (e.g. fertility and mortality), catastrophic habitat changes, and dispersal are still relatively unknown (M. Chase, unpubl. data). It is known, however, that the geographic range of elephants extends across international boundaries and elephants disperse to and from Zimbabwe, the Caprivi Strip in Namibia, Angola and Zambia (Chafota and Owen-Smith 1996). Spinage (1990) suggests a carrying capacity of approximately 135 000 elephants for northern Botswana. The model presented here assumes that elephants will emigrate to neighbouring countries (or die) when they exceed an ecological carrying capacity of 140 000 animals, but the possibility of immigration is excluded. 31
34. [34.](https://image.slidesharecdn.com/b2cf288c-5ffb-4db2-aac3-0c115465eba7-150612075258-lva1-app6891/95/owencherylsamantha2005msccbthesis-34-638.jpg?cb=1434095639)On condition that revenue from tourist hunting is used as a conservation tool and spread further than profit for hunting operators, it can provide economic incentive to protect areas from agricultural encroachment and human settlement - thus protecting the animals that hunters are paying to shoot (Bothrna 1989; Hudson et a11989; Metcalfe, 1994; Caro 1998). In order to have a real conservation effect, hunting must be a long-term option and quotas should reflect its sustainability (Caro 1998). To ensure long-term viability of trophy males, hunting quotas need to be allocated in proportion to both the size of the elephant population and the rate of supply of individuals with trophy-quality tusks. The model predicts the total male population, but more importantly it predicts the number of males with trophy-quality tusks that can be used as a baseline against which hunting quotas can be set. The minimum legal weight of a trophy tusk is 11 kg; lighter tusks are confiscated from hunters by the government. Elephants in the model reach the potential trophy-quality tusk window when they tum 20, the age when they have the potential of carrying tusks of >10 kg. Once in this age window, those actually carrying trophy-quality tusks are defined by the proportion of elephants at each age whose heaviest tusk meets the legal requirement, and whose tusks are not broken. The rise in tusk breakages as males get older (Fig. 8), may be due to the increase in fights between males for prime positions at artificial water holes, where pumped water flows in. Breakage also increases as the last sets of molars wear down and elephants use their tusks more frequently for accessing food. According to hunting operators, client demands for trophy tusks vary - some are after a perfect matching pair, others don't mind if tusks are chipped. Likewise, a weight of 23 kg may be acceptable to some whereas others will not shoot unless an elephant has tusks >27 kg. Operators regard a tusk weighing 27 kg as a 'reasonable trophy', but complain tusks are "not what they used to be - at 45 kg per side" (P. Heburn pel's. cornm.). The information gathered from analysis of data from hunted elephants in Botswana between 1996 and 2004 has enabled a great deal to be learned about the effects and pattern of hunting. The mortality pattern of hunted elephants, interesting in itself, served 32
35. [35.](https://image.slidesharecdn.com/b2cf288c-5ffb-4db2-aac3-0c115465eba7-150612075258-lva1-app6891/95/owencherylsamantha2005msccbthesis-35-638.jpg?cb=1434095639)as an empirical guide for simulating different levels of hunting pressure. The determination of mortality patterns aIlows for the effects of different offtakes to be simulated with confidence, aIlowing for realistic applications in management (Pilgram and Western 1986). The model depicting the pristine population of elephants produces an age structure of trophy-quality males that remains constant over time (Fig 15). The models predicting trophy-quality frequency under the observed, double and triple the observed hunting offtakes, however, shows the age structure and therefore tusk-weight distribution becoming increasingly truncated with increasing hunting pressure (Figs 16-18). For hunters, this means that fewer of the older animals with heavier tusks are available to be shot and predicts a decrease in the average sizes of trophy tusks. Trophy hunting, by its very nature, is selective and therefore when the hunting bag is increased the population of trophy-quality bulls will always be reduced (Craig and Gibson 1993). The current situation There has been no substantial change in bull trophy size over the past nine years (Fig 10), indicating that the age structure has reached an equilibrium with hunting pressure. The only significant decrease in trophy quality was from 1996 to 1997, when the average age and weight of hunted elephants decreased from 41 years and 27 kg to 39 years and 25 kg, respectively. Within this time frame the number of animals shot with 31-35 kg tusks decreased by 19%. From 1997-2004 the average age remained between 37 and 39 years old and the average heaviest tusk weight per hunted individual stayed at a constant 25 kg. This pattem is most likely due to the fact that 1996 hosted the reintroduction of trophy hunting, giving hunters the opportunity to shoot bulls that had developed larger tusks during the period when hunting was banned. Under the cun'ent hunting offtake, the frequency of males with trophy tusks between 11 and 25 kg increases from hunting year 0 to hunting year 20. By year 20, the model predicts that there are 1 387 individuals carrying trophy-quality tusks weighing 21-25 kg, 33
36. [36.](https://image.slidesharecdn.com/b2cf288c-5ffb-4db2-aac3-0c115465eba7-150612075258-lva1-app6891/95/owencherylsamantha2005msccbthesis-36-638.jpg?cb=1434095639)indicating that trophy hunters' demands will continue to be met. The number of 26-30 kg tusks increases in the first few years but by year 20 the number decreases back to almost the original quantity. The same pattern is true for the classes of 31-35, 36-40, and 41-45 kg tusks, but by year 20, there are fewer of these tusks available than in year O. Despite truncating the population, the age structure under the observed hunting bag scenario still retains enough sexually mature animals to maintain a stable population. Therefore, the present level of trophy hunting appears extremely unlikely to threaten the availability of trophy-quality tusks in the future. The model assumes that hunting has no impact on the sex ratio, resulting in a slight bias towards fewer rather than more males left in the population. Although this presents a worst case scenario by artificially reducing the number of elephants entering the population as the hunting bag is increased. At low population sizes, the fact that hunters are only allowed to remove males may result in difficulties for females in finding mates (Ginsberg and Milner-Gulland 1994), thus lowering fecundity values (Poole 1989; Fergusson 1990). However, the low proportion of males removed from the Botswanan population by hunting (0.1%, 0.2% and 0.3% under the current, double and triple scenarios respectively) prevents this flaw being a cause for concern. It is assumed that the population in northern Botswana is large enough to ensure that males are not a limiting factor and every female is able to become pregnant every 3.41 years (the calving interval). The Department of Wildlife and National Parks in Botswana is responsible for issuing hunting permits for hunting concession blocks, each of which is allocated to hunting companies. Concession areas are given six or 12 permits to hunt, depending on whether they are private or community owned, respectively. In anyone year only three out of the 23 concessions allocated hunting quotas did not use their concession for hunting due to management philosophies that adhered to photographic tourism rather than trophy hunting. The evidence in Table 4, depicting the percent of quotas actually used between 1996 and 2004 suggests that there is no need to increase the hunting quota. 1996 was the only year in which less than 50% of the quota was not used. After a peak in 2000 of 34
37. [37.](https://image.slidesharecdn.com/b2cf288c-5ffb-4db2-aac3-0c115465eba7-150612075258-lva1-app6891/95/owencherylsamantha2005msccbthesis-37-638.jpg?cb=1434095639)almost 90%, the proportion of quota used dropped to ca 70-80% and has remained fairly constant for the past four years. Interviews with hunting operators in Kasane revealed that the larger, older bulls are rarely seen in the concession areas and operators believe that they move into 'safe' areas during the hunting season (April to September). Indeed it is possible that disturbance caused by hunting may cause elephants to seek sanctuary within national parks and reserves that act as population reservoirs (Chafota and Owen- Smith 1996, Caro et al 1998). Hunting operators admitted that in some years hunting bags did not reflect the quality and quantity of trophy tusks observed in the field. Scenarios for increased huntingpressure Simulating increased hunting bags demonstrates the effects of hunting on every age class and hence forecasts the sustainability of males with trophy-quality tusks. The model predicts an annual growth rate for the elephant population of 6%, close to the figure of 7%, given by Calef (1988) as the maximum possible. Under pristine conditions, once the population reaches carrying capacity, the growth rate and the population's age distribution remains constant. If the current hunting bag is doubled, the model predicts an increase in the number of tusks weighing 11-25 kg, but by year 20 there are 59 fewer tusks between 21-25 kilograms than under the current hunting bag. There is a constant decrease of tusks weighing between 26-30 kg, resulting in 191 less individuals in year 20 than there were in year O. Tusks weighing 31-40 kg follow the same pattern as under the observed hunting bag, increasing in year 4 but decreasing by year 20, and by year 20, only 2 animals with trophy tusks >41 kg remain. When the hunting bag is tripled, hunting takes a severe toll on males aged 40+ years. By year 7, less than 100 trophy individuals survive to be 40 years or older; by year 14 there are less than ten >45 years old, and by year 17 there are no males more than 47 years old. Hunting at this level allows males with tusks weighing 11- 25 kg to increase and therefore absorb the hunting pressure, but the sustainability of supply of older bulls at this 35
38. [38.](https://image.slidesharecdn.com/b2cf288c-5ffb-4db2-aac3-0c115465eba7-150612075258-lva1-app6891/95/owencherylsamantha2005msccbthesis-38-638.jpg?cb=1434095639)level is questionable. By year 20, males with tusks weighing 26-30 kg decrease to almost half the number of animals as in the stable age distribution; males with tusks weighing 31-35 kg decrease to only four individuals and there are no bulls with tusks >35 kg. Selective hunting of males with the heaviest tusks under a hunting pressure greater than double the current hunting bag could therefore result in adverse effects on breeding, age structure, sex distribution and social organisation of the population. However, the population could remain stable under this hunting pressure if restrictions were put in place to prevent the hunting ofmales carrying tusks >25 kg. Sensitivity analysis ofcalfsurvival rates Models of the elephant population dynamics by Hanks and McIntosh (1973) have shown that although variations in reproductive rates playa major part in regulating population growth, a variation in mortality, especially neo-natal mortality, is a more important mechanism for controlling populations. Similarly, a study by Caughley (1970) on the eruption of Himalayan Thar Hemitragus jemlahicus in New Zealand found that variation in the mortality rate, mainly during the first year of life, had the biggest impact on the population's growth rate. The survival rate of elephant calves in their first year of life is relatively unknown compared to the survival rate of elephants>1 years old, and estimates of this parameter from different populations vary greatly. The model was based on an extremely high survival rate, estimated by Van Aarde et al (2004), of 95±0.05%. Increased predation by lions, drought or a decrease in the availability of food are all factors that could influence the survival of young calves. Relative to the estimated first year survival rate of 0.95, a survival rate of 0.64, based on an estimation by Laws (1969), reduced the number of trophy-quality bulls under the current hunting bag by 40% over a 50-year time period (Fig 19). Given, therefore, that a change in juvenile survival rate might have a greater impact on the supply of trophy-level animals that does the current hunting pressure, future research should consider developing an effective and accurate means of monitoring changes in first-year survivorship. 36
39. [39.](https://image.slidesharecdn.com/b2cf288c-5ffb-4db2-aac3-0c115465eba7-150612075258-lva1-app6891/95/owencherylsamantha2005msccbthesis-39-638.jpg?cb=1434095639)Conclusions The model developed in this study indicates that, even in the absence of refuges such as national parks, the current take-off of trophy bulls is sustainable. Numerically, it would still be sustainable with double the current hunting pressure, although within two decades, the supply of the larger trophy animals would have largely dried up. Therefore, increasing the hunting quota for elephants to double its current level would be an acceptable management decision, but given that on average, only 68% of the hunting quota has been used in the 9 years since hunting was unbanned, it is highly unlikely that an increased quota will be fully utilised. Current predictions about sustainability rest to a considerable extent on the estimate of first-year survivorship (0.95) being accurate. Whilst all other evidence from the models suggest this estimate to be robust, if survivorship was to be reduced, this would have a direct effect on the supply of males carrying trophy-quality tusks. Under the worst-case scenario based on a field measurement (first-year survivorship of 0.64), the supply of trophy-quality tusks would be reduced by approximately 40% within 50 years. Devising an accurate protocol for monitoring first-year survival should therefore be seen as a research priority. Acknowledgements I wish to thank my supervisor, Dr. Phil Hockey, for assisting me with the analysis, development of the model and conunenting on the write-up. I also thank Dr. Colleen Moloney for her comments and assistance on the development of the model. The model was based on data collected by Debbie Peak at Mochaba Professional Trophy Handling in Maun, data collected under the direction of Dr. Rudi van Aarde at the University of Pretoria's Conservation Ecology Research Unit, data made available by Dr. Ian Whyte on elephants culled from Kruger National Park between 1975 and 2000 and data collected 37
40. [40.](https://image.slidesharecdn.com/b2cf288c-5ffb-4db2-aac3-0c115465eba7-150612075258-lva1-app6891/95/owencherylsamantha2005msccbthesis-40-638.jpg?cb=1434095639)by Michael Chase; the project would not have been possible without their generosity in sharing them. I thank Michael Chase and Kelly Lander for logistical support and for their kind hospitality in Botswana. I am grateful to Dr. Jolm Hanks for the endless supply of reference material and for sourcing the funding from the Shikar Safari Club for the field work. 38
41. [41.](https://image.slidesharecdn.com/b2cf288c-5ffb-4db2-aac3-0c115465eba7-150612075258-lva1-app6891/95/owencherylsamantha2005msccbthesis-41-638.jpg?cb=1434095639)References Anderson, D. (1975) Optimal expoloitation strategies for an animal population in a Markovian environment: a theory and an example. Ecology 56: 1281-1297. Ben-Shahar, B. (1997) Elephants and woodlands in northem Botswana: How many elephants should be there? Pachyderm 23:41-43. Bothma, J. (eds) (1989) Game Ranch Management. 1.L. van Schaik, Pretoria, South Africa. Calef, G. (1988) Maximum rate of increase in the African elephant. African Joumal of Ecology 26:323-327. Campbell, A.C. (1990) History of Elephants in Botswana, The Future of Botswana's Elephants, Report on Workshop of the Kalahari Conservation Society and Dept. Wildlife and National Parks. Caro, T., Pelkey, N., Bomer, M., Severre, E., Campbell, K, Huish, S., Ole Kuwai, 1., Farm, B. and WOOdW0l1hm B. (1998) The impact of tourist hunting on large mammals in Tanzania: an initial assessment. African Joumal of Ecology 36: 321-346. Caughley, G. (1966) Mortality patterns in mammals. Ecology 47:906 - 918. Caughley, G. (1970) Eruption of ungulate populations, with emphasis on Himalayan Thar in New Zealand. Ecology 51:53-72. Caughley, G. (1976) The elephant problem - an alternative hypothesis. East African Wildlife JoumaI14:265-283. Chafota, J., DuToit, 1., Lugoloobi, W., Malthare, 1., Owen-Smith, N., Roskaft, E., Stokke, S., Saether, RE. (1993) Report from a workshop to promote a collaborative elephant research project based in northern Botswana. Chafota, 1. and Owen-Smith, N., (1996) Options for the management of elephants in northern Botswana. Pachyderm No 22:67-73. Chase, M. Unpubl. data. Chase, M. (2004) The population status, ecology and transboundary movements of elephants in the okavango upper zambezi transfrontier conservation area. A funding report. Conservation International Okavango Corridor Programme, Child, G. (1968) An Ecological Survey of Northeastem Botswana. FAO publication No. TA2563, Rome. 39
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