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# Implementing immunocontraception in free-ranging African elephants at Makalali Conservancy

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**ABSTRACT**

The goal of programmes to provide contraception for elephants should be to formulate an approach that does not require the relocation or immobilisation of the same individual year after year, which would be long-lasting and cause minimal disruption to social and reproductive behaviour. The programmes should be simple to administer, safe and cost-effective, and must meet the objectives defined by managers in the field. An immunocontraceptive programme was initiated in a small free-roaming population of elephants at the Greater Makalali Private Game Reserve in Limpopo Province in 2000 to determine whether the porcine *zona pellucida* (pZP) vaccine can successfully control population sizes. Further objectives were to determine implementation costs and efficiency through a multi-faceted approach. We have demonstrated that immunocontraception meets the objectives set by managers in the field. Minimal social disruption was observed over the course of treatment, with the mode of delivery (ground or aerial vaccinations) determining the degree of stress within herds and speed of resumption of normal movement patterns. Aerial vaccinations resulted in the least disturbance, with target herds being approachable within a day. In 2005, implementation costs were R880–R1000/elephant/year, inclusive of darts, vaccine, helicopter and veterinary assistance. Irrespective of the source or method of vaccine delivery, a non-pregnant elephant is rendered infertile from 1st vaccine administration. The sooner immunocontraception is implemented, the sooner population growth rates can be controlled. pZP contraception is a realistic alternative management tool, particularly if used as part of a long-term management strategy. Mass-darting from the air eliminates the need for detailed individual histories of each elephant or for employing a person to monitor elephants. Thus, implementation of immunocontraception in larger populations is feasible and practical.

**Key words**: elephant management, *Loxodonta africana,* population control, pZP implementation.

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## INTRODUCTION

The African elephant plays an important ecological role in savanna[24], causing substantial changes in vegetation communities, less palatable species become more abundant and many large trees can be destroyed[24,29]. In a confined or 'closed' environment, some form of elephant population management is necessary. Traditional elephant population control methods have involved culling and translocation[14,25,28]. Animal protection groups have always been opposed to wildlife population control that involves culling, and lethal control has become unacceptable to the public at large as well[5,11,14,15,21,23]. Culling is also not feasible for small populations consisting of 1 to 4 family groups. Individuals within family groups are dependent on a highly developed socially-interactive system[18,20,21] and removal of part of the group results in severe stress for the remaining members. Thus, the best perceived culling method, which is the removal of entire family groups, would affect small populations too greatly. Translocation involving large numbers of elephants is impractical as there are very few areas large enough to receive them and permit population growth[24].

Contraception using a variety of methods has been used to control reproduction in wildlife for the last past 30 or so years[14,16,17,23]. Of these methods, immunocontraception with the porcine *zona pellucida* (pZP) vaccine has been demonstrated to be the most successful and practical for use in herds or groups of animals[2–6,12,14,16] and could be used as an alternative to culling for African elephants.

Work on the use of pZP to provide contraception for African elephants was started in the Kruger National Park (KNP) in 1995[11,12,15]. After an initial immunohistochemistry study, which proved the potential of the vaccine to effectively provide contraception for elephant cows[10], the vaccine was employed in 2 field trials. The 'ideal' fertility agent should be safe, reversible, effective and deliverable from a distance[14]. The trials showed that pZP vaccine safely and successfully controls fertility in free-roaming African elephants with an efficacy of up to 80 %[11]. Immunocontraception with pZP does not have hormonal side-effects, it will not harm the foetus should the cow be pregnant, and it is also safe in the food chain should the cow perish[11,14]. A further advantage is that it is completely reversible[11]. This contraceptive approach currently shows the most promise for non-lethal population control of African elephants[25].

With the 1st 3 phases of trials in the KNP completed, the 4th phase of the project was initiated. This phase aimed to determine the efficacy of pZP as a population control method in free-ranging elephant populations[2–6]. Owing to its manageable elephant population size (71 animals in January 2006) and 'closed' system status (fenced-in 22 500 ha reserve), the Greater Makalali Private Game Reserve's (GMPGR) elephant population was deemed ideal for this purpose. The elephants were relocated to the GMPGR from the KNP in 1994 and 1996 (13 and 24 animals, respectively), and thanks to the reserve's tourism activities, the population was habituated to vehicles and game-viewing activities[2–6]. In addition, identikits for each individual elephant had already been established and this facilitated vaccination and monitoring[2–6].

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The average annual population growth rate from 1996 to 2000, when the contraception programme was initiated, was 8.9 %[6]. This became a key factor in deciding to adopt this management option.

The regulation of the GMPGR population using immunocontraception and the social and behavioural effects stemming from it have been reported[2–6]. The aim of this paper is to describe the implementation of immunocontraception in a free-ranging elephant population. The specific objectives were to assess (1) the technical requirements of the programme, (2) its ease of implementation, (3) social disruption owing to its implementation, (4) field safety for management and elephants and (5) costs.

Table 1: **Immunocontraceptive vaccinations administered to the Makalali population 2000–2005.**

| Year | Year of project | New vaccinations | Total number of vaccinated cows |
|---|---|---|---|
| 2000[a] | 1st year | 0 | 18 |
| 2001 | 2nd year | 2 | 20 |
| 2002[b] | 3rd year | 3 | 23 |
| 2003 | 4th year | 0 | 23 |
| 2004 | 5th year | 0 | 23 |
| 2005 | 6th year | 0 | 23 |

[a]The 1st and 2nd booster intervals were 3 and 6 weeks, respectively, after the primary vaccination.
[b]Only the primary vaccination was administered to the new cows as they had given birth a short while before vaccine administration.

## MATERIALS AND METHODS

### *Study site*

The GMPGR is located on the Lowveld plain, 300–500 m above sea level close to the foothills of the Drakensberg Mountains in South Africa's Limpopo Province (30.49°S, 24.00°E)[8]. The reserve is bisected by the perennial Makhutswi River, originating in the Drakensberg Mountains and a tributary of the Olifants River[8]. The main vegetation type is *Combretum apiculatum* Mixed Bushveld[1]. This is a summer rainfall area with a mean annual precipitation of 450 mm[8].

### *Elephants*

Animals were identified according to individual characteristics including sex, age, unique ear patterns comprising nicks, tears and holes, the size and shape of tusks and other distinguishing features such as growths, lumps, scars and tail hairs[5,18,21]. When no distinguishing ear or tusk features were visible, ear venation patterns were used[5,26,27]. Prior to starting the programme, all the elephants, apart from infants and some juveniles, had complete identification kits comprising frontal, left and right sketched ear templates with corresponding photographs[2–5].

### *Vaccine and adjuvants*

The pZP antigen was produced by a modification of the methods described by Dunbar *et al.* (1980)[9] (Science and Conservation Centre, ZooMontana, Billings, Montana: 2000/03 vaccinations). Thereafter, it was supplied by the pZP Laboratory of the Department of Production Animal Studies, University of Pretoria[5].

The vaccine produced at the University of Pretoria was processed to the stage of *zona* ghosts. These were stored at –70 °C until required when they were thawed and heated to render them soluble. Finally the concentration was adjusted to give the required concentration of pZP proteins in 1.0 mℓ of phosphate-buffered saline (PBS).

In the 1st year of treatment, targeted animals received a primary vaccination followed by a 1st and 2nd booster injection at 3 and 6 weeks, respectively. Thereafter, a single annual booster was administered to maintain the contraceptive effect. Freund's Modified adjuvant (Sigma Chemical Co., St Louis, MO) (0.5 mℓ) was used for all primary vaccinations. In the case of boosters, 0.5 mℓ of Freund's Incomplete adjuvant (Sigma Chemical Co., St Louis, MO) was used for each vaccination.

Shortly before each day's vaccinations, the vaccine and adjuvant were made up. The vaccine and adjuvant were drawn up into the a single syringe that was then connected to a 2nd syringe by means of a plastic connector. The fluid was then pushed forwards and backwards from one syringe to the other through the connector about 60 times creating a stable emulsion. Each vaccination dart was then loaded with a total volume of 1.5 mℓ emulsified vaccine-adjuvant.

### *Dose of pZP vaccine*

Table 1 summarises the vaccination programme as well as the numbers of vaccinated cows from 2000 to 2005. In 2000 and 2001, all the targeted animals received vaccinations of 600 $\mu$g of pZP. For subsequent annual vaccinations, a single booster of 400 $\mu$g of pZP (except for 2002 when the effect of different pZP doses was tested and animals thus received either 200 $\mu$g, 400 $\mu$g or 600 $\mu$g of pZP). In June 2002, 3 more cows were added to the programme. However, these additional cows had recently given birth, and therefore, it was decided to administer only the primary vaccination. In 2004, 3 cows that were pre-pubescent at the time of the programme's inception attained puberty. It was decided not to vaccinate these individuals so that they could conceive their 1st calves.

### *Darts employed for vaccination*

For minimal impact and stress on the herds, the selected elephants were darted using the Dan-Inject® darting system (Dan Inject® International, Denmark) which is gas-powered unlike other darting systems that employ a small cartridge[2–5]. The rifle operates from a $CO_2$ cartridge that has a silent pressure adjustment of up to 16 bar (F Rohr, Dan Inject Skukuza, Kruger National Park, pers. comm., 2003). Depending on the length of the barrel used, the effective range is 1–40 m (F Rohr, Dan Inject Skukuza, Kruger National Park, pers. comm., 2003). Because the animals are not anaesthetised, the darts must be able to fall out by themselves. Two-mℓ darts and 60-mm smooth (barbless heads) needles that were modified by increasing the bore of the side ports and which would fall out a short while after impact were used[2–5]. The Dan-Inject® dart's luminous flight feathers makes it clearly visible in the field and easier to recover once it has dropped out post-vaccination.

For the 2003 vaccinations, owing to the expense of the Dan-Inject® darts, and because some vaccinations would be administered from a helicopter above the herd, they were substituted with disposable 2-mℓ Pneu-Darts®. Although the Dan-Inject® rifle is still used, its barrel has been replaced with a Pneu-Dart® 13-mm barrel to accommodate the Pneu-Dart® dart. In contrast to the Dan-Inject® darts, the Pneu-Darts® comprise a drug chamber as well as a 'marker' chamber. Marking substances such as paint or ginseng violet can be injected into these chambers. Upon impact, the drug (pZP) is injected from the drug chamber, the marker chamber's plunger discharges, and the marking substance is sprayed onto the elephant at the dart site.

This makes darted animals clearly visible from the air. In 2004 and 2005 only Pneu-Darts® were used. The marking substance used was ginseng violet.

### *Vaccination procedure*

GMPGR management stipulated that

vaccine administration should have minimal impact on herds. For this reason, the 2000, 2001 and 2002 vaccinations were administered remotely on foot or from a vehicle. Ground darting facilitated dart retrieval. Because drop-out darts were used, there was no need to immobilise target animals. None of the elephants was collared during the initial period from 2000 to July 2003 and so the darting team did not have telemetry facilities to locate target animals. Instead, the animals had to be located by traditional tracking methods from previously known positions. Once the animals were located, target cows were identified and the vaccines were administered intramuscularly[2–5]. To facilitate falling out of the darts, they were aimed below and to either side of the tail. In this position, tail swishing dislodged the darts. Darts that hit other areas were dislodged by muscle movement, which took somewhat longer.

In 2003, the GMPGR was expanded by 8000 ha[5]. To enable continuation of the high monitoring level, 4 elephant cows (one in each herd) were fitted with VHF radio transmitters attached to a collar after immobilisation from a helicopter[5]. Subsequently, the whereabouts of each cow could be determined at will, and its location for monitoring and vaccination became much easier. As the presence of the helicopter during the collaring exercise would be potentially stressing the population anyway, it was decided to perform as many of the annual vaccinations as possible from the air at the same time as the collaring exercise.

Owing to the speed and ease of vaccinating from the helicopter in 2003, the research team decided to vaccinate all but 2 animals ($n$ = 21) from it in 2004. All 23 animals were vaccinated from the air in 2005.

The 1st vaccinations were administered in May 2000. The target cows were administered with a primary vaccination dose and 2 subsequent 3-weekly boosters. Thereafter, at yearly intervals, a single booster injection was administered to ensure contraceptive effectiveness[2–6,15] (Table 1).

Following each vaccination, the date, vaccination site, the animal's longitudinal and latitudinal position recorded with a Garmin Global Positioning System (GPS), the animal's reaction and the darting source (vehicle/foot/helicopter) were recorded[2–5].

### Success of vaccine delivery

In order to document the success of vaccine delivery, an attempt was made to recover all darts during the 1st 3 years of the programme[2–5]. Delivery of the vaccine was regarded as successful when all the contents in the plunger in the drug chamber had been expelled. Unsuccessful or incomplete vaccine delivery occurred when some of the contents remained behind in the syringe. When an incomplete vaccine delivery was discovered, the animal was revaccinated.

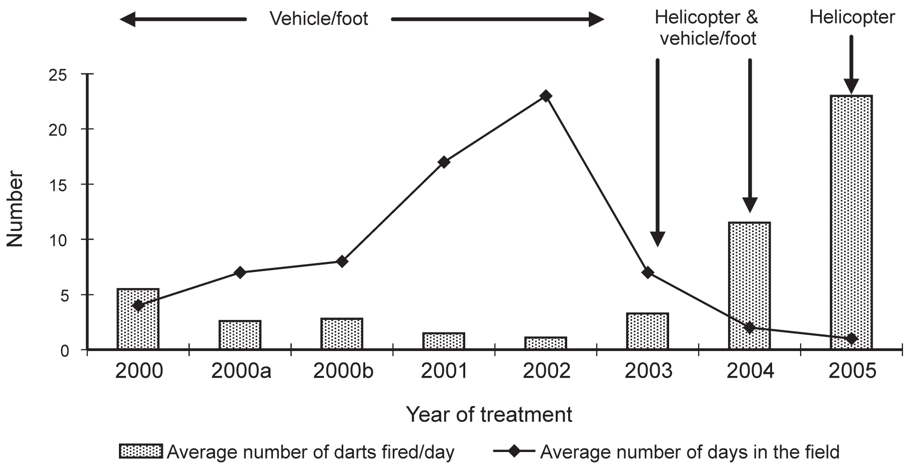


Fig. 1: **Efficiency in field implementation over successive treatment years 2000–2005. 2000a and 2000b refer to the 1st and 2nd booster, respectively, and vehicle/foot/helicopter refer to the mode of vaccination delivery**.

### Local effects of vaccine

Post-vaccination observations of the target animals were conducted to determine superficial side-effects. These included the formation of an abscess, suppuration, ulceration or inflammation at the vaccination site[7,19]. Target animals were located and previously recorded vaccination sites were examined from a distance with binoculars.

### Cost of vaccine delivery

The cost of vaccine delivery was determined for each year. This included the costs of the vaccine, adjuvant, darts, needles, $CO_2$ cartridges, and when applicable, helicopter costs as determined by the suppliers. Dan-Inject® (Dan-Inject International, Denmark) darts are reusable, with each dart reused at least once. For the purposes of cost calculation, the number of darts fired was halved to determine the minimum number of darts purchased.

## RESULTS

The sex ratio of the total population was 1:1, and comprised 33 males, 33 females and 5 of unknown sex (January 2006), making a total of 71 animals. There were 13 'adult' or free-roaming bulls, *i.e.* bulls >12 yrs and who were independent of their natal herds.

Pregnancy status did not affect the selection of individuals for vaccination. For the initial vaccinations in 2000, 18 cows (the breeding population) were targeted. Two additional cows were vaccinated in 2001 and 3 additional cows in 2002, respectively. From 2002, cows that reached breeding age (animals ≥ 8 yr) for the 1st time during a vaccination year were not vaccinated so that they could conceive their 1st calves. To date (January 2007), 23 cows have been vaccinated.

For the 2000, 2001 and 2002 vaccinations, a combination of darting strategies *i.e.* on foot or from a vehicle, were used[2–5] (Fig. 1, Table 2). Factors such as vegetation, terrain and habitat largely dictated whether the animals were darted on foot or from a vehicle.

For the primary vaccination and follow-up boosters, none of the elephants was collared. Locating the herds using traditional tracking methods proved relatively easy depending on habitat and terrain. The darting protocol stipulated that a vehicle not associated with either tourist activities or reserve management should be used to avoid any negative associations in elephants with tourist or management vehicles. The practicalities of this protocol proved impossible to follow, however. The closed vehicle used for darting had to be replaced with an open game-viewing one and the assistance of a driver was required. During the initial vaccinations, the animals associated the darting vehicle with darting and became increasingly wary of it[2,3,4,5]. As a result, the necessity to dart on foot increased (Fig. 1). In 2000, 2001 and 2002, the average time taken to complete all the vaccinations was 12 days (note that this includes all the days spent in the field, whether darts were fired or not). The number of days spent in the field increased and the average number of darts fired per day decreased, with an average of only 2 dartings per day (Fig. 1).

The decision to collar 4 elephants in 2003 resulted in a combination of darting

Table 2: **Dart retrieval rate, source of delivery and darting systems utilised for the Makalali elephant vaccinations 2000–2005.**

| | | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | Total number of darts |
|---|---|---|---|---|---|---|---|---|
| Dan-Inject® | Fired from vehicle | 47 | 4 | 15 | 6 | 0 | 0 | 72 |
| | Fired on foot | 15 | 21 | 10 | 0 | 0 | 0 | 46 |
| Dan-Inject® | Total darts fired | 62 | 25 | 25 | 6 | 0 | 0 | 118 |
| | Darts retrieved | 79 % | 68 % | 48 % | 83 % | 0 | 0 | 83 (70%) |
| | Unsuccessful darts due to: | 13 % | 4 % | 8 % | 0 | n/a | n/a | 11 (9%) |
| | a) No discharge | 6 % | 0 | 0 | 0 | n/a | n/a | 4 (3%) |
| | b) Incomplete discharge | 5 % | 4 % | 4 % | 0 | n/a | n/a | 5 (4%) |
| | c) Misfire | 2 % | 0 | 4 % | 0 | n/a | n/a | 2 (2%) |
| Pneu-Dart® | Fired from ground | 0 | 0 | 0 | 0 | 2 | 0 | 2 (3%) |
| | Fired from helicopter | 0 | 0 | 0 | 17 | 21 | 23 | 38 (97%) |

from the vehicle and a helicopter during this year. In 2004, the same strategy was employed. Seventeen (74 %) and 21 (91 %) cows were vaccinated from the helicopter (Table 2). In 2005, all vaccinations were administered from it.

The collaring of an individual from each herd remarkably improved the darting team's productivity, as each collar has its own unique frequency, and thus individual herds could be located more quickly and easily. This considerably reduced the amount of time spent simply trying to locate a given herd. The vaccination procedure from the helicopter was rapid. For example, the 2004 vaccinations of 21 elephants were conducted within 30 min. In 2003, 2004 and 2005, time spent in the field decreased while the average number of darts fired per day increased (Fig. 1).

In general, when darting from the ground, the herd's reaction was dependent on the reaction of the target animal herself, or more precisely, on her own rank or where she was located (position within the herd). In 70 % of cases, when younger animals were darted 1st, the rest of the herd did not stir.

However, when darting from a helicopter, the entire herd responded to the presence of the helicopter and all the animals moved away. There was no negative association with the darting team or vehicles, as the animals were only exposed to stress during the aerial vaccination procedure[5].

For the vaccinations in 2000, 2001 and 2002, the Dan-Inject® (Dan-Inject International, Denmark) darting system was used. The discharge status of recovered darts was used to determine the efficacy of vaccination from the darting system[3,5] (Table 2). Dart retrieval rates for these years were 79 %, 68 % and 48 %, respectively. During this period, only 10% of the dartings were recorded as unsuccessful. In these cases, the animals were revaccinated. From 2003, vaccinations were largely administered with disposable Pneu-Darts® fired from a helicopter (Table 2), making dart retrieval difficult, and for reuse, unnecessary.

Of the 18 cows vaccinated and boosted between May and June 2000, 89 % displayed granulomas (a local side-effect of the vaccine) within 3 months of the initial vaccination[2,3,5]. These ranged in size from 2–10 cm in diameter and were all eventually resorbed. Only 3 cows developed granulomas of approximately 10–12 cm in diameter after the primary vaccination in 2000. Although they were still present by the 5th annual vaccinations in 2005, they were markedly reduced in size. For subsequent annual vaccinations, there was a marked reduction in the number (<10 %) and size of granulomas formed. No granulomas greater than 5 cm formed.

Table 3 outlines the programme's costs for 2000–2005. For the 2000–2002 vaccinations, the vaccine was purchased from

Table 3: **Costs incurred during the Makalali vaccinations 2000–2005.**

| | 2000[3] | 2001 | 2002 | 2003 | 2004 | 2005 |
|---|---|---|---|---|---|---|
| Dan-Inject® Darts @ R178.00/dart[1] (number of darts in brackets) | R5518 (31) | R2136 (12) | R2136 (12) | R712 (4) | R356 (2) | R0 |
| Pneu-Darts® @ R85.00/dart (number of darts in brackets) | R0 | R0 | R0 | R1445 (17) | R1785 (21) | R1955 (23) |
| Vaccine @ $20/dose (2000/02)[2] (number of doses in brackets) | R11160 (62) | R4500 (25) | R4500 (25) | R0 | R0 | R0 |
| Vaccine @ R100/dose (2003–2005) (number of doses in brackets) | R0 | R0 | R0 | R2300 (23) | R2300 (23) | R2300 (23) |
| Helicopter | R0 | R0 | R0 | R7524[4] | R7980[5] | R10819[6] |
| Number of elephants vaccinated | 18 | 20 | 23 | 23 | 23 | 23 |
| **Average cost of vaccinations/elephant** | **R927** | **R332** | **R289** | **R520** | **R540** | **R655** |

[1]Dan-Inject darts were used at least twice each during the 2000/02 vaccinations, thus, the number of actual darts fired is halved in order to determine actual cost of darts for these years. Four and 2 Dan-Inject darts were used in 2003 and 2004, respectively.

[2]Vaccine was obtained from the USA at an exchange rate of R9:$1.

[3]The year 2000 costs were high because each animal received a primary and 2 booster vaccinations. A total of 62 darts was fired, including 11 revaccinations due to unsuccessful darts.

[4]Helicopter time for 2003 included 5.5 h flying time including ferry to Makalali. Flying time was high because the exercises included vaccination, collaring and biopsy procedures of 4 and 1 elephants, respectively. Therefore, costs for 2003 vaccinations are calculated at the rate per hour for 2003 (R3300) and on the number of hours flown as per 2004, *i.e.* 2 hours in total.

[5]Helicopter time for 2004 included 1 hour of flying time and 1 hour of ferry costs.

[6]Helicopter time for 2005 included 1 hour of flying time and 2 hours of ferry costs.

The above costs do not include veterinary fees or salaries for the project, darts, man and elephant monitor.

ZooMontana at approximately US$20 per dose. During this period, the exchange rate was an average of R9:$1, *i.e.* R180/dose. For vaccinations from 2003 onwards, the vaccine was purchased from the University of Pretoria at approximately R100 per dose (including the adjuvant). Table 3 includes the extra doses of vaccine used owing to incomplete vaccine delivery (Table 1). The average cost per Dan-Inject® dart (complete with needle, flight, sleeve and $CO_2$ cartridge) was R180 including value added tax (VAT). The average cost per Pneu-Dart® dart (complete with needle, flight and $CO_2$ cartridge) was R85/dart including VAT. Using the ZooMontana vaccine and Dan-Inject® darts, the average cost of vaccinating 1 animal was approximately R360. When the locally produced vaccine was used, these costs were substantially reduced *i.e.* R280/animal for the Dan-Inject® system and R185/animal for Pneu-Dart® system. If the animals are to be vaccinated from the air, an average flying rate of R3800/hour is applicable, depending on the type of helicopter used. Ferry costs were also added to the final tally (Table 3).

## DISCUSSION

Originally, it was decided to vaccinate from the ground in order to facilitate dart retrieval, test the efficacy of delivery and achieve minimal disturbance to the herds. To achieve this, it was essential that all elephants were identified and recognisable, which ensured that each target animal could be vaccinated repeatedly during the contraception programme and that we could be 100 % certain that every target animal had been vaccinated timeously and had received the full dose. This made it possible to comprehensively follow-up and monitor their behaviour.

The Dan-Inject® Dart System was used for ground darting because dart delivery is silent and the luminous flights facilitate dart retrieval. We recovered 79 % of the Dan-Inject® darts[3]. When all the animals moved off immediately after a dart had been fired, dart retrieval was high, but depended on whether or not the target animal's path of movement could be located. Occasionally, darts could not be retrieved because they had fallen in grass layers and could not be found. If the target animal and the rest of the herd did not immediately move off but continued feeding, younger members of the herd often pulled the dart out of the target animal or picked it up from the ground and played with it or carried it off, making retrieval more difficult.

However, as the programme progressed and the elephants began to associate the team with the darting procedure, each round took longer and longer. The 1st round for the primary vaccinations in 2000 lasted 4 days but by 2002, it took more than 20 days.

The greatest impact of pZP implementation was on the behaviour of the elephants – more specifically, the interaction between the vaccination team and the herds. The effect was most pronounced during the initial vaccination series when the animals would continuously move or run away from the vaccination vehicle/team, but remaining relaxed and accessible to the tourist game drive vehicles[2,3,4,5]. Darting from the ground appeared to cause less stress than from the air, judging by the flight response and movement patterns of the elephants. It took, however, much longer[5]. Furthermore, the dart gun's range of 15–40 m necessitated getting very close to the elephants, which posed obvious dangers to both the research team and elephants. The animals nevertheless resumed normal movement patterns within 2 weeks of the cessation of ground darting[2–5]. Thus, managers in the field need not be concerned about any prolonged social disruptions as a result of vaccine administration from the ground.

Choice of darting systems did not appear to have any significant influence on the animals' reaction to being darted. The degree of reaction appeared largely determined by the individual herself, her position within the herd as well as the weather and wind conditions[2–5].

The use of radio-collars facilitated vaccine administration greatly. Herds could be located at will, reducing the time spent looking for, and darting from, the ground and thereby increasing efficiency of the team.

Vaccinations administered from the helicopter resulted in far greater perceivable stress in the animals. This perception was based on observations of bunching of the herd and flight patterns. The duration of disturbance, however, was much shorter than when darted from the ground, and the animals resumed normal movement patterns and appeared to be settled within a day of vaccinations[5]. Safety in the field for both elephants and operators was improved because of the reduced human–elephant interactions associated with darting from the ground. This 'short-lived' stress and disruption to the herd was more favourable and in line with management objectives[3,4,5]. Furthermore, the helicopter vaccinations did not compromise further monitoring initiatives as the elephants appeared to be reacting to the helicopter, rather than to being darted. According to the Warden of the GMPGR (pers. comm., 2003) the expense of helicopter vaccinations far outweighed the disadvantages of the less expensive ground vaccinations owing to the turn-around time and animal's responses.

As part of the research protocol, veterinary fees for vaccine administration were not included in the Makalali programme. There is a concern that contraceptive implementation may be prohibited by high veterinary and helicopter costs. Veterinary fees vary between R2500 and 3800/day, and helicopter rates are approximately R3800/hour (J Bassi, BassAir, pers. comm., 2005). Helicopter vaccinations are administered quickly with a darting time of about 30 seconds per female. As such, veterinary fees can be incorporated with vaccine and dart costs on an individual elephant basis. At Makalali, implementation costs ranged from R520–R655 per animal including the darts, vaccine and helicopter costs. In 2005, immunocontraception was implemented on the neighbouring Thornybush Game Reserve. Thornybush covered all expenses pertaining to implementation, and costs amounted to R880–R1000/elephant, for darts, vaccine, helicopter and veterinary fees.

Irrespective of the source or method of vaccine delivery, a non-pregnant elephant will be fully contracepted from the 1st year of vaccine administration. As the vaccine does not affect pregnancies in progress, 100 % reproductive control should be achieved by the 3rd year[6]. The sooner immunocontraception is implemented, the sooner the population's growth rate can be manipulated. When technology and experience are available, the use of immunocontraception in larger populations is recommended. This can be carried out using a mass-darting approach rather than darting individually identified elephants. Identifying the matriarch, a key individual within the herd or clan, or an individual fitted with a radio collar or identification would take place on the basis of family or clan ID. Thus, depending on the management objectives that have been set, it is possible to predetermine a 'level of intervention' and target a proportion of the population. It is feasible to dart 80 % or more cows within a group from a helicopter with a darting time of about 30 seconds per female. The use of marker darts further ensures that individuals are not darted more than once.

Although monitoring is an essential component of a long-term management plan, neither an elephant monitor nor detailed population history is necessary to implement the immunocontraceptive. Through its multi-faceted approach, the

Makalali model has demonstrated that immunocontraception appears to meet all the objectives formulated by managers in the field regarding technical requirements, ease of implementation, field safety, procedural costs and vaccine efficacy[5]. This makes its application in larger populations far more feasible as contraception in these populations is simply a matter of scaling up the effort expended at Makalali, and is thus a matter of resource allocation dependent on local circumstances rather than any technical constraint. Managers of larger reserves now need to assess pZP contraception as a realistic alternative management tool, particularly as part of a longer-term management strategy.

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