IVth International Wildlife Management Congress

PROCEEDINGS

James W. Cain III and Jason P. Marshal, Editors

9-12 July 2012

Durban, South Africa
### IVth INTERNATIONAL WILDLIFE MANAGEMENT CONGRESS

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<table>
<thead>
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<th>Members</th>
<th>Members</th>
<th>Members</th>
</tr>
</thead>
<tbody>
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</tr>
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FOREWORD

Paul Krausman, Ph.D.
2012 President, The Wildlife Society

In July 2012, wildlifers from around the globe gathered in Durban, South Africa for the IVth International Wildlife Management Congress (IWMC). The Wildlife Society (TWS) initiated the concept of the IWMC nearly 20 years ago. The first IWMC was held in San Jose, Costa Rica, in September 1993 (before the first TWS Annual Conference in 1994), drawing 521 participants from 66 countries—a gratifying turnout allowing an exchange of information between developed and developing nations. The second IWMC occurred in Godollo, Hungary, in summer 1999, where 357 participants gathered from 40 countries. The third took place in Christchurch, New Zealand, in December 2003, with 943 attendees from 52 nations—the largest gathering of wildlifers ever in the Southern Hemisphere. The IVth IWMC, co-hosted with the Wildlife and Environmental Society of South Africa, was also a success with nearly 400 attendees from 35 countries. The atmosphere was charged with dynamic energy from discussions of rhino poaching, tiger conservation, fragmentation by roads and canals, international models of conservation, cross border cooperation, conflict management, wildlife ranching, and contemporary concerns across North America, Europe, Africa, Asia, and the other corners of the world. Radio and newspaper journalists closely covered the event and broadcast the news widely in Japan, Germany, South Africa, and elsewhere around the world, providing powerful exposure for issues that concern us all.

As the IVth IWMC in Durban illustrated, the question of how to address human influences on wildlife is a global concern that requires international cooperation among wildlife scientists and managers. Such international collaboration has become increasingly important to The Wildlife Society (TWS). Indeed, the importance of our involvement in this arena cannot be overstated. Wildlife is, after all, an international resource, and all wildlifers should view it as such. This kind of international collaboration with partners in the host country is essential if TWS is to effectively address the mounting challenges to wildlife management and conservation. These include the human population explosion, habitat loss and fragmentation, disease emergence, the spread of invasive plants and animals, climate changes, pollution, the devaluation of wildlife through practices such as game farming, the decline or lack of dedicated conservation funding, threats to the sustainable use of wildlife, changing property rights, negative human attitudes towards wildlife, and the disconnect between humans and nature, which leads to conservation apathy. These are only some of the challenges biologists worldwide have to deal with in the day to-day management and conservation of wildlife species. International congresses bring these issues to the world stage and convince us of the importance of meaningful involvement with wildlife beyond the borders of North America.

One of the seven pillars of the North American Model recognizes wildlife as an international resource, and TWS has always acknowledged the importance of this principle and taking steps to be involved in international management and conservation. This priority is reflected by our own membership, which now extends well beyond North America to include members in 51 countries around the globe, from Andorra to Uruguay. Many of our international colleagues join us at our An-
Annual Conference to share their knowledge and learn from the science, research, and fieldwork of North American wildlifers.

International wildlife management is something TWS will always be involved in. The Society has always been concerned with worldwide events related to wildlife. This remains one of our strengths, and is becoming more important than ever as human populations grow and habitats shrink. Aside from its merits for wildlife conservation, international collaboration to protect our natural resources reflects our shared humanity and enriches the human spirit—a win for all species that inhabit the Earth.

Dramatic changes in international wildlife management are as fast paced as the changes in the world of publication—the move from paper to paperless manuscripts and books. The proceedings of the first and second IWMC were published by TWS, but for the third IWMC TWS only published the abstracts due to publication expenses and rising costs of international postage. For the IVth IWMC the Congress organizers opted for on-line publishing. This is still a fairly new concept and one not embraced by all members of our profession. Thus, of the 135 oral presentations, 30 posters, and papers in workshops, panels, and symposiums presented, we only received a handful of manuscripts to include in the electronic proceedings. Fortunately, they cover the globe and are representative of the papers at the Congress.

As we wrap up the IVth IWMC, plans are underway for the V IWMC in Sapporo, Japan in 2015. I encourage you to come and look forward to seeing you all there. Keep it wild!

ABOUT THE WILDLIFE SOCIETY

The Wildlife Society is committed to a world where humans and wildlife co-exist. We work to ensure that wildlife and habitats are conserved through management actions that take into careful consideration relevant scientific information. We create opportunities for this to occur by involving professional wildlife managers, disseminating wildlife science, advocating for effective wildlife policy and law, and building the active support of an informed citizenry.

Our mission is to represent and serve the professional community of scientists, managers, educators, technicians, planners, and others who work actively to study, manage, and conserve wildlife and habitats worldwide.

The members of The Wildlife Society manage, conserve, and study wildlife populations and habitats. They actively manage forests, conserve wetlands, restore endangered species, conserve wildlife on private and public lands, resolve wildlife damage and disease problems, and enhance biological diversity. TWS members are active across the United States, Canada, and Mexico, as well as internationally.

The products of The Wildlife Society include essential, practical, and objective information for wildlife professionals. We provide research, policy information, and practical tools in print and electronic forms, along with vibrant professional networks that allow solutions to wildlife conservation and management challenges to be anchored in science.
# Table of Contents

What is the Future of Bison Conservation? ................................................................. 1

Wildlife Management and Conservation in Europe: Transboundary Solutions .................. 9

The Insularization of Amboseli National Park, Kenya ......................................................... 16

Habitat Associations of Persian Wild Ass (*Equus hemionus onager*) in Qatrouyeh National Park, Iran .......... 25

Stewardship - The Role of Rural Residential Estates in Nature Conservation in South Africa .................. 31


Evaluating Strategies to Favor Community Participation in the Conservation of Andean Cats ................ 43

Mitigation to Minimize Mortality Along the All-American Canal, California, USA ....................... 47

Involving Communities in Wildlife Ranching in Zimbabwe: A Grass-roots Initiative .................. 53

Restoration and Wildlife Conservation as an Economic Income Alternative ......................... 64

Predation Management in the United States: The Federal Wildlife Services Program .................. 69

Managing Human-Wildlife Conflicts on the “Hard Edges” Symposium and Panel Discussion ........... 76

The Effect of Woodland Caribou Range Components on Habitat Selection and Forestry Activity .......... 81

Developing an Organizational Relocation Policy .................................................................... 90

Porcine Zona Pellucida Immuncontraception of African Elephants (*Loxodonta africana*): Beyond the Experimental Stage ................................................................. 95
PORCINE ZONA PELLUCIDA IMMUNOCONTRACEPTION OF AFRICAN ELEPHANTS (LOXODONTA AFRICANA): BEYOND THE EXPERIMENTAL STAGE

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ABSTRACT: In southern Africa there is a need for elephant (Loxodonta africana) population control, especially in small- to medium-sized, fenced reserves. The objectives of this study were to investigate the effects of porcine zona pellucida-immunocontraception on the reproductive rate as well as the safety during pregnancy of elephant cows in 7 private game reserves in South Africa. A total of 108 individually-identified cows were treated and monitored for 6 years. Primary vaccinations consisted of 400 or 600 μg porcine zona proteins with 0.5 ml Freund’s modified complete adjuvant and boosters of 400 or 200 μg zona proteins with 0.5 ml Freund’s incomplete adjuvant. Vaccine was delivered remotely: year 1, primary plus 2 boosters 3—6 weeks apart; year 2 onwards, annual boosters. Birth of calves was monitored continually and the result expressed as a percentage of cows treated on an annual basis. During years 1 and 2, 35 (32.4%) and 22 (20.4%) calves were born, respectively. No more calves were born from year 3 onwards. One cow conceived around the time of primary vaccination and a second between the primary vaccination and first booster. Two calves died soon after birth from unrelated causes. The remainder survived and were normal healthy calves. One hundred percent of cows passed the 4-year, 67.6% the 5-year, and 47.2% the 6-year inter-calving interval. The results show that it is possible to achieve a contraceptive efficacy of 100% in small- to medium-sized free-ranging populations of African elephants.

KEY WORDS: African elephants, game reserves, efficacy, immunocontraception, porcine zona pellucida, vaccine.
ing on the size of the population. Despite being very costly, translocation is regarded as an ideal solution; however, in South Africa, habitat availability is limited (Delsink et al. 2006).

Besides enlargement of parks the only other option to manage elephants is to decrease reproductive success by means of contraception. In selecting a contraceptive method for free-ranging mammals such as African elephants, it must be efficient, reversible, safe, remotely deliverable, which largely determines the cost and have a minimal impact on the social behaviour of the target species (Kirkpatrick and Turner 1999). Immunocontraception using porcine zona pel-lucida (pZP) vaccine satisfies all these requirements as has been shown in intensive studies in domestic and wild horses (Liu et al. 1989, Kirkpatrick and Turner 2008) white tailed deer (Turner et al. 1992, McShea et al. 1997, Rutberg and Naugle 2008) and a number of other free-ranging and captive-held herbivores (Deigert et al. 2003, Frank et al. 2005, Kirkpatrick and Frank 2005, Kirkpatrick et al. 2009). The putative mechanism for the success of pZP immuncontraception is the production of antibodies that bind to ZP proteins of target animals’ oocytes to prevent sperm binding (specifically to ZP3; Clarke and Dell 2006), fertilisation and thus pregnancy. Fortunately zona proteins have been well-conserved across mammal species and antibodies to pZP have been shown to recognise the African elephant ZP proteins (Fayrer-Hosken et al. 1999).

Earlier immunocontraception trials on African elephants in the KNP showed that the porcine pZP vaccine is safe and effective as a contraceptive in African elephant cows and, in the short term, reversible (Fayrer-Hosken et al. 1997, 1999, 2000). The final efficacy rate achieved was 80% of vaccinated cows. This initial work was followed by an extensive study in the Greater Makalali Private Game Reserve (Makalali). The vaccine was shown to be 100% effective and, once all cows pregnant at inception of the program had calved, no more calves were born from the third year of the project (Delsink et al. 2006, 2007).

This paper describes the effect of pZP vaccine on reproductive rate of free-ranging African elephant cows in medium and 6 small reserves over periods of 6 years. Makalali is included in this study as additional information is included.

**STUDY AREA**

The game reserves, their sizes, provincial locations in South Africa and the broad vegetation types of each are shown in Table 1.

**METHODS**

The protocols for this project were approved by the University of Pretoria’s Animal Care and Use Committee, Project number: VO49/11. The elephants on each of the 7 reserves were introduced by means of translocation and adult bulls were present on each reserve. Game reserve, year of inception of the contraception program and number of cows of reproductive age (Laws 1966, Lee et al. 1995) vaccinated during year 1 were: Makalali, 2000, 18 cows (Delsink et al. 2006, 2007); Mabula, 2002, 4 cows; Phinda, 2004, 19

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### Table 1. African elephant (Loxodonta africana) populations on the seven private game reserves where cows were treated with pZP vaccine.

<table>
<thead>
<tr>
<th>Game Reserves</th>
<th>Makalali</th>
<th>Mabula</th>
<th>Phinda</th>
<th>Shambula</th>
<th>Thornybush</th>
<th>Welgevonden</th>
<th>Kaingo</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size (ha)</td>
<td>24 500</td>
<td>8 000</td>
<td>22 800</td>
<td>8 000</td>
<td>11 548</td>
<td>35 000</td>
<td>8 461</td>
</tr>
<tr>
<td>Provinicial location</td>
<td>Limpopo</td>
<td>Limpopo</td>
<td>KwaZulu Natal</td>
<td>Limpopo</td>
<td>Limpopo</td>
<td>Limpopo</td>
<td>Limpopo</td>
</tr>
<tr>
<td>Broad vegetation type</td>
<td>Granite lowveld</td>
<td>Central sandy bushveld</td>
<td>Zululand lowveld/West Maputaland clay bushveld</td>
<td>Central sandy bushveld</td>
<td>Granite lowveld</td>
<td>Waterberg mountain bushveld</td>
<td>Central sandy bushveld/western sandy bushveld</td>
</tr>
<tr>
<td>Population size (n)</td>
<td>53</td>
<td>11</td>
<td>92</td>
<td>10</td>
<td>35</td>
<td>117</td>
<td>9</td>
</tr>
<tr>
<td>Cows treated (n)</td>
<td>23³</td>
<td>4</td>
<td>19</td>
<td>4³</td>
<td>19</td>
<td>35</td>
<td>35</td>
</tr>
<tr>
<td>Age of cows (years)</td>
<td>12-50</td>
<td>13-16</td>
<td>10-35</td>
<td>19-25</td>
<td>6-31</td>
<td>9-44</td>
<td>10-40</td>
</tr>
<tr>
<td>Cows (n) calved before treatment</td>
<td>No data</td>
<td>3</td>
<td>18</td>
<td>No data</td>
<td>11</td>
<td>25</td>
<td>No data</td>
</tr>
<tr>
<td>Estimated mean calcving% before treatment (number of years)⁴</td>
<td>21.7%³</td>
<td>25.0% (3)</td>
<td>21.0% (6)</td>
<td>No data</td>
<td>16.7% (6)</td>
<td>20.6% (6)</td>
<td>No data</td>
</tr>
<tr>
<td>Mean annual calcving% during years 1 and 2 of the study</td>
<td>32.6%</td>
<td>12.5%</td>
<td>39.5%</td>
<td>25.0%</td>
<td>15.8%</td>
<td>30.0%</td>
<td>25%</td>
</tr>
</tbody>
</table>

³Classifications as per Mucina and Rutherford (2010)
⁴18 cows were treated in 2000 (Delsink et al. 2000); 2 added in 2001 and 3 in 2002
⁵Only vaccinated twice during year 1 (2004) and boosted for another 3 years. Moved to another game reserve in 2008 with no bulls
⁶Per number of cows judged to be of breeding age
⁷Adapted from Delsink et al. 2006
cows; Shambala, 2004, 4 cows; Thornybush, 2005, 19 cows; Welgevonden, 2005, 35 cows and Kaingo, 2005, 4 cows. Additional cows were added during years 2 (2 cows, Makalali) and 3 (3 cows Makalali) (Delsink et al. 2006, 2007), and in years 4 (Mabula, $n = 1$) and 5 (Makalali, $n = 5$) cows were removed from the program so that they could be allowed to reverse. Either before or during the course of year 1 each target animal was individually identified (Delsink et al. 2002). This allowed vaccination to take place on an individual cow basis. Prior to treatment, the populations typically had an inter-calving interval of 4.5—5 years and at inception of each program cows were at various unknown stages of reproduction. At the beginning of year 5, after 4 years of contraception, the Shambala population was captured and translocated to Entabeni Private Game Reserve where no bulls of reproductive age were present. The vegetation type (Waterberg) is similar in the 2 reserves. Monitoring of the cows continued on the new reserve.

Vaccine and Vaccine Delivery
The pZP antigen was produced by a modification of the methods described by Dunbar et al. (1980). The vaccine was manufactured at the Science and Conservation Centre, ZooMontana, Billings, MT for the 2000—2003 vaccinations. Thereafter, it was produced and supplied by the pZP Laboratory of the Department of Production Animal Studies, University of Pretoria. During year 1 each cow of reproductive age was given 3 pZP vaccinations; primary of 400 μg (600 μg at Makalali and Mabula) pZP in 1 ml phosphate buffered saline (PBS) with 0.5 ml Freund’s complete modified adjuvant (Sigma Chemicals Co., St Louis, MO); 2 boosters of 200 μg (400 μg at Makalali and Mabula) pZP each in 1 ml PBS with 0.5 ml Freund’s incomplete adjuvant (Sigma Chemicals Co., St Louis, MO). The intervals between vaccinations were 3—6 weeks. The 4 cows each in Shambala and Kaingo only received 1 booster during year 1. This was followed by annual boosters with 200 μg (400 μg at Makalali and Mabula during 2000—2003; thereafter 200 μg) pZP in 1 ml PBS with 0.5 ml Freund’s incomplete adjuvant. Shortly before use, the pZP antigen and adjuvant were mixed using 2 syringes joined by means of a connector. The fluid was pushed forwards and backwards between the syringes approximately 60 times creating a stable emulsion. Darts were then loaded with the emulsion. During the first 3 years at Makalali, DanInject® (DAN-INJECT ApS, Børkop, Denmark) darts with 60 mm needles were used (Delsink et al., 2007). Thereafter and on the other reserves, Pneu-Dart® (Pneudart, Williamsport, PA) darts with 50 mm 13 gauge needles with gel collars were used. Elephants were either darted from the ground or a helicopter. To facilitate the identification of cows within a group already darted during helicopter work, most cows were vaccinated with Pneu-Dart® mark and inject darts containing a pink dye (Wonder Mark®, Mafuta Products, Ventersdorp, South Africa).

Monitoring of Cows Post Vaccination
Cows on all game reserves were mostly seen 1—3 times a week but during wet periods spotting intervals were sometimes longer and as much as 2 weeks between sightings. Birth dates of new calves were taken as the date of first sighting. Mothers were identified with their calves that were either in close proximity or being nursed (Delsink et al. 2002). Duration of gestation was taken as 22 months (Laws 1966, Hodges et al. 1994). Using this period, stage of gestation could be calculated in cows pregnant at the time of inception of contraception or shortly thereafter. To simplify reporting, gestation was divided into trimesters as follows: first trimester, 0—8 months; second trimester, 9—15 months and third trimester, 16—22 months.

Data Analysis
The total number of calves born per annum for years 1 through to 6 was expressed as a percentage of the total number of cows treated each year. Expressing the an-

Table 2. Number and percentage calves born to treated African elephant (Loxodonta africana) cows 1—6 years after the start of pZP vaccination on 7 private game reserves in South Africa.

<table>
<thead>
<tr>
<th>Number of reserves</th>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
<th>Year 4</th>
<th>Year 5</th>
<th>Year 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cows treated</td>
<td>108</td>
<td>108</td>
<td>108</td>
<td>107</td>
<td>98</td>
<td>98</td>
</tr>
<tr>
<td>Calves born</td>
<td>35</td>
<td>22</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Calving %</td>
<td>32.4%</td>
<td>20.4%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
</tbody>
</table>

*One cow removed to allow reversal (Mabula)

5 cows removed to allow reversal at Makalali and 4 Shambala cows moved to Entabeni Game Reserve with no bulls of breeding age
nual reproductive rate as a calving percentage (calves born/annum/100 cows) was preferred to population growth rate because of the varying circumstances of each population. The \( \chi^2 \) test was used to analyse annual differences in calving percentage. As the year of commencement of contraception differed between reserves (2000—2005) they were normalised so that the date of primary vaccination was the first day and 365 days later the last day of year 1. The cows added to the trial during years 2 and 3 at Makalali were also normalised to fit the data. Day 366 was then the start of year 2 and so on. The numbers of cows treated each year varied from 98—108 as a result of some individuals being removed from the program for reversal and with the translocation of 4 cows from Shambala to Entabeni Game Reserve (Table 2). With a gestation period of 22 months pregnancies that would have been initiated during the first 4 years at the old reserve would have given rise to the birth of calves during the first 2 years at Entabeni.

### RESULTS

Approximate calving data was available for 5 of the 7 reserves prior to inception of contraception and varied from 16.7% to 25.0% in terms of annual calving percentage per cow of breeding age (Table 1). The mean calving percentages for years 1 and 2 of the trial varied from 12.5% to 39.5% between reserves with an overall annual mean of 26.4% for 108 cows. This was equivalent to 1.06 calves per cow per cycle of 4 years and a mean inter-calving interval of 3.8 years.

Following primary vaccination 35 calves were born during year 1 and 22 during year 2 providing calving percentages of 32.4% and 20.4.3%, respectively (Table 2). No calves were born during years 3, 4, 5 and 6 (\( P < 0.001 \)). With the exception of 2, all calves (\( n = 57 \)) were conceived prior to the primary vaccination (Table 3). One calf was conceived around the time of primary vaccination and the other between the primary vaccination and the first booster. Of the 108 cows vaccinated during year 1, 100% passed the 4-year, 67.6% (73 of 108) the 5-year and 47.2% (51 of 108) the 6-year intercalving interval. From the calving dates it was apparent that 57 cows were at various stages of pregnancy. One calf died as a result of a physical injury soon after birth and another as a result of haemorrhage from the umbilicus at birth. The remaining calves were healthy and survived. Table 3 indicates the stage of pregnancy when the calves as embryos or foetuses were exposed to the primary vaccination. There was an even spread of gestation stages in terms of pregnancy trimesters. About one third (\( n = 18 \)) were in the first trimester and were thus exposed to possible effects of the vaccine as early as the embryonic stage.

Calculated according to their calving dates, 2 of the 5 cows that were allowed to reverse during year 5 at Makalali, (last vaccination in June 2004) conceived 23 and 34 months after the last treatment, respectively. The remaining 3 cows at Makalali and 1 cow at Mabula have yet to calve 7 years after the cessation of treatment.

### DISCUSSION

The mean calving percentage of 26.4% for all 7 reserves during years 1 and 2 of the trial was higher than those recorded prior to inception of contraception in the 5 reserves that had historical data. There are 2 possible reasons for these differences. Firstly, contrary to post-inception, birth dates of calves were not available in most reserves during the previous years and ages of calves were estimated according to shoulder height (Laws 1966, Jachmann 1988, Lee and Moss 1995). Secondly, a number of cows in the trial only reached reproductive age around year 1 of the trial and some were even younger. Although we compensated cow numbers to correct for this, figures quoted prior to inception of the program should only be regarded as estimates. The mean calving percentages for years 1 and 2, on the other hand, are in agreement with recently published data for introduced populations (Mackey et al. 2006) which quotes population growth rates of up to and even exceeding 10%. Our data for years 1, 2 and the mean for the 2 years shows population growth rates of 10.8%, 6.1% and 8.5%, respectively. The fact that fewer calves were born during year 2 than year 1 is likely to be due to chance.
As reported previously (Delsink et al. 2006) no more calves were born from the third year onwards in this study. The mean inter-calving interval of <4 years (3.8 years) has been passed in 100% of females while 67.6% and 47.2% of cows passed 5- and 6-year intervals, respectively. For Makalali and Mabula, excluding the cows taken off contraception, no calves born to the original 21 treated cows after 10 years. These data once again demonstrate the efficacy of the vaccine to control fertility in African elephant.

The question that surely must be asked is, from when onwards in terms of the initial vaccinations are elephant cows infertile? Our data reflect that 1 cow conceived around the time of the primary vaccination when the antibody titre was either baseline or just starting to increase. A second cow conceived between the primary vaccination and first booster indicating that at least one booster is necessary to provide sufficient antibodies to block sperm-zona binding and thus a pregnancy from taking place. All remaining 55 cows that calved after inception of the program had conceived prior to the primary vaccination. The elephants that were treated with a lower dose of pZP (400 μg, primary and 200 μg for boosters vs 600 μg, primary and 400 μg for boosters) gave equivalent results from year 3 onwards. They have, however, not been treated for as long as the cows in Makalali and Mabula. Based on these results we have routinely used the lower dosage regimen since the beginning of 2004. The doses required to achieve immunocontraception with pZP in the elephant are considerably smaller than is required for horses (100 μg) if one adjusts for body mass. Similarly the dose of GnRH vaccine used to immuno-regulate androgen secretion in the pig (400 μg) is relatively much larger than is used for the same purpose in African elephant bulls (600 μg; Denys et al. 2010).

Curiously, the 95% efficacy of pZP immunocontraception achieved over a period of 17 years in wild horses (Kirkpatrick and Turner 2008) was lower than that achieved in African elephant cows. The collective efficacy of pZP immunocontraception in 24 ungulate species, 25 bears and 11 sea lions was 93.3% and ranged from 60% (nyala; Taurotragus angasi) to 100% in 16 other species such as bison (Bison bison), mountain goats (Oreamnos americanus), wapiti (Cervus canadensis), fallow deer (Dama dama) and moose (Alces alces; Frank et al. 2005). Efficacies within the ungulate species varied from 60—83% in 6 species and 91.6—100% in the remaining 18 species. All animals reported by Frank et al. (2005) were held and treated in zoos. The 1 major advantage that possibly contributes to the success rate in elephants is the long interval of approximately 4 years between calves. This means that, with a gestation period of 22 months, the elephant cow takes approximately 2 years to conceive again. The precise physiology of the latter period is unknown but thought to be similar to lactation anoestrus seen in some domestic species like the sheep and the pig (Bertschinger et al. 2008). Ahlers et al. (2012) in a 1-year study found that of 9 adult and 5 subadult cows treated with pZP and monitored by means of faecal progesterone metabolite concentrations, 6 showed regular and 2 irregular luteal cycles. Three cows that showed no proper luteal cycles had calved a mean of 9.3 months and 21.3 prior to the start and end of the study, respectively. This would indicate that the cows were acyclic or in anoestrus throughout the study period. The remaining 3 acyclic cows were subadults indicating that they had not reached puberty yet. Furthermore, at any 1 time, one can expect approximately 50% of African elephant cows to be pregnant (Bertschinger et al. 2008). Thus in the elephant there is ample time during the presumed anoestrous and pregnancy periods to achieve good pZP antibody titres capable of preventing fertilisation and pregnancy later on. The very first 2 pZP-immunocontraception field trials in elephants recorded contraceptive success rates of only 56% and 80%, respectively (Fayrer-Hosken et al. 2000). In both trials 400 μg and 200 μg pZP was used for the primary and booster vaccinations, respectively, but instead of Freund’s adjuvants, synthetic trehalose dicorynomycolate (5 mg per vaccinations) was used as adjuvant. During the first trial (n = 18; efficacy 56%) the boosters were administered 6 weeks and 6 months after the primary vaccination. In the second trial (n = 10; efficacy 80%) 2 booster were administered at 2-weekly intervals.

Just like as in the previous study in elephants (Delsink et al. 2006), we clearly demonstrated the safety of pZP-immunocontraception during pregnancy. The loss of 2 out of 57 calves was accidental and unrelated to the use of the vaccine. Irrespective of the stage of pregnancy during vaccination, the 55 other calves were born healthy and viable and have survived until today. This means that no developmental abnormalities during pregnancy could be attributed to the use of the vaccine in elephants.

Previously short-term reversibility of pZP-immunocontraception could be demonstrated in 3 free-ranging African elephant cows after only year 1 treatment (primary and 2 booster vaccinations). Twenty-two months after the primary vaccination all 3 cows were found to be pregnant on transrectal ultrasound examination (Fayrer-Hosken et al. 2000). The present study investigated the reversal potential in 6 cows that had been treated for 3 (n = 1) and 4 (n = 5) years, respectively. Two cows treated for 4 years conceived 25 and 36 months after the last treatment with pZP. The
remaining 4 cows have yet to produce a calf. It seems thus that the interval from last treatment to reversal is quite variable. Two studies have investigated ovarian function using faecal progesterone metabolite concentrations in free-ranging elephant cows treated for 2 to 3 (n = 14; Ahlers et al. 2012) and 4 years (n = 4; Benavides et al. 2012), respectively. With exception of cows that had calved a mean of 9.3 months before the start of the study (Ahlers et al. 2012), all adult females treated with pZP showed evidence of luteal activity. Although the studies were 12 and 14 months long, respectively, neither one could demonstrate negative effects of pZP treatment on luteal ovarian function. In both studies, faecal progesterone concentrations were significantly lower during the dry than the wet season and, in pZP-treated and untreated cows at Entabeni (Benavides et al. 2012), seasonal anoestrus was common. Importantly the latter study showed that, in the absence of conception, free-ranging elephant cows do not necessarily cycle continuously as was previously believed (Bertschinger et al. 2008).

MANAGEMENT IMPLICATIONS
Immuonococontraception using the pZP vaccine is highly effective as a method of birth control in African elephants. Calving in treated animals ceases two years after inception of the program. It is 100% safe for conceptuses at any stage of development. The delivery of the vaccine is remote and at no stage requires target animals to be caught or immobilized. The largest population treated so far is Welgevonden with 117 elephants of which 35 cows of reproductive age were targeted. Despite the mountainous terrain of the reserve, a 100% efficacy was achieved meaning that the treatment of larger populations is feasible. pZP-immuonococontraception presents a proactive means of population control in elephants whereas culling is reactive, and once implemented, must continue indefinitely if it is to succeed. Reproductive rate in African elephants is density dependent (Laws 1969; Laws et al. 1975) and the response to culling will be an increase in this rate. Finally, pZP-immunococontraception provides managers of small to medium-sized reserves with a viable and ethically acceptable means of controlling reproduction in African elephants.

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LITERATURE CITED


