Regulation of a small, discrete African elephant population through immunocontraception in the Makalali Conservancy, Limpopo, South Africa

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Populations of the African elephant, *Loxodonta africana*, are growing rapidly in southern Africa, to the extent that population control has become essential. The management option of translocation is no longer realistically available, whilst culling has become ethically unacceptable, especially to the general public. Previous immunocontraception trials on elephants with Porcine Zona Pellucida (PZP) vaccine demonstrated that it is safe, effective, reversible, remotely deliverable, and has had no evident adverse side effects. We demonstrate effective contraceptive management of a discrete, small population of free-roaming elephants in the Makalali Conservancy, Limpopo province, South Africa. Complete reproductive control has been demonstrated in all 18 original targeted females, who have by now passed the population's average intercalving interval of 56 months without giving birth. A zero population growth rate has been maintained within this target group since August 2002. On the basis of this small sample over a short period, immunocontraception should be considered a viable means of population management as an alternative to long-term culling strategies in small populations.

Introduction

Natality and immigration have a net positive influence on the size of an animal population whereas mortality and emigration have the opposite effect. The combined effects are referred to as the 'population flux'. Populations do not attain the theoretical maximum rate of increase very often.[1] That requires readily available food and a low density of animals such that there is negligible competition for resources. These conditions are most closely approached when a population is in the early stages of increasing its numbers following the release of a nucleus of individuals into an area from which they were formerly absent.[1]

In closed systems with limited food, space and water, the manipulation of the population's growth rate is of critical importance to the future survival of that population. Such systems are isolated from emigration by fencing[1,2] and some form of population control is essential to maintain an acceptable population density. Culling excess animals is proposed by some managers but is no longer deemed ethically acceptable, particularly to the public.[3–6] By 2001, 800 elephants had been translocated [mainly from the Kruger National Park (KNP)] to 58 small, fenced reserves in South Africa.[2] Survey data for 2001 demonstrated that relocated populations had a female bias with 0.79 males to one female and that, in these populations, almost half comprised adult and subadult females, indicating substantial potential for rapid population growth.[2] Population growth rates averaged 8.3% p.a., but five reserves had annual rates above 13%; the highest reported annual growth was 16.5%.[2] These results indicate that the translocation of elephants has been very successful. For this reason, opportunities for translocation to regulate expanding populations are now very limited as most suitable areas in southern Africa are already occupied by elephants.[6]

Preliminary trials have demonstrated that immunocontraception of elephants with Porcine Zona Pellucida (PZP) glycoproteins combined with an adjuvant, is safe, effective, reversible and remotely deliverable with no observed adverse side effects,[7–9] thus offering an alternative means of population management.

The aims of the study reported here were to determine the efficacy of the immunocontraceptive vaccine as a method of population control, including its long-term effects on population growth rates in a free-roaming elephant population in the Makalali Conservancy in Limpopo province, South Africa. We also determined the time taken to achieve reproductive control and the extent to which growth rates can be actively manipulated. We estimated also the probable impact on the Makalali population by 2010 of the current management strategy.

Methods

The Makalali Conservancy, a 24 500 ha reserve situated on the lowveld plain at altitudes of 300–500 m above sea level, has as its main vegetation type the *Combretum apiculatum* veld of the Mixed Bushveld.[9,10] The perennial Makhutswi River, originating from the Drakensberg Mountains and a tributary of the Olifants River, bisects the reserve in a west–east direction.[10] The conservancy was one of the first to receive translocated elephants. Intact family groups were introduced in 1994 (13 animals) and in 1996 (24 animals). Over the years, there has been immigration of eight bulls through break-ins. Of these, one broke out and was later relocated to a neighbouring reserve, and two bulls were destroyed. Only two calf deaths have been observed. In this reserve, therefore, it is mainly the effects of immigration and natality that result in changes to population number.

In January 2006, the population of 73 elephants at Makalali comprised 28 females aged ≥ 8 years, distributed in four herds of 8–22 animals, and 14 independent adult males. The animals are habituated to vehicles, easily accessible and we have exact identifications and relationships for all individuals.[9] The population's history since introduction has been reconstructed by tracing individual elephants' life histories through photographic records,[9] annual census counts combined with archival video material captured during translocation and subsequent acclimatization in the boma, and known birth dates. We tracked each female individually through time, and added a calf for each female at 56-month intervals starting at the time of her last known calf. The total population in January of each year was calculated by adding the new calves to the previous year's total. This procedure assumes each breeding female produces a calf after the average inter-calving interval and that there are no deaths or introductions during the period of estimation. To date, Makalali has not experienced any adult cow mortalities since introduction. The first cow death is expected after 2010. We estimate, based on observed mortality hitherto (two calf deaths over 10 years out of a total of 30 calves born on the reserve), that less than one calf is likely to die before 2010. Age-specific mortalities have, therefore, not been factored into our calculations.

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Table 1. The effect of contraception on the size of the Makalali Conservancy elephant population.

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Total population size on 1 January (estimated from 2007)[a]	45	47	53	62	66	65	68	71	73^	74^	74^	75^
Calves born during the year (estimated from 2007)	2	5	8	4	0	3	2	1	1^	0^	1^	0^
Immigration	0	3	2	0	0	0	2	1				
Emigrations	0	0	1	0	0	0	0	0				
Observed mortality	0	2	0	0	1	0	1	0				
Effective population size (estimated from 2007)[b]	45	47	52	60	64	64	67	69	70^	71^	71^	72^
Estimated population size based on calving interval of 4.7 years without contraception	45^	47^	51^	60^	66^	70^	72^	81^	90^	96^	99^	108^
Rate of increase with contraception (estimated from 2007, and excluding new introductions and fatalities)[d]		1.04	1.11	1.15	1.07	1.00	1.05	1.03	1.01^	1.01^	1.00^	1.01^
Estimated rate[c] of increase based on calving interval of 4.7 years without contraception		1.04^	1.09^	1.18^	1.1^	1.06^	1.03^	1.13^	1.11^	1.07^	1.03^	1.09^
% Reduction due to contraception[e]		0	–2	3	3	6	–2	10	10	6	3	8

[a]Total population size for 2007 through 2010 includes 2 births to untreated pre-pubertal cows that will be allowed to produce their first calves. (Age of first calving is based on that observed on the reserve prior to contraception.)
[b]Effective population size excludes five adult males that broke into the reserve (3 in 2000 and 2 in 2001), and two calf mortalities (both in 2000) as these are irrelevant to the contraception programme.
[c]Estimated rate is that expected if contraception had not been introduced. We assume zero mortality and an inter-calving interval of 56 months.
[d]Calculated rate for 2006–2010 based on continued contraception of all females that have produced their first calf.
[e]Figure excludes mortalities.
^ Estimated.

In May 2000, all the adult females aged >12 yr (18 animals) were vaccinated with 600 μg PZP + 0.5 ml of Freund's Modified Adjuvant (FMA)(Sigma Chemical Co., St Louis).[9] Target animals were identified and darted remotely from foot or vehicle using drop-out darts (Dan Inject® International, Denmark) with smooth, barbless needles.[9] The vaccination of pregnant elephants (who have a gestation period of 22 months) with PZP has no effect on gestation, on the fetus or on parturition,[4–6,8,9] so pregnancy status was not a criterion for selection. Births have been recorded in females as young as 9–10 yr, so the breeding population was classified as females ≥8 yr for subsequent vaccinations.

After the initial dose, the 18 target animals received two booster vaccinations of PZP (600 μg) emulsified in Freund's Incomplete Adjuvant (FIA) two to three weeks apart.[9] The second booster (in June/July 2000) is considered to be the 'vaccinational birthday' of the herds. In June 2001, the 18 target animals received their first annual booster vaccination. To test the efficacy of dosage strength, 600 μg, 400 μg and 200 μg PZP were administered with 0.5 ml FIA to four, nine and five animals, respectively. Two additional cows were added to the vaccination programme under the regime described above[9] and each received 3 × 400 μg doses in a 6-week cycle. For all subsequent annual vaccinations, dosage strength was kept constant (at 400 μg PZP). In June/July 2002, all 20 of the target animals received their first or second annual booster, respectively, and an additional three cows were vaccinated according to the above regime. In 2003, all 23 target animals were vaccinated and no new cows were added to their number. Four of these individuals were anaesthetized and examined for pregnancy using trans-rectal ultrasonography. By July 2003, five breeding cows remained unvaccinated to allow them to conceive and produce their first calves. In 2004 and 2005, the same 23 cows were re-vaccinated and no new cows were added to the vaccination programme.

Results

We observed an average inter-calving interval of 56 months (48–72 months) for the period from 1994 to 2002. At other small, enclosed reserves, estimated calving interval varied from 3 to 5 years.[11] The vaccination programme was initiated in May 2000, but as the first 2 years of the reproductive cycle in pregnant females under the vaccination regime are not influenced by PZP, they have been included in the inter-calving rate calculation.

By the second year of the project (2002), 17 calves were born to 23 vaccinated cows. Based on the vaccinational birthdays of these cows and the known birth dates of their calves, we concluded that 14 of these target animals were pregnant prior to contraception (at the time of contraception, these target animals' gestation status ranged from one to 21 months). The remaining three target animals were vaccinated for the first time with a primary vaccination (400 μg + 0.5 ml FMA) only after the birth of their first calves.

No births were recorded in 2003, the third year of the project.

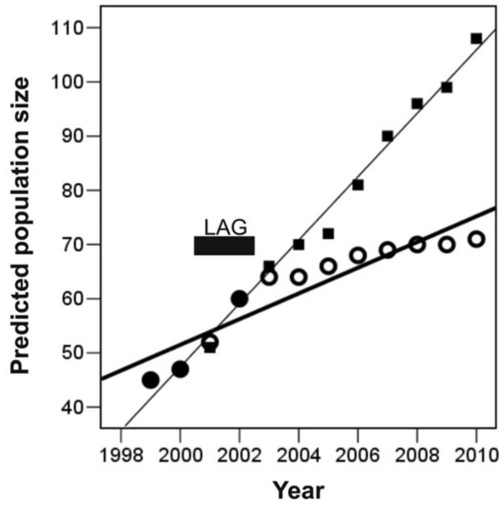

Fig. 1. The effect of contraception on population size at the Makalali Conservancy. Open circles and thick line indicates the projected population size with contraception; the closed squares and thin line represent the projected population without contraception. The black bar above the curves indicates the lag effect before contraception as a result of elephants already pregnant prior to darting. See Table 1 for details, and text for statistical test.

Nor had any of the four anaesthetized, contracepted females conceived (0/4) in that year, but two were cycling as evidenced by the presence of larger follicles as determined from trans-rectal ultrasonography. By January 2006, since the programme's inception, six additional cows had not calved for a period of 69 months, 13 months longer than the average inter-calving rate, indicating that full reproductive control had been achieved in at least 10 animals (43%). As there have been no births in targeted animals since August 2002, full reproductive control appears likely amongst the remaining targeted females (no births had been recorded in these animals for 50 months in October 2006; 6 months shy of the population's inter-calving interval). The absence of births in 2003 indicates that reproductive control was achieved in the third year because target animals that were pregnant prior to contraception would have calved and subsequently been contracepted.

The detailed population history[9] allows for the rate of increase (excluding mortalities and introductions) to be determined for the population. The estimated projected population size for the Makalali population without immunocontraception totals 108 animals by 2010 (Table 1). However, with reproductive control in place there was a significant reduction in population growth over the period 2003–2010 (General Linear Model: Covariate = treatment effect (contracepted versus non-contracepted): $F_{1,11}$ = 9.02, P = 0.012) (Fig. 1, Table 1). This translated to an estimated population size in 2010 of 72 versus 108 animals, or an estimated reduction of 33% in population size after 10 years of programmed contraception.

Discussion

The control of elephant populations has historically been by culling and translocation.[12,13] Culling maintains the population at the highest potential growth rate, although the short-term and longer-term effects involving loss of bond group or family members, are unknown.[3] In addition, the wider acceptability of culling as a long-term strategy without exploring alternatives is doubtful. A feasible alternative to managing populations is thus urgently needed.

We have demonstrated at Makalali that it is possible to achieve contraception in field trials, and that if desired, we could achieve 100% contraception in a small population. It is possible in a known, small population to apply contraception on an individual basis, even to the extent of allowing calves to be born to certain females. Culling is the only option that will immediately solve the problems of an overabundance of elephants as contraception will not reduce numbers[6] until mortality rates exceed birth rates (the lag effect for introduced populations such as at Makalali being at least 20 years because the oldest animals present are only 45 years of age). PZP immunocontraception has been demonstrated to be safe, reversible and humane. Most importantly, it can successfully control and manipulate population numbers in small to medium-sized populations (<500 elephants). Immunocontraception is therefore a tool that can be adapted to meet different management objectives, by reducing and eventually stabilizing population growth rate.

Because it is safe to vaccinate pregnant females, contraception can be implemented by mass-darting groups from the air (as undertaken at Makalali in the last two years of implementation). Thus, immobilisation or identification of cows is not a requirement for immunocontraception. This has also been demonstrated when 43 cows were successfully vaccinated from a helicopter at the 30 000 ha Welgevonden Private Game Reserve without immobilization or any individual identikits of that population (Delsink *et al.*, pers. obs.).

The immunocontraceptive trials in the KNP and at Makalali represent a combined 10-year study on the short- to medium-term effects on behaviour and social structure of experimental animals and their herds. These trials have not demonstrated aberrant or unusual behaviour with the medium-term and sustained use of PZP on the experimental herds. In the KNP trials,[5] the behaviour of the PZP-treated cows was similar to those untreated.[13] There is also no evidence to suggest that the PZP vaccine has any adverse effects on the behaviour of matriarchal groups or bulls.[14] Despite these early, encouraging results, however, studies longer than the five years conducted so far are essential.[14] For the present, we regard contraception as the most efficacious and viable population control method for discrete elephant populations.[14–16]

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