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Chapter 4

FERTILITY CONTROL AND AFRICAN ELEPHANTS: A NEW PARADIGM FOR MANAGEMENT

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ABSTRACT

African elephants (*Loxodonta africana*), like most large charismatic wildlife species today, require some form of management to keep expanding populations within the biological limits of static or decreasing habitat. To a large extent, African elephant populations are confined to national or regional parks and private game reserves and have, therefore, limited range. When they move from these protected areas human-elephant conflicts arise, and if they do not move from the protected areas, significant and sometimes negative alterations in the habitat will result. Thus, there exists the paradox of an endangered species where population growth must be regulated.

Historically, population management of elephants relied on culling and to a lesser degree translocation. The former has become socially and politically unsettling, and the latter is constrained by the availability of suitable habitat on a continent with rapidly growing human populations. The volatility resulting from culling is derived, to a large degree, from a major conflict between conservationists, who dwell on the importance of the species and populations and habitat, and politically powerful animal protection groups and socially evolving views emanating from a general public that places a higher value on individual animals. Culling also focuses on symptoms of the larger problem and short-term solutions and ignores the root cause of the population growth, i.e., reproduction.

Beginning in the 1970s, the concept of fertility control found its way into the management options for species such as North American wild horses, urban deer, and captive exotic species in zoological gardens. Early attempts focused on steroid hormones in an attempt to mimic human contraception, but the challenges faced with controlling wildlife populations were very different. Steroid related pathologies, restricted delivery choices, behavioral and physiological side effects, high costs and regulatory hurdles soon redirected efforts in the direction of immunocontraceptives.

After successes with immunocontraception in a variety of wildlife species in the U.S., the technology was tested in elephants in the Kruger Park in the Republic of South Africa. Between 1996-2000, field trials with porcine zona pellucida (PZP) resulted in positive results with regard to contraceptive efficacy, delivery and safety. Immediately following these successful trials, actual management was initiated in a wildlife conservatory (Makalali) in RSA, and within just a few years zero population growth was attained in this population. By 2010, 13 different game parks were applying PZP immunocontraception to the management of elephant populations. To date no significant negative behavioral or physiological consequences have emerged and acceptance of this approach is growing. Fertility control has become the means by which the gap separating the conservationists from the animal protectionists can be bridged with regard to the management of elephant populations throughout the continent. Equally important, a politically and publicly acceptable large-scale management tool for this species may be at hand.

INTRODUCTION

The African elephant (*Loxodonta africana*) is an iconic species inhabiting the African continent and perhaps more than any other, evokes images of that continent. As with many other charismatic species in Africa and elsewhere, the elephant also finds itself in the center of major contemporary conservation issues. In 1979 there were an estimated 1.3 million elephants inhabiting the African continent, but only two years later this population had been reduced to about 609,000 animals (Douglas-Hamilton 1989). In Kenya alone, the population decreased from an estimated 167,000 animals to about 25,000 between 1972 and 1989 (Poole et al. 1992). The primary cause for this precipitous decline in Africa's elephants was poaching for the acquisition of ivory (Douglas-Hamilton 1972; Kerley 2008), and/or to reduce elephant damage to private property (Hoffman 1993) although several droughts also contributed to localized declines during the 1970s (Poole et al. 1992). In South Africa, crude population estimates placed the elephant population at about 100,000 prior to 1652 (Hall-Martin 1992). Over the next 240 years the South African elephant population declined to a point where it was considered "exterminated" (Whyte 2001; Hall-Martin 1992; Skead 1980, 2007), with only three relic populations remaining. Similar trends occurred in all other African countries (for a comprehensive review of African elephant population history see Scholes and Mennell (2008).

Four events led to a rebound in African elephant populations. These include the creation of protected reserves and national parks, the 1990 Convention in Trade in Endangered Species (CITES), changes in societal values that leaned more to animal welfare sentiments, and broad anti-poaching initiatives throughout the continent. Collectively, these events reversed the declining trends in many African elephant populations and numbers began increasing steadily. The CITES ivory ban resulted in a significantly increased level of public awareness of the plight of Africa's elephants and this in turn resulted in widespread financial support and increased commitment for anti-poaching surveillance and law enforcement in African national parks. A well-known example of this latter phenomenon was the establishment of the semi-autonomous Kenya Wildlife Service (KWS), which established a well armed, highly trained elephant protection operation, complete with sophisticated communications equipment and aircraft (Poole et al. 1992).

It is unlikely that Africa's elephant populations will ever reach the pre-1970s numbers, but some populations have recovered to the point where habitat change is occurring or anticipated as a result of the impact. Increases in elephant populations are not even across all years or all African countries. For example, between 2002 and 2006, South Africa's elephant population grew by almost 27% (Blanc et al. 2007). In Kenya populations are estimated to be increasing by almost 4% annually (Moss 1992).

The many years of heavy poaching activity forced numerous elephant populations to seek refuge in smaller and compressed habitats (reserves and parks). During their absence outside national parks and reserves, habitats that had previously supported elephants had been converted to agricultural use, setting the stage for elephant-human conflicts. Increasing habitat damage (or change) inside the parks and increased conflicts between agriculturists and elephants outside the parks occurred. In Kenya, for example, the KWS initiated the fencing of several preserves, including Shimba Hills National Reserve, Mt. Kenya National Park, and Aberdares National Park, largely to protect subsistence farming along the borders. The fences, however, led to increased habitat damage (or change) within the parks. The same approach and phenomenon has occurred in other African countries.

Collectively these events associated with increased populations, shrinking habitat, and elephant-human conflicts set the stage for increased emphasis on a more restrictive management approach. African countries have never reached a consensus on regulation methods either before the decline of elephant populations in the 1970s and 1980s or since the ivory ban and the start of recovery, but there is consensus that elephants need to be managed (Owen-Smith et al. 2006). South Africa and Zimbabwe, for many years relied on culling, either by shooting, or by first immobilizing the animals with scoline and then shooting. Entire family units were herded by helicopter, shot and butchered. In reality entire family groups were seldom captured and survivors were severely traumatized by the disruption of the matriarchal family units. Juveniles (up to 4 years) were sometimes spared and sent to zoos or wildlife parks (Moss 1992). In South Africa, culling was not insignificant and over a 34-year period of time more than 14,000 elephants were legally destroyed in the Kruger National Park alone (Slotow 2008). Culling was discontinued in 1994, for a variety of reasons, not the least of which was public opposition (Carruthers 2008). In Kenya, culling was not used as a management tool, also for a variety of social, financial and political reasons. Translocation of elephants to other habitat, game parks and reserves was also utilized as elephant manage tools, but high cost and limited available habitat, coupled with robust elephant reproductive performance made this approach unrealistic (Grobler 2008).

It is not the purpose of this paper to discuss in detail the pros and cons of elephant culling or translocation. Both are highly charged subjects and cross over from pure wildlife management and science to social, cultural, economic and/or political issues. The larger dilemma, however, is an old conflict that transcends one species or any one country. This is the conflict between the professional wildlife manager, or the conservationist, and the animal welfare advocate. The former, by virtue of training and interest, focuses their attention on habitat, biodiversity, and animal populations. The latter, however, largely on the basis of social or ethical considerations, places more value on the individual animal. While it might be biologically important to cull a group of elephants in an overpopulated park, the consequences for the individual elephants take precedence for this latter group. This conflict is commonly seen in issues regarding wild horses, urban deer and bison, just to mention a few other species. We will not, here, attempt to debate the "rightness" or "wrongness" of these approaches, but rather to simply point out that the conflict is historic and poses a dilemma. How can this gap be bridged in such a manner that allows habitat protection and individual animal safety? Can it be bridged?

There is a second overriding problem that obfuscates reasoned thinking on most sides of the debate. If one were to ask a large body of interested individuals, professionals or lay people, 'what are the problems of excessive animal populations', a very interesting array of answers come back. A sampling (which, would vary with the species in question) might include: damage to the habitat; starvation; conflict with humans (or livestock, vehicles, or crops), displacement of other species, or zoonotic diseases, among others. If, in fact, these were the problems, removal of animals by whatever means (hunting, culling, poisoning, trapping, translocation) would solve the "problem". But history has shown that this is not true. All of these approaches to animal overpopulations can provide some short-term relief, but eventually the "problem" will return. There is nothing wrong with these short-term approaches *if* it is recognized that they will have to be applied forever, and *if* the public approves, and *if* the approaches are legal, and *if* the law allows, and *if* the economics are reasonable. That is a lot of *ifs*! The "problem(s)" will return because the species in question will simply reproduce itself back into the original dilemma and the removal solutions will have to go on forever, and so will the social, political, economic and cultural conflicts. Worse, in some cases, removal strategies more often than not induce the target species to reproduce at faster rates than before after their densities are decreased, through the phenomenon of compensatory reproduction (Kirkpatrick and Turner 1991a). Stated another way, removal of animals can actually exacerbate the "problem", over the long term. In reality, none of the "problems" listed above are in fact the "problems". They are merely *symptoms* of a problem. The problem, simply, is reproduction. In the final analysis, it was reproduction that brought the elephant back from the brink of extermination. Protection helped, but without successful reproduction, the elephants would not have recovered. This is not a complex construct. Global warming probably has its roots in human population increases. This is also true for natural resource depletion, loss of wildlife habitat, massive economic disruptions, increased poverty, malnutrition, even wars, and so forth, and until human population growth – reproduction - is restrained the symptoms of overpopulation will not go away. The same is true for elephants.

THE BIRTH OF A NEW PARADIGM

In the early 1970s an old concept, fertility control, emerged for a new application, the regulation of large wildlife species (Kirkpatrick and Turner 1985). The original focal species was the wild horse of North America. This species, like the African elephant, has the protection of law (the Free Roaming Wild Horse and Burro Act of 1971), like the elephant, it has a high reproductive potential, like the elephant it evokes large emotional responses (negative as well as positive) from a significant portion of the public, like the elephant, it has a serious impact on its environment, and like the elephant, it has a variety of conflicts with humans. Other parallels could be constructed, but they may not be necessary.

Between 1971 and 1986, research focused on inhibiting sperm production in stallions, by means of a long-acting form of testosterone (Kirkpatrick et al. 1982; Turner and Kirkpatrick 1983). By means of a negative feedback route, exogenous testosterone caused a decrease in pituitary follicle stimulating hormone (FSH) and luteinizing hormone (LH), which in turn led to oligospermia and an 83% reduction in foals among mares bred by the treated stallions. Despite pharmacological success, this approach had no practical value. It was expensive, the steroid could pass through the food chain, and animals had to be captured for treatment, creating a great deal of stress. Before proceeding, however, a set of hypothetical guidelines was developed for the "ideal wildlife contraceptive". These guidelines were developed around the wild horse but were clearly applicable to many other species (Kirkpatrick and Turner 1991b). These guidelines included: (1) reversibility in contraceptive action, (2) an efficacy of at least 90%, (3) ability to deliver the agent remotely, (4) inability to pass through the food chain, (5) safety for use in pregnant animals, (6) minimal effects on social behaviors, (7) no short or long-term debilitating health effects, and (8) low cost.

At this point attention turned to immunocontraception. The concept was put forth at the First International Conference on Wildlife Fertility Control, held in Philadelphia in 1987 (Hunter and Byers 1996). At that time, there were only two realistic vaccine-based approaches, including vaccines against the gonadotropin releasing hormone (GnRH) and the zona pellucida of the ovum. Preliminary trials with GnRH vaccines did not prove efficacious with wild horses (Goodloe et al. 1996). Attention shifted to the zona pellucida. The mammalian zona pellucida is a non-cellular membrane surrounding the ovum and is composed of several glycoproteins that collectively make up the sperm receptor (Sacco and Shivers 1973). When these proteins from pigs (porcine zona pellucida, or PZP) are administered to species outside the family Suidae, they cause an immune response and the generation of antibodies against the PZP glycoproteins. Despite sufficient differences across species in zona protein epitopes that make up the sperm receptor in mammals, to elicit antibodies, there is also significant homology among these proteins across species. Thus, after destroying the PZP immunogen, the anti-PZP antibodies search for similar protein and will attach to the target animal's own zona proteins, causing steric hindrance and blocking fertilization (Timmons and Dunbar 1988).

The first trials with PZP and captive horses were successful in inhibiting reproduction (Liu et al. 1989). Over the next two decades the vaccine was applied to free-ranging wild horses with success (Kirkpatrick et al. 1990, 1991, 1992, 1995a; Kirkpatrick and Turner 2008) at both the individual and population levels. The vaccine was administered remotely, by means of small 1.0 cc darts and over time the vaccine proved effective (Turner and Kirkpatrick 2002; Kirkpatrick and Turner 2008), safe to give to pregnant mares (Kirkpatrick et al. 1991; Kirkpatrick and Turner 2003), reversible in its contraceptive action (Kirkpatrick et al. 1991; Kirkpatrick and Turner 2002), caused increased longevity (Kirkpatrick and Turner 2007), improved body condition (Turner and Kirkpatrick 2002), demonstrated no short or long-term debilitating health effects (Kirkpatrick et al. 1992, 1995a; Kirkpatrick and Turner 2007), and did not alter social behaviors (Powell 1999; Ransom et al. 2010). Consisting of a 55,000 MW complex quaternary structure glycoprotein, PZP could not pass through the food chain. Finally, the cost was extremely low compared to traditional methods of control requiring capture (about $25US/dose). In short, the vaccine met virtually all the requirements of the "Ideal Wildlife Contraceptive" (Kirkpatrick and Turner 1991b).

In rapid succession the PZP vaccine was successfully applied to free-ranging burros (Turner et al. 1996a), captive and free-roaming urban white-tailed deer (Turner et al. 1992, 1996b; Naugle et al. 2002; Rutberg and Naugle 2008), wapiti (Garrott et al. 1998; Shideler et al. 2002), and more than 80 species of captive exotic animals in zoological gardens (Kirkpatrick et al. 1995b, 1996, 2009; Deigert et al. 2003; Frank et al. 2005; Lane et al. 2007).

ON TO ELEPHANTS

By the early 1990s, the rebounding elephant populations in Africa stimulated concern for management, and the emergence of wildlife fertility control as a successful management tool brought these two issues together. In May 1992, a meeting was held in Amboseli National Park, Kenya, bringing together experts from around the world to discuss elephant fertility regulation. This meeting, in effect, created a consciousness about a completely new approach to elephant management. Many potential approaches were discussed, including steroids, immunocontraception, and abortifacients. The conclusions of the meeting were put forth in a document know as the Amboseli Accord and stated (in its original form and punctuation):

- "The predicted increase in human numbers *in Africa* and southeastern
- Asia, which will continue throughout the foreseeable future, will progressively
- reduce the habitat available to wild elephant populations. The survival
- of African and Asiatic elephants will therefore depend on the creation and
- support of elephant reserves and sanctuaries in their natural habitat.
- As wild elephants are forced to congregate in the reserves where they
- will be protected from their traditional predator, man, their numbers
- will increase.
- To conserve the habitat in their remaining range, some form of
- Elephant population control will need to be found. We are in agreement
- that periodic slaughter of a population is ethically unacceptable, a
- method of last resort, a fate that those noble, sentient, social animals
- do not deserve at the hand of man.
- We are therefore resolved to embark on an immediate programme of
- research and development to produce humane methods of elephant
- population control. We need a range of new technologies designed
- specifically for use on wild elephant populations. It is only in this way
- that we can insure the long-term future of the elephants on earth."(Kenya Wildlife Service 1992)

Immediately following this landmark meeting, the first elephant fertility control experiment got under way. Dr. Bonnie Dunbar, a signatory to the Amboseli Accord and perhaps the foremost pioneer in the biology of zona proteins and Dr. Eric Schwoebel, both of the Department of Cell Biology at Baylor University School of Medicine initiated a project in Laikipia National Park in Kenya. Elephant researcher Joyce Poole assisted and the trial was conducted under the leadership of Dr. Richard Leakey, of the KWS. Six female elephants were inoculated with a primer dose of PZP, and three were given a second inoculation. Antizona antibody titers revealed a significant elevation, particularly after the second booster inoculation. Prior to this pilot study there has been great concern that strong adjuvants such as Freund's Complete adjuvant would cause unacceptable injection site reactions, but no such disturbances resulted (Dunbar 1994). Unfortunately, the project ended before actual contraceptive data could be collected, largely because of a change in leadership at KWS, but the door was now open.

Shortly thereafter, in 1994, the primary group utilizing PZP in American wildlife fertility control projects approached the Kenya Wildlife Service with the intent of establishing a long-term comprehensive PZP elephant fertility control trial in Kenya. This occurred shortly after the charismatic KWS leader, Dr. Richard Leakey vacated the directorship and the Service's attitude regarding fertility control was at best ambivalent. Interestingly, several well know elephant research groups discussed the subject, voiced approval of the concept, but were opposed to any such research occurring with "their" elephant populations. Nothing useful came of the inquiry (J. F. Kirkpatrick, pers. Comm.).

In 1995, a year after culling was suspended in the Kruger National Park in South Africa, a second inquiry was made by the same research group. Along with a veterinary reproductive specialist from the University of Pretoria, the group proposed a PZP trial in the Kruger Park. While some skepticism was apparent, the park invited a proposal and subsequently approved it. In September 1996, a full-scale elephant immunocontraceptive project was initiated in the Kruger Park.

The application of a glycoprotein-based vaccine to a new species cannot be assumed to be successful on the basis of previous work with other species. While virtually all taxon groups outside the Family Suidae will raise antibodies against PZP, as Dr. Dunbar had already shown with elephants in Kenya, there is no guarantee that those antibodies will cross-react with the sperm receptor of the new species. A certain degree of homology must exist between epitopes of the target animal's sperm receptor proteins and the PZP. A study with labeled rabbit anti-PZP antibody demonstrated that binding occurred in the zona pellucida of elephant oocytes (Fayrer-Hosken et al. 1999) and successful contraception with a captive elephant at the Calgary Zoo indicated that indeed, there was sufficient homology for the anti-PZP antibodies to block fertilization.

Adult female elephants were immobilized from a helicopter with the immobilizing drug etorphine and the tranquilizer azaperone and examined to determine pregnancy status by means of a transrectal ultrasound examination. Twenty-one were found to be non-pregnant and were given an initial inoculation of 600 µg PZP emulsified with synthetic trehalose dicorynomycolate (S-TDCM) adjuvant, fitted with radio collars and released. Booster inoculations were given remotely, from a helicopter three and six months later. Twenty control elephants received a placebo of sterile water and adjuvant. A year later the elephants were recaptured and tested, via ultrasound, for pregnancy. Only nineteen of the 21 experimental elephants were recaptured because two lost their radio collars and could not be found. Nine (47%) were pregnant, while 16 (80%) of the control elephants were pregnant (Fayrer-Hosken at al. 2000). In a subsequent experiment, 10 additional elephants were treated as described, but boosters were given at two and four weeks, and efficacy increased to 80% (2 of 10 were pregnant).

Reversibility was documented. Seven of the elephants from the initial group were given either a placebo booster (3) or a single PZP booster (4). The 3 cows taken off contraception all conceived within the next year, while those boosted maintained infertility but continued to cycle (Fayrer-Hosken et al 2000). Thus, the vaccine performed in elephants much as it had in wild horses and deer, although with a lower efficacy.

By 2000, the fundamental research questions had been answered and the Kruger experiments were concluded. The same year the Greater Makalali Private Game Reserve in Limpopo in South Africa began actual management of its small (75) elephant population. The objectives of this first management-level trial were to test the effectiveness of PZP immunization for actually controlling the population, evaluating behavioral responses, evaluating different dosages of PZP, and comparing the cost and effectiveness of aerial delivery versus ground darting. A major change in protocol was established in alignment with horse and deer trials in the U.S. Instead of the S-TDCM adjuvant, Freund's Modified adjuvant (FMA) was utilized for the initial priming inoculation and Freund's Incomplete adjuvant (FIA) was utilized for subsequent booster inoculations. The adjuvant, a major issue in the effectiveness of the PZP vaccine has been discussed in detail elsewhere (Lyda et al. 2005; Kirkpatrick et al. 2009). Doses of 200 µg, 400 µg and 600 µg, all emulsified with FMA, were given at time 0. All booster inoculations consisted of PZP + Freund's Incomplete adjuvant, which is little more than paraffin oil, at 2 months and 6 months, and annual booster inoculations were given thereafter. All animals were identified by unique markings. Behavioral observations were based on 15-minute time budgets as described by Pulliam and Caraco (1981) and Moss (1988).

Over ten years, PZP contraception proved effective in controlling population growth. Because there are no deleterious effects of vaccination during pregnancy, and because of the lengthy 22-month gestation period, population growth showed a modest increase during the two years following the initial treatments, allowing for the birth of calves that were *in utero* during treatment. Thereafter, zero population growth was attained, until some cows were withdrawn and permitted to breed again. The 8 years pre-contraception inter-calving interval (mean of 56 months; range = 48-72 months) and the increase after contraception translated into a projected 33% decrease in population size after 10 years of programmed contraception. Remarkably, the efficacy of the PZP vaccine over ten years in Makalali is 100% among non-pregnant treated cows, a level of efficacy that has not been achieved with any other free-ranging species.

No behavioral differences, with a focus on family group fission/fusion and home range, were noted between treated and untreated females nor were any disruptions of social groups or behavior noted (Delsink et al. 2007a). All dosage protocols worked equally well. Of 62 cows that were treated during pregnancy and which produced calves, 60 were healthy and survived their first year (Bertschinger 2020). One died from a physical injury and another of a hemorrhage from the umbilical cord. Approximately one third of the exposed fetal calves were classified as embryos (first trimester) when they were exposed to the PZP, yet none suffered ill effects. Darting from the ground was effective, but was time consuming. Over time it also caused some temporary wariness by the elephants to the darting vehicle. It required 12 days to treat 23 cows from the ground, while the same number for cows could be treated from a helicopter in 30 minutes. In general, ultrasound examinations corroborated the results from the Kruger Park experiments, indicating that treated cows continued to cycle, based on the presence of corpora lutea and mature follicles.

Local and temporary injection site reactions occurred in about 90% of the treated cows in the form of small abscesses or swelling, however, all resolved themselves without complications (Delsink et al. 2006) and without any indications that they were causing discomfort to the animals. These local injection site reactions were not different, qualitatively, or quantitatively, from those seen in elephants darted with immobilizing drugs (Bengis 1993), suggesting it has less to do with the vaccine or adjuvant than with the dart needle pushing dermal bacteria into the wound.

Also corroborating the original Kruger results, reversal studies in Makalali indicated that the treated cows will return to fertility and one cow did so after five consecutive years of treatment and two others after three years (AK Delsink, Pers. Communication). The average cost of immunocontraception ranged from a low of Rand289/elephant to a high of R1500/elephant, depending on whether darting was conducted from the ground or from a helicopter. (Delsink 2006; Delsink et al. 2002, 2006, 2007b; Bertschinger 2010). In contrast, the cost of culling varies with the number of animals culled and the existence of a local market for meat and hides. In the Kruger Park, for example, the cost of culling 800 elephants is about R6600/elephant (Grant 2005), however, the income generated from culling (meat, hide, but excluding ivory) comes to about R7000/elephant if a local market exists (Whyte 2001). In a smaller park (Madikwe Game Preserve) the cost for culling ten elephants is about R3962/elephant, but no local market exists for hide and meat. Thus, the cost of immunocontraception is less than most culling operations and at worst close to the cost of culling where markets exist for products.

Following Makalali's lead, 12 other game parks and reserves in South Africa have initiated contraceptive management of their elephants with PZP. These include Mabula, Thaba Tholo, Shambala, Phinda, Thornybush, Welgevonden, Kaingo, Karongwe, Tembe, Amakhala, Kapama, and Hlambanyati. The Shambala elephants were translocated to a new reserve (Entabeni) after four years of treatment, and while no bulls are present in the new preserve, no calves have been born to date. The data from these parks will add the to the growing body of knowledge regarding the effectiveness of the vaccine in elephant populations and all other parameters of importance. For an eloquent, comprehensive and detailed summary of the results of these trials see Bertschinger (2008). It is reasonably clear now, after 14 years of study and ten years of management level contraception, that a management tool exists that is safe, humane, cost-effective and publicly acceptable.

From a safety perspective, the field trials with free-ranging elephants mirror the results of management with a limited number for captive elephants, including animals at the Calgary Zoo, the Oregon Zoo, The San Diego Zoo (J. F. Kirkpatrick, pers. Comm.), and Riverbanks Zoo (Fayrer-Hosken et al. 1997,1999). While it is true that free-ranging animals cannot be examined on a daily basis and some minor side effects might be missed, the captive animals have been seen on a daily basis by keepers and veterinarians.

One area of elephant biology that has not been studied in general to any extent is genetics, and no studies have examined the genetic consequences of various management strategies. Intuitively, the removal of elephants, by any means, culling or translocation, must limit gene flow within a population. This is particularly true if young animals that have never reproduced are removed. Genes are lost to the population forever. While nothing definitive has been published, anecdotal reports suggest that years of poaching, where the emphasis has been on animals with large tusks, has had consequences, particularly where the poaching targets have been matriarchs. This would be particularly important in small confined populations within game parks. In contrast, contraception, used within the scope of a well-designed management plan simply delays reproduction rather than preventing it forever. It has already been demonstrated that 23 years of contraceptive treatment of a small island-bound population of wild horses has suffered no genetic consequences from a management approach that allows every mare the opportunity to reproduce at some point in her life (Eggert et al. 2010). These data suggest a more genetically responsible approach for elephant management lies in fertility control.

From a broad scientific standpoint, PZP immunocontraception has an overwhelming advantage over other fertility control approaches. Perhaps the greatest advantage it imparts is the extreme "downstream" point of action in the reproductive process. Steroids, or any contraceptive agent that interferes with steroids will by definition have an immense effect on behavior and systemic physiology. The zona vaccine has but a single target receptor throughout the mammalian body, that being the sperm receptor of the ovum or mature oocyte (Sacco and Shivers 1973; Palm et al. 1979; Barber and Fayrer-Hosken 2000). Fifteen years of research with non-human primates (Sacco et al. 1986) and twenty-three years with wildlife (Kirkpatrick et al. 2009) have corroborated this feature of the PZP vaccine. This is in contrast to some recently developed gonadotropin releasing hormone (GnRH) analogs and vaccines that have receptor sites in an amazing array of tissues throughout the mammalian body (McCoy 1994; Skinner et al. 1995, 2009; Schoefield et al. 2002; Bahk et al. 2008). Thus, any long-term side effects of PZP vaccination will be from contraception itself and the absence of young, rather than physiological disturbances.

THE FUTURE

Despite a clear breakthrough in the realm of science, neither wildlife fertility control in general nor elephant contraception in particular have reached their potential, largely for two reasons. First, the technology must be improved to make treatment of free-ranging wildlife more convenient, and second, the political, cultural and social issues surrounding the subject must be addressed in a rational and cogent manner.

The paradigm of wildlife fertility has changed in recent years. The original question posed 25 years ago, was, 'can wildlife contraceptive management be achieved?' As we have seen, the answer is yes. But now the question has become, 'can we do this easier and cheaper?' In many respects this second question is driving the lack of progress. The single largest weakness in the current technology is the inability to deliver a single inoculation and cause several years of infertility. The need for annual booster inoculations raises the cost – although it is still competitive with other management approaches – and requires considerable manpower over time. For many species this is an attractive feature of the PZP vaccine, because there is a desire to have maximum flexibility in breeding opportunities. This is the case with zoological gardens. However, for free-ranging wildlife, it represents a problem. To that end, several research initiatives have been mounted to find a formulation of the PZP vaccine that will allow a single inoculation that will deliver several years of contraception. One such approach is to incorporate the PZP antigenic protein into small pellets of lactide-glycolide, a non-toxic material that upon exposure to tissue fluids will erode slowly and cause a controlled release of the PZP (Turner et al. 2001, 2002, 2007; Liu et al. 2005). The pellets can be administered by trocar or by dart. Results with African elephants, however, were not encouraging (Turner et al. 2008). A second approach under consideration is the incorporation of PZP into a biodegradable gel, prepared from blends of polylactate-co-glycolic acid and a plasticizer such as polyethylene glycol 400 (Thosar et al. 1996). These polymer gels have been routinely used in the manufacture of synthetic bioabsorbable surgical sutures. This material injects as a gel and then forms a semi-solid mass in the tissue. As the solidified mass erodes, the active ingredient is released at various rates, depending on the gel formulation. This approach has been used successfully to deliver contraceptive steroids to captive wildlife (Tell et al. 1999; Looper et al. 2001; Wheaton et al. 2010). This work is ongoing.

The entire issue of elephant fertility control, however, was clouded at the very beginning because of a second trial that occurred in the Kruger Park simultaneously with but independently of the PZP trial. Ten elephant cows were captured and treated with 17-beta estradiol implants. Contraceptive efficacy was very high (Goritz et al. 1999), but serious side effects resulted. The females went into persistent estrus for a 12-month period (Bartlett, 1997; Butler 1998) and several calves were lost (Whyte and Grober 1998). The elephant estradiol trials were terminated by the Kruger Park officials immediately after these findings. Nevertheless, years after the Kruger PZP and estradiol trials were concluded, a public that has almost no background for discerning hormonal contraception from immunocontraception continues to confuse the outcomes of the two trials.

The larger issue, however, is the ambivalence or outright hostility to the fertility control approach by various groups. This opposition is usually based on cultural objections, economic factors, or social orientations, and of course, political objections follow closely behind. Opposition to wildlife fertility control in general arose long before elephants were the target species, and has grown over the years where this approach has been used in other species (Kirkpatrick and Turner 1997a,b). The opposition to elephant contraception comes from many quarters, including, ironically, those who oppose culling. Indeed, the many opposition factions, each driven by a separate agenda, make this discussion very difficult. Thus, at the risk of oversimplifying, let us examine just a few opposition factions.

The sport hunting of elephants is still permitted in South Africa, Zimbabwe, Botswana, Namibia, Cameroon and Tanzania (Owen 2006), and generates revenue and fuels the argument that only when a species provides economic value will it be protected. Thus, the hunting community has little interest in accepting a non-lethal solution to elephant management. Those who favor culling point to the income derived, not just from meat, hide and ivory, but from the temporary employment these operations offer to local residents. This faction too generally opposes fertility control. Their own arguments, however, have become diluted by the decreased value of elephant products caused by the CITES convention (Blignauf 2008). Elephant managers who have no real agenda on either side of the consumptive or non-consumptive use of elephants often argue against fertility control because of doubts that it will be a useful technique with large populations. While their concerns may be valid, the final judgment will not be rendered until fertility control is tried in these settings. That is the purpose of research.

Opposition, however, is not confined to those who favor consumptive uses of elephants. One of the initial opponents of elephant fertility control, just as the original Kruger Park trials were beginning was the International Federation for Animal Welfare (IFAW). The objections focused on potential changes in the very complex social behaviors of this species. Later, as the technology and the trials made it clear that fertility control was feasible, the arguments against it came from other sources and became more focused. While short-term trials (5-10 years) have revealed no behavioral effects, some groups have cautioned that large-scale management efforts should not be mounted until the longer-term effects have been studied (Whitehouse and Kerley 2002). There is concern over the possibility that long-term fertility control can lead to sterility rather than contraception, that cows that normally do not cycle but once every 5-9 years would begin to cycle every 15 weeks, disrupting the social structure of the herd, and that fewer calves over longer periods of time would prevent young animals from learning the nurturing behavior of adult females in the herd (Whyte, 2001). All of these concerns are legitimate and must be studied carefully.

At the same time, however, the "loyal" opposition to elephant fertility control often fails to recognize that *some* form of management will be utilized in the interim. This opposition often fails to grasp the concept of risk-benefit. Even if there are some consequences of fertility control that are of concern, how do they compare with current practices (sport hunting, culling, translocation)? Until an accurate comparison of the consequences of all alternative methods of elephant management are presented, the manager and the public cannot make informed decisions (Kirkpatrick 2007).

Finally, there are arguments against elephant fertility control based on the recognized fact that a "silver bullet" does not yet exist. The lack of a single inoculation long-acting form of the vaccine, coupled with questions about long term behavioral or physiological effects are often used to avoid or delay management at the present time. This approach fails to recognize that in the interim, elephants will continue to breed, populations will continue to increase and the problems will only grow larger. At the current time, immunocontraception represents a management tool that works, has no deleterious effects at least over ten years, is economically sound and that is the least intrusive or disruptive of all alternative management procedures available. It should be put to work now, and as improvements are developed we can celebrate the increase in effectiveness.

CONCLUSION

The management of Africa's elephants is extremely complex, involving quantifiable dimensions such as the economics of culling, or sport hunting, ecotourism, property damage, human safety, and habitat degradation (or change!). At the same time some non-quantifiable dimensions entwine themselves throughout the entire issue and even include moral or ethical considerations. Despite the social, economic, cultural, ethical, political and moral disturbances that surround the issue of elephant fertility control, it is clear that the new paradigm is here to stay. While there are still facets of the science and technology that may have potential effects upon physiology and/or behavior and that must be studied further, a careful analysis thus far – over 15 years - demonstrates that these effects will be minimal. In fairness, elephant fertility control cannot be judged *ex parte*, but must be evaluated in the light of all other alternative management paradigms. There are still shortcomings in the technology itself, and it is likely that continuing research will overcome these. It is also clear that a lack of public understanding clouds the larger issue of elephant management and fertility control in general. That can only be overcome with effective public relations and education, something that has been sorely missing to this point.

Perhaps the most encouraging dimension of the entire paradigm is that if there will be any approach to elephant management that bridges the gap – or at least narrows the chasm - between conservationists and animal welfare interests, between science and ethics, it will be fertility control. This has shown itself to be true with other species, in other settings, and management of the African elephant will surely fall this way too. Despite this prediction, contraception alone cannot be viewed as the ultimate solution to the African elephant "problem". That will lie with protecting the integrity of natural reserves and parks, curbing human population growth, and providing relief form all the symptoms of human overpopulation that impinge on wildlife in general and elephants in particular.

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