THE MANAGEMENT OF FREE-RANGING LIONS ON ENCLOSED PROTECTED AREAS

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ABSTRACT

We investigated the potential impacts that free-ranging lions have within a small (<1000 km²), enclosed protected area, and the subsequent challenges to managers. Smaller protected areas, because of perimeter fences which do not allow for immigration and emigration, suffer consequences in the form of over-population, inbreeding depression, the decline of prey and other predator species, conflict with neighbouring communities as a result of break-outs, and, in some cases, the spreading of intra- and interspecies disease. Lions are very prolific breeders and, in all cases investigated, reserves exceeded their local carrying capacity within a relatively short period of time. Within the Greater Makalali Private Game Reserve (GMPGR) we highlight the complexities of managing lions within small, enclosed reserves. A range of management interventions can potentially achieve short and/or long-term reserve objectives. The specific interventions assessed were: relocation, contraception, hunting, and artificial takeovers. None of the intervention methods resulted in long- term behavioural or social changes within the lion population. Constraints on lion management are more from societal values than biological or technological influences. If applied in the correct manner, at the correct time, all of these interventions or a combination of them will assist in achieving management objectives.

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INTRODUCTION

Presently in South Africa, lions (*Panthera leo*) are mainly restricted to isolated populations in national parks, provincial parks, and private game reserves, historical ranges having been lost to Africa's burgeoning human population (Hunter 2001). Lions have, however, received a respite in the form of the rapid expansion of the tourism industry in South Africa, which has resulted in considerable energy being devoted to restoring natural ecosystems, mainly by the initiative of the private sector. The restoration of large carnivore species in many areas where they had previously been exterminated has been one of the most prominent of these efforts (Hunter 1999, Vartan 2001, Hunter *et al.* 2007). Since 1994, lions have been introduced on many game reserves, because these animals hold deep emotional appeal to the general public and are the single most sought after species for tourists visiting reserves (Hunter 1999, Mbenga 2004). Furthermore, lions also engender aesthetic and economic appeal to smaller reserves (Power 2002).

The other side of this positive trend is that managing lion populations within enclosed protected areas produces a myriad of challenges, due to the fact that the smaller the reserve, the more intensively it needs to be managed (van Dyk 1997). Poor advice from conservation authorities or irresponsible management practices (often unintentional) implemented by landowners and concessionaires result in these challenges being compounded. This lack of knowledge invariably results in at least one, but more often than not, several of the following consequences: overpopulation (Vartan 2001); inbreeding depression (Vartan 2001, Hedrick and Miller 1992, Newmark 1996, Packer *et al.* 2005); the demise of other predator and prey species (Hunter 1999; Mills and Shenk 1992); break-outs as a result of pressure from other lions within the protected area (Steele 1970); the intra- and interspecies spread of disease; and conflict with local communities in the event of stock loss or the loss of human life (Hunter 2001, Packer *et al. 2005*).

Active management (often viewed as a necessary evil) is necessary to ensure that protected areas achieve their purposes and maintain the natural processes for which they were established (Pressey 1996) The strong ecological and sociological influences that lions have on the environment will be accentuated on small, enclosed reserves which have no ecological buffer, and are surrounded by alternative, and potentially conflicting, land-use practices. Although the effect of lions on the underlying prey populations can be substantial in small reserves, and require intensive management such as re-introductions of prey species (e.g. Power 2002 in the Pilansberg and Madikwe reserves, Slotow *pers. comm*. 2007, Peel *pers. comm*. 2007 in the Sabi Sands), the key issue of concern is rapid population growth (Druce *et al*. 2004a, Vartan 2001, Hunter *et al*. 2007). Fast population growth is a result of (1) high recruitment, and (2) artificial changes/influences such as the absence of infanticide, diseases, and intraspecific conflict, all of which contribute to limiting population growth (Packer *et al. 1988*). In addition, small private reserves reliant on tourism as their primary source of revenue typically have high prey species stocking rates, thus ensuring a constant food source for lions, resulting in no starvation taking place (Vartan 2001).

In open systems, a male coalition holds tenure over the pride, and effectively excludes strange males from siring cubs with pride females (Packer *et al*. 1991). Competition amongst males for pride tenure is intense, the average tenure being 2 (Packer *et al*. 1988) to 3 (Stander 1991) years. Infanticide is common when males take over a new pride; most females with dependent offspring lose their cubs within a month of a takeover, and those that are pregnant lose their cubs shortly after giving birth (Packer & Pusey 1984). On enclosed protected areas, with only 1 resident pride, this cannot take place.

Typically, enclosed game reserves experience high rates of population increase where prey species are abundant and competition is low (Vartan 2001). This is due to a combination of no opportunities for emigrations or immigrations (Vartan 2001), low natural mortality rates and the fact that lions are very proficient breeders (Packer & Pusey 1987, Rudnai 1973b). This results in lion populations on enclosed

reserves reaching or exceeding their local carrying capacity within a relatively short period of time (Hunter 1999).

The aim of this study, using the Greater Makalali Private Game Reserve (GMPGR) as a case study, is to highlight the complexities of managing lions within small, enclosed reserves. The biology of lions on the GMPGR has previously been described (Druce *et al*. 2004a, Druce *et al.* 2004b), and lion population growth has been extremely high (Druce *et al*. 2004b). A range of management interventions can potentially achieve short and/or long-term reserve objectives. The successes of these interventions both in terms of the biological consequences, but also in terms of the sociological influences are assessed. The state (1) prior to intervention, (2) the intervention plan, (3) logistical considerations, (4) the consequences of, and (5) the costs and success of interventions are outlined. The specific interventions assessed were: Relocation, contraception, hunting, and artificial takeovers.

METHODS

Study Site

The 24 000 hectare GMPGR is situated in the Central Lowveld region, east of the Drakensberg Mountains. The area can be described as a Lowveld plain and the altitude varies between 300m and 500m above sea level (Druce 2000). The landscape within the protected area is characterized by undulating terrain, interspersed with rocky outcrops. The main vegetation types are Mixed Lowveld Bushveld (Low & Rebelo 1996, Type 19) and Mopane Bushveld (Low & Rebelo 1996, Type 10). The area falls within a summer rainfall region (October to April), with an average rainfall of 450mm. The area is reasonably hot and dry. Generally, the temperatures vary between 7°C and 36°C. Several non-perennial watercourses and the perennial Makutswi River, a tributary of the Olifants River as well as the Selati River drain the GMPGR.

The GMPGR management pioneered the field of re-establishing free-range lions on private property in South Africa. A pride of 6 lions (2 males and 4 females) were released onto the reserve in mid 1995. As expected, these numbers have increased

over time. Studies conducted on the GMPGR (Druce *et al.* 2004b) demonstrated that from the 6 lions originally relocated (2 males and 4 females), 35 lions were born at a rate of 11.6% per year over a period of 7.5 years (Figure 1 updated to 2006 population). This illustrates the need for management intervention in order to maintain lions and prey species in a state of dynamic equilibrium. Fortunately, the lions are reasonably habituated to game drive vehicles, allowing easy and close approaches. All individuals were individually known through distinctive markings.

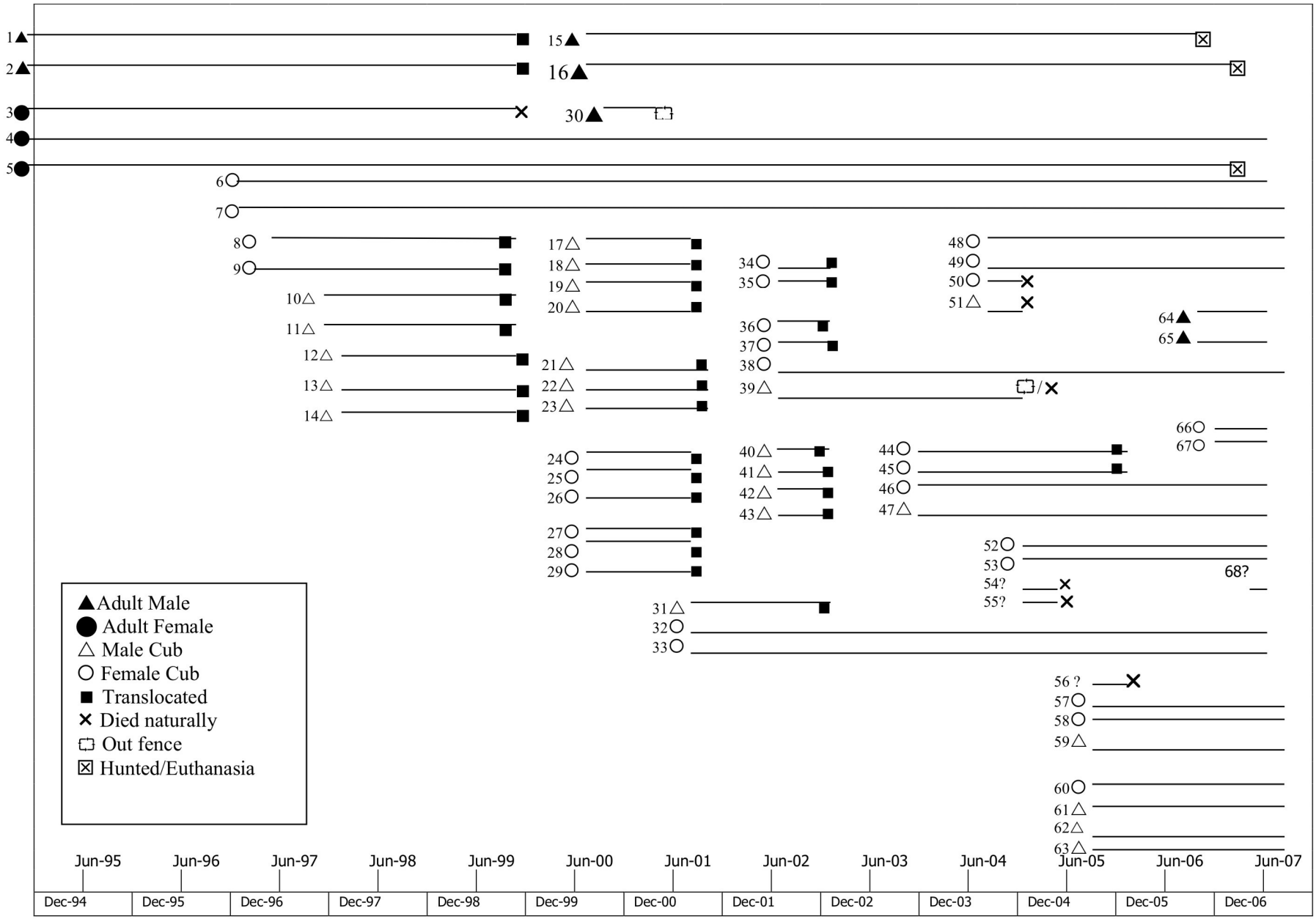

Figure 1: History of GMPGR lion population from April-05 to Dec-06. (Updated from Druce *et al.* 2004a)

Management Context

The GMPGR is made up of several privately owned properties, the internal fences of which have been removed. The reserve is governed by a voluntary organization constituted and incorporated with the objects and powers set forth in a constitution. Strict regulations are in place, which limit the amount of development. Income is provided through low impact eco-tourism, live game sales, and limited hunting, the quotas of which are arrived at scientifically. A single manager/warden implements the Board policies and strategies according to the reserve objectives.

The management aim of the GMPGR was largely to provide a low impact high-end tourist experience in a sustainable manner. Specific lion related objectives to achieve this were to maintain the adult lion population in the region of 8 individuals: the demography being as close as possible to a 2 adult male coalition, 6 adult females; and a mixture of 8 to 12 sub-adults and cubs (total lion population: 16 to 20). Tourists were able to see lions regularly on the 24 000 hectare reserve (Kettles *pers. obs*. 2006), and the pride had a good cross-section of adults, sub-adults and cubs. More importantly this number did not have a negative impact on prey species numbers (Druce *et al*. 2004a), and certain species numbers were actually marginally increasing (Table 1), indicating that the lion population was sustainable at those levels. In order to substantiate this, management removed 70 waterbuck, 211 impala, 34 kudu, 6 giraffe, 16 zebra, 16 blue wildebeest, 2 hippopotamus and 1 white rhino during this period. Furthermore, rainfall played no significant role. The GMPGR has a mean annual rainfall (MAR) of 450mm. During the period 2000 to 2006, the following rainfall was recorded: 2000/01 413mm (92% of MAR), 2001/02 561mm (125% of MAR), 2002/03 242mm (54% of MAR), 2004/04 613mm (136% of MAR), 2004/05 450mm (100 of mean MAR) and 2005/06 538mm (120% of mean annual rainfall).

Table 1: Prey species numbers on GMPGR in 2004 and 2006.

Species	2004	2006	Trend
Wildebeest	456	465	up
Bushbuck	67	84	up
Duiker	42	25	down
Eland	17	17	constant
Elephant	72	73	up
Giraffe	136	150	up
Hippo	17	13	down
Impala	1917	1743	down
Kudu	504	510	up
Nyala	32	50	up
Rhino	12	10	down
Steenbok	15	23	up
Warthog	459	478	up
Waterbuck	251	183	down
Zebra	531	542	up

Data source: ARC Annual Report (2006) to reserve management. Annual total count in August/September from helicopter with 2 observers.

Translocation

Translocation is the removal and re-introduction of game from one reserve to another by means of live game capture. New venues were sought; either directly or via game capture operators, which would host the lions which were aimed to be removed. These venues were usually newly established private game reserves hoping to increase their attraction to tourists by hosting members of the so called "Big Five" (Mbenga 2004). The capture of lions is a reasonably simple procedure as is evidenced in Table 2. The capture can be structured in a way so as to have little or no cost to the seller. The management of the GMPGR found best age at which lions may be captured for relocation was between 18 and 22 months. This is because lions are fully weaned by this age and male lions are usually expelled from the pride at this age. Lions at this age are also able to fend for themselves and are adaptable to new circumstances (Kettles *pers. obs* 2002). Captures were planned weeks in advance. Invariably, 3 days before the capture was scheduled, the lions' position on the reserve was established and their movement closely monitored to ensure that the capture would be executed efficiently and that as little time as possible was spent locating the lions. This significantly reduced the veterinary costs.

The live capture of lions on the GMPGR involved darting via a Dan-Inject® dart gun using 3ml darts, fired by qualified veterinarians. This system was found to be the most suitable, as the gun fires the dart by means of compressed air, making the dart delivery reasonably quiet. It was noted that the noise from dart guns fired by means of a .22 calibre blank often alarmed the lions, causing them to scatter. The selected lions were darted from the back of a four-wheel drive vehicle, and depending on whether lions were darted during the day or night, Zoletol or a cocktail of Nedetomidine and Ketamine were used as an anaesthetic. Nedetomidine and Ketamine can be reversed by injecting the lions with Atipamezole. Zoletil cannot be reversed (Rogers *pers. comm.* 2007). Zoletil® was normally used at night when it was cooler, as it tends to affect the animal's ability to thermo-regulate, which could lead to hyperthermia during the hot daylight hours. The capture and transportation of lions has already been described by McKenzie and Burroughs (1993).

For each translocation, the following data were collected: age and sex of the group, ease of capture, costs of relocation, destination of lions, which other lions the captured lion associated with at the time of capture, and whether or not any income was generated from the relocation. Ease of capture was classified according to a subjective scale of (1) being very easy to (5) being very difficult. The criteria used for this scale was: ease of locating targeted animals, density of the bush (thick bush makes darting difficult, while open areas make the process easier), behaviour of the lions (were they skittish, mobile or relaxed?), and the time of day/weather (cool weather results in fewer complications with the anaesthetic; and lions tend to be more mobile at night; anaesthetized lions are harder to locate at night and the risk is high of walking into unanaesthetized lions while looking for anaesthetized lions), and whether or not lions responded to call up recording or bait.

The location of the selected lions was established before the arrival of the veterinarian who would administer the anesthetic. This would be done by means of traditional tracking (none of the GMPGR lions were fitted with telemetry equipment). Once the lions were located, they were attracted to more accessible locations by playing recordings of either lions at a kill or warthog distress calls. Recordings of adult male lion vocalizations were played on three or four occasions and in all cases,

scared away the lions of our young target group. When lions had not recently fed, bait in the form of an impala or warthog carcass was offered to the lions in order to keep them in a specific accessible area. When the lions were found feeding on a kill they had made, this simplified the capture process. The movements and behaviour of the remaining pride (those not captured) were monitored for 7 days following the capture.

Contraception

Deslorelin as a contraceptive has been successfully used in other wild carnivores in southern Africa including cheetahs, African wild dogs and leopards (Bertschinger *et al.* 2001a).

The decision to apply contraception was aimed not at stopping all the lionesses from breeding, but rather at slowing down their rate of breeding by administering the contraceptive GnRH analogue deslorelin (Bertschinger *et al.* 2001b) to selected females on a rotational basis. The remaining females were allowed to breed as per normal. Management decided to follow this route, as a pride without any cubs or sub-adults is unnatural, and this could possibly lead to behaviour abnormalities. Furthermore, the presence of juvenile and infant cubs is an important draw card for tourists.

Deslorelin works by blocking the hormone GnRH secreted by the pituitary gland, which controls the oestrus cyclicity in cats. Thus, under this method, lions will not have an oestrus cycle (Bertschinger *et al.* 2001a). Administering GnRH analogue deslorelin involved anaesthetizing the lioness and inserting a slow-release implant subcutaneously in the neck region. The implant is cylindrical, approximately 2mm in diameter and 4mm in length. This renders the implant invisible and ensures that there is no irritation. The implant is effective for a period of 18 months (Bertschinger *et al.* 2001a), and monitoring has revealed that thereafter, the lionesses cycle normally, but will only conceive after their second or third cycle. Technically, the procedure is thus effective for 2 years (Bertschinger *et al.* 2001a).

Hunting

On the GMPGR, 2 male lions were hunted and the management objective was biological rather than financial. These 12-year-old lions were half brothers and formed the dominant coalition on the reserve, with tenure over the pride for 6.5 years. The average length of tenure for a male coalition seldom exceeds 3 years (Rudnai 1973b, Packer *et al.* 2005). The consequences of such a long tenure are that the males invariably mate with their female offspring, which from a genetic standpoint was undesirable. Individual lions were selected by management and made available to hunting outfitters who found suitable trophy hunters.

In order to make the hunts as ethical as possible, the first hunt took place while the males were separated in order to limit stress for the non-targeted lion. Furthermore, the hunts were conducted on foot and on both occasions, the hunter's shot was backed up by a shot from the professional hunter, ensuring a swift kill. No baits were used and hunts took place during the day.

Artificial Takeover

In the GMPGR, only 1 adult male coalition occurred at any one time, and natural takeovers were not possible. In order to ensure genetic variability and avoid inbreeding, male coalitions were replaced artificially through the removal of existing males and the introduction of a new coalition. Two artificial takeovers were implemented, one in 1999 and the other in 2006, when the 2 male coalition was removed, and new unrelated 2 male coalitions from different gene pools were introduced.

RESULTS

Translocation

Up until 2002, the GMPGR desired pride size was maintained by simply removing excess sub-adults once they had reached the age of 18 to 22 months, as they were at an age of being capable of fending for themselves. Thirty-five such lions were subsequently relocated to other game reserves (Table 2).

In all, 33 lions were moved in 12 different translocation operations (Table 2). The average group size was 2.75. All groups sold, with the exception of an 8 animals mixed group of 4 males and 4 females (sold 06/03/03) were single sex groups. This was as a result of the target animals being related, and the purchasers not wishing to have related founder groups established on their properties for genetic reasons. Six groups were translocated immediately after capture, while 6 were held in a boma for an average of 27 days prior to translocation. The ease of capture ranged from 1 to 5, the average being 2.83 (Table 2). The main criteria affecting ease of capture were thick bush, and groups that were mobile and unwilling to respond to recordings or bait. Most of the lions were sold to game reserves in the Kalahari. The translocated lions sold averaged an income of R7 143 per male and R7 000 per female. Two males were exchanged for another 2 males at no profit, while 4 females and 3 males were donated to other game reserves.

Table 2: History of lions translocated from the GMPGR to other game reserves.

Target Animal's ID	Approximate Age at relocation	Sex	Time/Date of Capture	Ease of Capture Index (1 very easy, 5 extremely difficult)	Destination	Cost	Income
1, 2	70 months	M x 2	Sold – 11/07/99	3	Kapama	0	Exchanged for 2 new males
8, 9	27 months	F x 2	08/99	2	Karongwe	0	0
10, 11	21 months	M x 2	09/99	1	Selati	0	R12 000
13, 14,15	21 months	M x 3	Boma - 22/07/99 Sold – 11/99	2	Free State	0	0
17, 18, 19, 20	17 months	M x 4	Boma - 09/07/01 Sold - 27/08/01	3	Kalahari	0	R24 000
21, 22, 23	17 months	M x 3	Boma – 11/08/01 Sold – 12/09/01	4	Kalahari	0	R22 000
24, 25	17 months	F x 2	Sold – 06/09/01	2	Kalahari	0	R16 000
26, 27, 28	16 months	F x 3	Boma – 11/08/01 Sold – 06/09/01	3	Kalahari	0	R24 000
29	16 months	F x 1	Boma – 28/08/01 Sold – 29/08/01	2	Kalahari	0	R8 000
31	21 months	M x 1	Boma – 08/03/03 Sold – 11/03/03	2	Kalahari	0	R10 000
34, 35, 36, 37	15 months	F x 4	Sold – 06/03/03	4	Kalahari	0	R24 000
40, 41, 42, 43	15 months	M x 4	Sold – 06/03/03	4	Kalahari	0	R32 000
44, 45	32 months	F x 2	Sold – 03/06	2	Kapama	0	0

Contraception

In all, the contraceptive was administered to 7 lionesses. In each instance, the procedure was successful in that the treated females did not mate or conceive within a 22-month period (Table 3).

The insertion of the GnRH analogue deslorelin implant itself was a straight forward procedure. The most difficult component of the operation, as with translocation, involved the actual location and anaesthetizing of the target animals.

Table 3: Summary of contracepted lionesses on the GMPGR.

Individual Number	Date of Contraception	Cubs born	Difficulty Index	Comments
4	28/07/02	3	4	No cubs since 2005. Too old to conceive now (14yrs).
6	27/03/03	0	3	No cubs born. Never observed mating.
	20/05/04		2	
7	26/03/03	0	2	No cubs born. Never observed mating
	20/05/04		2	
	13/02/07		1	
32	27/03/03	0	3	Currently pregnant. Expect cubs July 2007.
33	27/03/03		3	Did not conceive for 2 years. Lost litter of 2 to hyaenas in March 06. Sighted in 01/07 with 1 very young cub.
38	20/05/04	0	2	Was observed mating in May 2007.
59	13/02/07	0	1	Too soon to have results.

The contraception of lions at a first glance appears to be an expensive management intervention (Table 4). However, the costs of not applying contraception, in the form of loss of prey individuals through predation and challenges arising from over-population or inbreeding, outweigh the implementation costs by a wide margin.

Table 4: Summary of costs of lion contraception on the Greater Makalali Private Game Reserve

Average Group Size	Veterinary Fees @ R1300/hour	Veterinarian Travel Charges @ R9.00/km	Costs of Anaesthetic Per Lioness	Cost of GnRH Implant Per Lioness	Total Average cost per Lioness
2.25	R2600.00	R1260.00	R507.00	R560.00	R2189.70

Hunting

The two old dominant males were able to be removed without disrupting the behavioural and social dynamics of the remaining pride. The management intervention also brought in substantial revenue that could be reinvested into conservation initiatives. Furthermore, the removal of these lions allowed for the introduction of a new coalition, and in so doing, resulted in an artificial takeover, and unrelated genetic stock.

The two lions were hunted on two separate occasions, by two separate hunters. Management was fortunate in at the time of both the hunts, the targeted males were by themselves. Both were stalked on foot and shot cleanly. The fact that they were by themselves at the time they were hunted resulted in no disruption to the rest of the pride. From one week prior to each hunt, management monitored the movements of the lions in order to make the hunt as quick and efficient as possible. The first lion was observed approximately 1.5 hours before the arrival of the hunter at about 07h30. Upon his arrival, the lion was tracked on foot and was shot at 11h13. The second lion hunt proved to be more challenging in that the lion had moved from where he was last observed the day prior to the hunt. The lion was finally located at about 17h30, only 1 hour before sunset, and was immediately shot.

Artificial Takeover

The results from the 1999 introduction were exactly as would be expected from a takeover in an open system. Upon their release from the boma, the 2 new males sought out the female pride, asserted their dominance and killed all the cubs. What was not anticipated, however, was that the new males would kill the oldest and most dominant lioness, after actively seeking her for 1 week (see Druce *et al.* 2004a for details). This particular lioness was very old (approximately 14 years) and was probably at the end of her reproductive life anyway.

This exercise resulted in management being able to achieve their objectives of introducing new genes into the pride and of preventing the old males from breeding with their progeny. In addition, the resultant infanticide resulted in the population being reduced.

The behaviour of the lions in the 2006 introduction varied in that they established themselves in the eastern section of the reserve, and to date (July 2007) have not yet joined a pride (Kettles *pers. obs*. 2007). This is more than likely a result of them still being reasonably young (2.5 years old) and inexperienced (Kettles *pers. obs*. 2007). Although infanticide did not occur during this introduction, management's objective of reducing the population growth rate was met because these young males did not breed for at least six month to date. The introduction of these younger males was less disruptive to the pride than that of the older males.

The costs of both these introductions was negligible due to the fact that in the first instance, the lions that were removed were exchanged for another two lions and the deal was structured in such a way that the capture and relocation costs were borne by the other party. In the second introduction, the new males were donated to GMPGR, and the only cost was that of collecting them (approximately 900km @ R4.00/km – R3600.00).

DISCUSSION

Translocation proved to be both cost-effective and practical. Because lions were translocated young, their consumption of prey species was cumulatively relatively low. Furthermore, their size and weight simplified the capture and transportation operations. In each instance, the actual cost of the capture (veterinary fees and transport) was borne by the purchaser and the funds received from a sale were a nett amount, i.e. no other costs were applicable. In each instance it was negotiated that the risk of an animal dying due to veterinary complications became the purchaser's once the anaesthetising dart struck the lion. During the first 48 hours after the capture these animals tended to be elusive at their new destination, but soon settled down, displaying no avoidance behaviour or undue aggression towards vehicles or each other. No break-outs occurred.

At the time, these lions were readily sold to emerging game reserves wishing to re-introduce lions. During the past 6 years, however, it has become increasingly difficult to sell these lions as virtually all the other small, enclosed reserves also have excess lions, and the market has collapsed due to over-supply. Furthermore, the draft Department of Environmental Affairs and Tourism (DEAT) National Lion Management Policy forbids the selling of free-range lions to reserves smaller than 1000 hectares, or to lion breeders (De Klerk *pers comm.* 2007). This limits the market even further. Besides the above, the ethics of selling free-ranging lions to managers of small areas or breeding projects where the lions are kept in small enclosures is questionable. Tour operators or members of the press finding out that properties are supporting the 'canned lion hunting' industry can cause irreparable damage to a tourist venue via negative media publicity.

Contraception has become an accepted management tool on small protected areas. The main reasons for carnivore contraception in southern Africa are to

slow down the rate of breeding rather than to effect permanent sterilization (Bertschinger *et al*. 2001a), and to limit the use of more drastic population control measures such as culling. The earlier progesterone implants caused emasculation or sterility in lionesses (Bertschinger *et al.* 2001a). No such problems were observed with the deslorelin implants (Kettles *pers. obs* 2006).

To date, no behavioural or health related side-effects as a result of this form of contraception have been noted (Bertschinger *et al.* 2001a). During the period 1999 to 2007, a study by Bertschinger *et al* (2007) carried out over 150 treatments on at least 70 lionesses*,* all with no observed side effects. Successful programmes of a similar nature to this have been initiated on the Thornybush, Touchstone, Welgevonden and Mabula game reserves (Bertschinger *pers. comm*. 2006).

Using deslorelin achieves the objective of lowering the breeding rate, and reduces the challenge of selling live excess lions. Furthermore, because females will be administered contraceptives rotationally in the long term, the animals will all get to breed and live a reasonably natural life. The GnRH deslorelin implant offers a safe and reversible method of contraception in small numbers of captive and free-ranging wild carnivores. Repeated oestrus cycling of females, as seen with porcine zona pellucida (pZP) vaccine (Kirkpatrick *pers. comm*. 2000) and weight gains and increased incidence of uterine and mammary tumours or endometrial hyperplasia observed with progestogens implants (Munson & Mason 1991), appear unlikely with deslorelin treatment.

In South Africa, hunting has encouraged the conversion of land use from domestic livestock back to wildlife and in so doing has aided the re-establishment of certain endangered species (Thompson 2003). Hunting is also the mainstay of conservation in North America and Europe. If carried out ethically and quotas are determined scientifically, the hunting of adult lions appears to be an option in managing lion populations, considering the high

trophy price of these animals; up to R150 000. for a big maned male, and R30 000 for a female (Luyt *pers. comm*. 2006).

The hunting of lions is an emotive subject amongst the general public and owners/managers of lions should be made aware of the possible pitfalls. Properties reliant on tourism as a source of income could face boycotts or negative publicity from those tour operators who are not in favour of hunting. Management must also be cognizant to the fact that the hunting of male animals can only significantly reduce the overall population size when the rate of removal of males is so high that females can no longer be impregnated (Milner-Gulland 2003). Too frequent trophy hunting of males could also potentially cause male takeovers to become sufficiently common to prevent cubs from reaching adulthood as a result of frequent infanticide (Swenson 1997, Greene *et al.* 1998; Bertram 1975; Packer 2000). This can be avoided simply not hunting males younger than 5 or 6 years old. This allows younger males to have to opportunity to hold tenure over a pride long enough to rear a cohort of young (Whitman *et al*. 2004).

Careful consideration should be given to hunting lions if the motivation for doing so is purely financial. A male is only recognized as being a trophy at the age of 5-6 years (Grobler 1997, Whitman *et al.* 2004), and by this time he has already consumed prey that in financial terms far outweighs what he can be sold for (Kettles *pers. obs*. 2006). Based on Power's observation that the average male lion eats 6.5kg/day (2002), a lion would have eaten in excess of 11 000kg of meat by the time he was 5 years old. Assuming that the game the lion has eaten is worth an average of R20/kg, this amounts to R220 000. A lioness would eat 1.5 times less, but the figures would still not make trophy hunting viable.

Adult male lions are sold live for anything between R20 000 and R100 000 while adult females are sold live for between R3 000 and R9 000 (Van Altena *pers. com. 2007*). The truth is that the vast majority of these lions end up

being hunted at their new destinations anyway, at a large profit to the new owners.

The decision to hunt lions on GMPGR was based on biological rather than financial objectives. This was further constrained by social and political issues such as tourist sensitivity and government regulations. Hunting on the GMPGR was a profitable management intervention.

Providing new venues are available for excess lions, translocation appears to be the most cost effective and simple to implement management intervention. However venues for translocated lions are becoming increasingly scarce. As a result, the management of many protected areas are now willing to donate excess lions to venues willing to accept them. In time to come even the donation of lions will become an unlikely option due to supply superceding demand (Kettles *pers. obs.* 2007).

Artificial takeovers were easy to implement, but should be viewed more as a method of introducing new genes into a population than in reducing population size. When infanticide took place population growth was reduced only for a very short period, as lionesses came into oestrus a few days after loosing cubs, and the gestation period is relatively short (3.5 months). This will result in the cubs being replaced within about 4 months (Kettles *pers. obs.* 2006). Trophy hunting is perfectly compatible with the strategy of artificial takeovers, as the lions needing to be removed are invariably old, and thus have the highest trophy value.

Each of the interventions discussed have their individual merits, and they should all be considered for implementation as lion populations are capable of growing at an alarming rate.

Table 5: Comparison of Effectiveness of Various Management Interventions.

Intervention	Cost	Ease of Implementation Index (1 – 5)	Efficacy: Short-Term Population Size	Efficacy: Long-Term Population Size
Translocation	Positive	2.6	Good	Good
Contraception	Negative	3	Poor	Fair
Hunting	Positive	3	Good	Fair
Artificial Takeover	Positive	2	Good	Poor

This assessment has revealed that a wide range of practical or technological interventions for lion management are available to wildlife practitioners. As long as the interventions are well planned and executed with the help of suitably qualified professionals (including veterinary supervision), there appear to be few constraints that will hinder a manager in choosing an appropriate intervention to assist in achieving objectives. The issues appear to be influences resulting from societal values (such as aversion to hunting) or extremely manipulative interventions (such as contraception) rather than biological or technological influences. When applying any of these interventions, perhaps the most important challenge, therefore, is striking a balance between social issues and the attainment of biological objectives.

References:

BERTRAM, B. 1975. *Social Factors Influencing Reproduction in Wild Lions.* Journal of Zoology 177: 463-482

BERTSCHINGER, H.J, TRIGG, W, JOCHLE, W, & HUMAN, A. 2001a. *Induction of contraception in some African wild carnivores by down regulation of LH and FSH secretion using the GnRH analogue deslorelin.* Journal of Reproduction. 60: 41-52

BERTSHINGER, H.J., ASA, C.S., CALLE, P.P., LONG, J.A., BAUMAN, K., DeMATTEO, K., JOCHLE, W., TRIGG, T.E. and HUMAN, A. 2001b. *Control of reproduction and sex related behaviour in exotic wild carnivores with the GnRH analogue deslorelin: preliminary observations.* Journal of Reproduction and Fertility: 57: 275-283

BERTSCHINGER, H., DE BARROS VAZ GUIMARÃES, M., TRIGG, T. & HUMAN, A. 2007. *The use of deslorelin implants for the long-term contraception of free-ranging and captive lionesses.* Proceedings from the 6th International Conference on Fertility Control for Wildlife. York. United Kingdom

DRUCE, D. 2000. *Factors Affecting Millipede, Centipede and Scorpion Diversity in a Savannah Environment*, MSc Thesis, University of Natal, Durban.

DRUCE, D., GENIS, H., BRAAH, J., GREATWOOD, S., DELSINK, A., KETTLES, R., PACKER, C., HUNTER, L., & SLOTOW, R. 2004a. *Prey Selection by a Reintroduced Lion Population in the Greater Makalali Conservancy, South Africa.* African Zoology. 39: 273-284.

DRUCE, D. GENIS, H., BRAAH, J., GREATWOOD, S., DELSINK, A., KETTLES, R., PACKER, C., HUNTER, L., & SLOTOW, R. 2004b.

Population demography and spatial ecology of a reintroduced lion population in The Greater Makalali Conservancy, South Africa. Koedoe. 47: 103- 117.

GREENE, C., UMBANHOWAR, J., MANGEL, M., CARO, T. 1998. *Behavioral Ecology and Conservation Biology.* Oxford University Press, Oxford.

GROBLER, D. 1997. *Trophy Hunting Potential for Large Cats in South Africa.* In: J. VAN HEERDEN (Ed.) Proceedings of a symposium on lions and leopards as game

GUGGISBERG, C. 1975. *Wild cats of the World.* London. David & Charles.

HEDRICK, P.W., and MILLER, P.S. 1992. *Conservation Genetics: Techniques and Fundamentals.* Ecological Applications 2: 30-46.

HUNTER, L. 1999. *The Socio-ecology of Re-introduced lions in Small Reserves: Comparisons with Established Populations and the Implications for Management in Enclosed Conservation Areas.* Preliminary Project Report. Biology Department. University of Natal.

HUNTER, L. 2001. *Tooth and Claw. The Future of Africa's Magnificent Cats.* Africa Geographic, June 2001. Cape Town. Hirt & Carter.

Hunter, L., Skinner, J.D., Pretorius, K., Carlisle, L.C., Rickleton, M., Walker, C., & Slotow, R. 2007. *Reintroducing lions Panthera leo to northern Kwazulu-Natal, South Africa: short-term biological and technical successes but equivocal long-term conservation. Oryx* 41: 196-204

LOW, A.B. & REBELO, A.G. 1996. *Vegetation of South Africa, Lesotho and Swaziland.* Department of Environmental Affairs and Tourism, Pretoria.

MBENGA, E. 2004. *Visitor Wildlife Viewing Preferences and Experiences in Madikwe Game Reserve, South Africa.* M. EnDev. Thesis. University of KwaZulu-Natal. Pietermaritzburg.

McKENZIE, A.A. (ed). 1993. *The Capture and Care Manual.* Pretoria. Wildlife Decision Support Services.

McKENZIE, A.A. & BURROUHJS, R.E.J. 1993. *The Chemical Capture of Carnivores*. In: McKenzie, A.A. (ed). The Capture and Care Manual. Pretoria. Wildlife Decision Support Services.

MILNER-GULLAND, E.J. 2003. *Reproductive Collapse in Saiga Antelope Harems.* Nature. 422: 135.

MILLS, M.G.L., & SHENK, T.M. 1992. *Predator- Prey Relationships: The Impact of Lion Predation on Wildebeest and Zebra Populations*. Journal of Animal Ecology 61: 693–702.

NEWMARK, W.D. 1996. *Insularization of Tanzanian Parks and the Local Extinction of Large Mammals*. Conservation Biology 10: 1549-1556.

PACKER, C., PURSEY, A. 1984. *Infanticide in carnivores.* Infanticide in animals and man. (ed. Hansfuter G & Blaffer-Hardy S). 31-44. New York. Aldine.

PACKER, C., PUSEY, A. 1987. *The evolution of sex biased dispersal in lions*. Behaviour. 101: 275-310

PACKER, C., HERST, L., PUSEY, A., BYGOTT, J., HANBY, J., CAIRNS, S., BORGERHOFF, M. 1988. *Reproductive success of lions*. T.H.

Clutten-Brock, ed. Chicago. Reproductive success. P363-383. University of Chicago Press

PACKER, C., GILBERT, D., PUSEY, A., BYGOTT, J., O BRIEN, S. 1991. *A molecular genetic analysis of kinship and cooperation in African lions.* Nature. 351: p562-565.

PACKER, C. 2000. *Infanticide is no fantasy*. Am. Anthropol. 102: 829-831.

PACKER, C., HILBORN, R., MOSSER, A., KISSUI, B., BORNER, M., HOPCRAFT, G., WILSHURST, J., MDUMA, S., SINCLAIR, A. 2005. *Ecological Change, Group Territoriality, and Population Dynamics in Serengeti Lions.* Science. 307: 390.

POWER, R. 2002. *Evaluating how many lions a small reserve can sustain.* South African Journal of Wildlife Research. 33(1): 3-11.

PRESSEY, R.L. 1996. *Protected Area: Where Should They Be and Why should They Be There?* I.F. Spellerberg (ed). Conservation Biology. p. 171 -185. Longman Group Limited. Essex.

RUDNAI, J. 1973. *Reproductive biology of lions (Panthera leo* Massaica Neumann) in Nairobi National Park. East African Wildlife Journal. 11: 241-253.

STANDER, P. 1991. *Demography of lions in the Etosha National Park*. Madoqua. 18: 1-9.

STEELE, N. 1970. *A Preliminary Report for the Study Into The Lion Population of Hluhluwe-Umfolozi Park*. Lamergeyer11:68-79

THOMPSON, R. 2003. *A Game Warden's Report.* Hartebeespoort, South Africa. Magron Publishers.

VAN DYK, G. 1997. *Reintroduction techniques for lion Panthera leo*. In: J. VAN HEERDEN (Ed.) Proceedings of a symposium on lions and leopards as game ranch animals pp82-91. Onderstepoort, Pretoria. Wildlife Group of the South African Veterinary Association.

SWENSON, J.E. 1997. *Infanticide Caused by Male Bears.* Nature 386: 450-451.

VARTAN, S. 2001. *Overpopulation and Inbreeding in Small Game Reserves: the Lion Panthera Leo as a Case Study.* MSc thesis, University of Cape Town, Rondebosch, South Africa.

WHITMAN, K., STARFIELD, H., QUADLING, S., PACKER, C. 2004. *Sustainable trophy hunting of African lions.* Nature. Published online: doi:10.1038/nature02395.

Personal communication

BERTSHINGER, H.J. 2006. Wildlife Gynaecologist. University of Pretoria.

DE KLERK, D. Extension Officer. Department of Environmental Affairs & Tourism. Phalaborwa. South Africa.

KIRKPATRICK, J. 2000. Reproductive Biologist. ZooMontana, Montana. USA.

PEEL, M. 2007. Ecologist. Agricultural Research Council. Nelspruit. South Africa.

ROGERS. P. 2006, 2007. Wildlife Veterinarian. Provet Wildlife Services. Hoedspruit. South Africa.

SLOTOW. R. 2007. School of Biological & Conservation Sciences, George Campbell Building, University of KwaZulu-Natal, Durban, 4041, South Africa.

VAN ALTENA, J. 2007. Wildlife Capture Expert. Catchco Africa. Pretoria. South Africa.