The reintroduction of large carnivores to the Eastern Cape, South Africa: an assessment

M.W. Hayward, John Adendorff, John O'Brien, Angus Sholto-Douglas, Charlene Bissett, Lucius C. Moolman, Peter Bean, Alan Fogarty, Dale Howarth, Richard Slater and Graham I.H. Kerley

Abstract Recently, conservation estate in South Africa's Eastern Cape Province has increased 10-fold resulting in large predators being increasingly reintroduced to restore ecological integrity and maximize tourism. We describe the reintroductions of large carnivores (>10 kg) that have occurred in the Eastern Cape and use various criteria to assess their success. Lion *Panthera leo* reintroduction has been highly successful with a population of 56 currently extant in the region and problems of overpopulation arising. The African wild dog *Lycaon pictus* population has increased to 24 from a founder population of 11. Preliminary results for spotted hyaenas *Crocuta crocuta* also indicate success. Wild populations of leopards *Panthera pardus* exist on several reserves and have been supplemented by translocated individuals, although deaths of known individuals have occurred and no estimate of reproduction is available. Cheetah *Acinonyx jubatus* reintroduction has also been less successful with 36 individuals reintroduced and 23 cubs being born but only 41 individuals surviving in 2005. Criteria for assessing the success of reintroductions of species that naturally occur in low densities, such as top predators, generally have limited value. Carrying capacity for large predators is unknown and continued monitoring and intensive management will be necessary in enclosed, and possibly all, conservation areas in the Eastern Cape to ensure conservation success.

Keywords *Acinonyx jubatus*, carnivores, *Crocuta crocuta*, Eastern Cape, *Lycaon pictus*, management, *Panthera leo*, *Panthera pardus*, reintroduction, South Africa.

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Introduction

Breitenmoser *et al.* (2001) lamented the dearth of published studies documenting the reintroduction of large predators in Africa; in 30 large carnivore reintroductions reported from Africa where the final outcome was known only nine were considered successful. However, many more translocations of large predators have occurred in Africa and this lack of published information is not a result of a lack of translocations but rather that conservation managers have been busy implementing translocations rather than writing about them.

The translocation of large carnivores is common (Rowe-Rowe, 1992; Hofmeyr & van Dyk, 1998; Hofmeyr *et al.*, 2003) yet post-release monitoring has rarely occurred and, where it has, the results suggest a low success rate with the causes of failures poorly understood (Hunter, 1998a). This has led several authors to conclude that the factors affecting translocation success of large carnivores are too poorly understood to justify this as a conservation strategy (Wemmer & Sunquist, 1988; Mills, 1991). Carnivore reintroductions are considered fundamentally more difficult than those of herbivores or omnivores (Griffith *et al.*, 1989).

Here we document the large, terrestrial predator reintroductions that have recently occurred in South Africa's Eastern Cape Province (Fig. 1). We define large

Matt W. Hayward (Corresponding author) and **Graham I.H. Kerley** Centre for African Conservation Ecology, Department of Zoology, Nelson Mandela Metropolitan University, PO Box 77000, Port Elizabeth, 6031, Eastern Cape, South Africa. E-mail hayers111@aol.com

John Adendorff and **Lucius C. Moolman** Addo Elephant National Park, PO Box 52, Addo, 6105, Eastern Cape, South Africa.

John O'Brien Shamwari Game Reserve, PO Box 91, Paterson, 6130, and Rhodes University, Grahamstown, Eastern Cape, South Africa.

Angus Sholto-Douglas and **Charlene Bissett** Kwandwe Game Reserve, PO Box 448, Grahamstown, 6140, Eastern Cape, South Africa.

Peter Bean Scotia Safaris, Paterson, 6130, Eastern Cape, South Africa.

Alan Fogarty Kariega Game Reserve, PO Box 13900, Humewood, 6013, Eastern Cape, South Africa.

Dale Howarth Pumba Private Game Reserve, 29-10th Avenue, Walmer, 6070, Eastern Cape, South Africa.

Richard Slater Samara Game Reserve, Graaff Reinet, South Africa.

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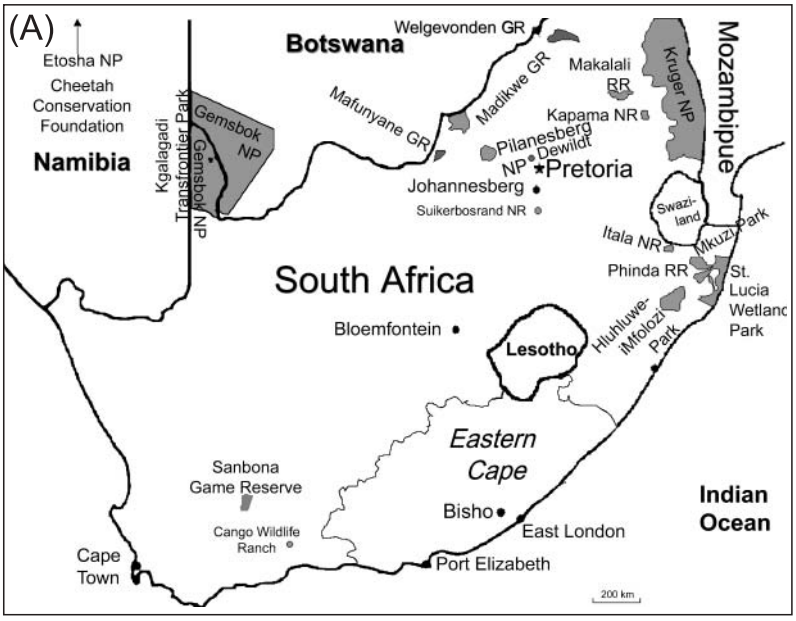

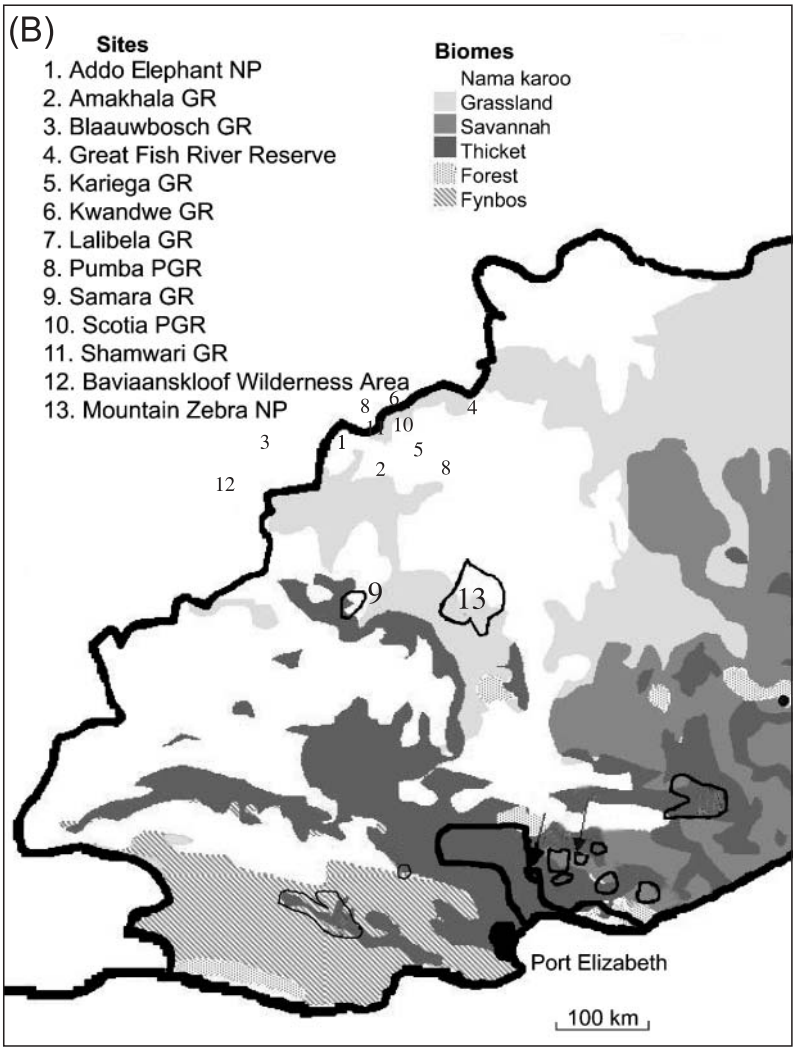

Fig. 1 (A) South Africa showing the location of the conservation areas mentioned in the text; Makalali RR includes Karongwe NR. (B) The Eastern Cape Province with the location of 13 conservation areas mentioned in the text (descriptions of 1–11 are given in Table 1) and biomes (adapted from Low & Rebelo, 1996). NP, National Park; GR, Game Reserve; PGR, Private Game Reserve; RR, Resource Reserve.

predators as those >10 kg, reintroduction as an attempt to establish a species within its historical range but where it has since been extirpated, and translocation as deliberate movement of wild individuals between parts of their range (IUCN, 1998). Given the global problem of large carnivore decline (Weber & Rabinowitz, 1996) documenting the results of such attempts is crucial for future conservation management.

Historical distribution of large predators

Large predators originally present in the Eastern Cape (with any current global IUCN Red List status; IUCN, 2006) were the black-backed jackal *Canis mesomelas*, African wild dog *Lycaon pictus* (Endangered), spotted hyaena *Crocuta crocuta* (Lower Risk: conservation dependent), brown hyaena *Hyaena brunnea* (Lower Risk: near threatened), aardwolf *Proteles cristatus*, honey badger *Mellivora capensis*, cheetah *Acinonyx jubatus* (Vulnerable), leopard *Panthera pardus*, lion *Panthera leo* (Vulnerable), serval *Leptailurus serval*, and caracal *Caracal caracal* (Skead, 1987). It is these species to which this review specifically relates.

Historically, black-backed jackals and honey badgers were ubiquitous throughout South Africa and they are still common. African wild dogs were recorded throughout the Eastern Cape (Skead, 1987) but the only extant populations in South Africa, prior to the reintroductions reported here, were in the north and north-east (Stuart, 1981). Although there are no historical records of brown hyaenas from the Eastern Cape, vagrants still entered the region between 1924 and the 1960s and were considered to have occurred throughout the drier regions of southern Africa (Skead, 1987) although they no longer occur in the Eastern Cape (Stuart, 1981). The spotted hyaena is also poorly documented historically but the few available records suggest it also occurred throughout the Eastern Cape (Skead, 1987). The few historical references to the aardwolf suggest it occurred throughout the Eastern Cape, albeit at low densities (Skead, 1987) and today it remains widespread.

Population estimates in 1996 suggested 30,000–100,000 lions survived in Africa (Nowell & Jackson, 1996) but more precise estimates in 2001/2002 were of only 16,500–30,000 (Bauer & Van der Merwe, 2004). Lions disappeared from the western half of the Eastern Cape in the 1850s but they survived in the Transkei region until the 1870s (Skead, 1987). Viable populations of lions in South Africa currently only occur in the former Kalahari-Gemsbok National Park, which has 92–125 lions (Castley *et al.*, 2002) of the 452 present in the entire Kgalagadi ecosystem, and Kruger National Park, which supports 2,200 (Bauer & Van der Merwe, 2004).

Leopards occurred historically throughout the Eastern Cape but today they survive only in the more remote mountains and forests away from human habitation (Skead, 1987). The leopard's ability to tolerate habitat modification enables it to live close to man. The paucity of historical records of cheetah in the Eastern Cape suggests it was scarce when Europeans arrived and was restricted to the drier, open country inland (Skead, 1987). Reintroductions to the more mesic habitats of the Eastern Cape may be extralimital. The serval was almost extinct in the Eastern Cape in 1987 but historical documents record it all along the coastal and subcoastal belt (Skead, 1987). The caracal is still common throughout the Eastern Cape (Skead, 1987).

Reintroduction sites

The Eastern Cape Province is South Africa's poorest and recently large areas of pastoralism in marginal lands has given way to more economically viable game farming, ecotourism and conservation (Kerley & Boshoff, 1997). This alteration in land use led to numerous species being reintroduced to former domestic livestock farms, including large predators. Eleven conservation areas in the Eastern Cape have reintroduced large predators since 1996 (Fig. 1; Table 1) to restore ecological integrity, conserve threatened species and maximize ecotourism. Each of these reserves is fenced with predator-proof, electrified fencing, ensuring they can be managed as distinct ecological units. Each also had electrified bomas enabling a pre-release captivity period (soft release). At the time the lands were purchased they contained black-backed jackal, caracal, aardwolf and the occasional vagrant leopard and honey badger.

Reintroductions

Details of all reintroductions considered here are given in the Appendix. Lions were first introduced in the Eastern Cape in 1996 at Scotia (Fig. 2). These individuals all had the same father, but two different mothers, and were 15 months old upon release. They initially caught their own prey but, as the available prey dwindled, the managers began supplementary feeding. The first truly free-ranging lions in the Eastern Cape were reintroduced to Shamwari in September/October 2000, as were cheetahs. In 2001 leopards, brown hyaenas and serval were reintroduced to Shamwari. African wild dogs were first reintroduced into the Eastern Cape at Shamwari in 2003 (Fig. 3). The first spotted hyaenas were reintroduced to Addo in 2003 (Fig. 3). Thereafter, the increase in the number of game reserves led to a rapid increase in the number of predators being reintroduced and those founder populations breeding.

Table 1 Carnivore reintroduction sites in the Eastern Cape (numbers refer to locations in Fig. 1B), with area, year of creation, year of first carnivore reintroduction, habitat, previous land use, and any relevant comments.

Site[1]	Area (ha)	Year	Year of 1st reintroduction	Habitat[2]	Previous land use	Comments
1. Addo Elephant NP	13,400 main camp (300,000 entire park)	1931	2003	Thicket & transformed grassland	Agriculture	
2. Amakhala GR	5,000	1999	1999	Nama karoo, thicket & transformed grassland	Agriculture	
3. Blaauwbosch GR	4,500	2004	2004	Thicket & transformed grassland	Agriculture	
4. Great Fish River Complex	44,000		1985	Similar to Addo	Agriculture or undeveloped	A contiguous conservation unit along the banks of the Great Fish River encompassing the Andries Vosloo Kudu Reserve, Double Drift GR & Sam Knott Reserve, & is adjacent to Kwandwe.
5. Kariega GR	5,000	2001	2001	Thicket, forest & savannah	Agriculture or undeveloped	
6. Kwandwe GR	19,978	2001	2001	Thicket, Nama karoo & transformed grassland	Agriculture	
7. Lalibela GR	7,500	2002	2002	Thicket & transformed grassland	Agriculture	
8. Pumba PGR	6,500	2005	2005	Thicket & transformed grassland	Agriculture	
9. Samara PGR	28,000	1997	2001	Nama karoo & grassland	Agriculture	
10. Scotia GR	1,600	1996	1996	As for Addo	Agriculture	Adjoins SE edge of Addo, but has been free of elephant browsing for 50 years; lions kept in 600 ha enclosure & are supplementary fed
11. Shamwari GR	18,746	1994	2000	Nama karoo, thicket & transformed grassland	Agriculture	

[1]NP, National Park; GR, Game Reserve; PGR, Private Game Reserve
[2]From Vlok *et al.* (2003)

Scotia's lions first bred at 36 months of age in 1999 and thrice since (Fig. 2). Shamwari's lions also first bred at 36 months and, by 2005, 18 cubs had been born. Kwandwe's lions trebled to 12, 4 years after reintroduction. Lions were released as two prides in Addo in September 2003. The unusual sex ratio of the founder population (four males and two females) was selected by managers to slow the potential population increase through infanticide by competing male coalitions. This was successful and by the end of 2005 four litters had been born although only three cubs of the last litter survive. Lalibela's lions have produced cubs but an adult male was removed after four giraffe *Giraffe camelopardalis* were killed by the male coalition. Kariega's lionesses were injected with contraceptives to facilitate settling into the new area by minimizing

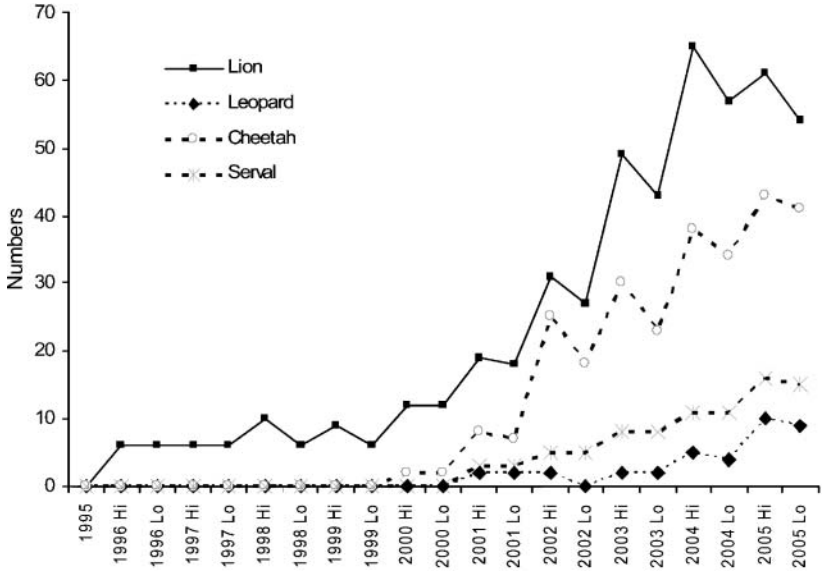

Fig. 2 Changes in total numbers of lion, leopard, cheetah and serval in Eastern Cape reserves following reintroduction in 1996. Hi relates to the peak in population size that year and Lo the lowest.

aggression and restricting breeding. Pumba released their 4-year old lions in 2004 and a captive-bred male and two female white lions in 2006.

Shamwari's first cheetahs were supplemented in 2002 and 2003 (Fig. 2). Cubs were born in 2005 that partially compensated for the deaths of two adults in 2004. Kwandwe had cheetahs when opened and these were supplemented in 2003 and with cubs in 2002 and 2004. Kwandwe's cheetahs have suffered a high mortality rate with five being killed by lions, three being killed by the male cheetah coalition and one dying of unknown causes (Fig. 4). Several other sites have reintroduced cheetahs.

Wild caught and rehabilitated leopards have been reintroduced to Shamwari, Kwandwe, Pumba, and Fish River but, because of monitoring difficulties, the population in the Eastern Cape reserves is unknown (Fig. 2). A young, adult male leopard was reintroduced to the Main Camp section of Addo in 2004 and a female followed in March 2006 (Hayward *et al.*, 2007). Other sections of Addo also support leopard populations; fishermen in the Woody Cape section reported being stalked by a leopard on the beach (A. Padayachee, pers. comm.), and kills and spoor attributable to leopards have been reported in the Nyathi, Zuurberg, Kabouga

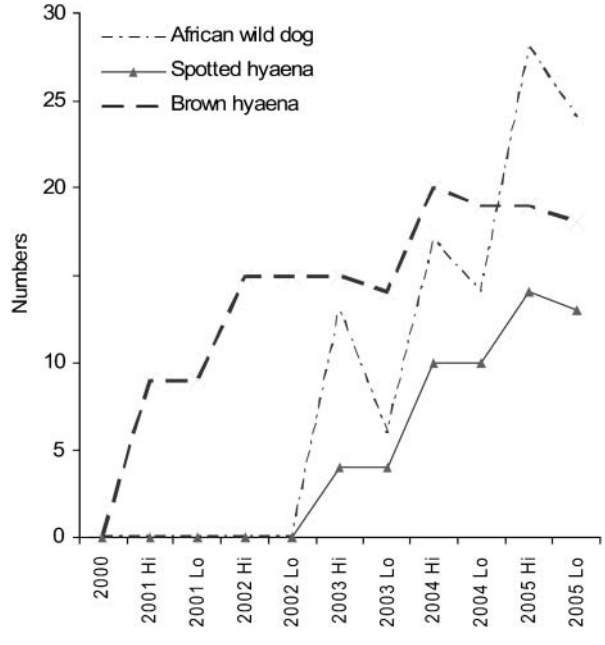

Fig. 3 Changes in numbers of African wild dogs and spotted and brown hyaenas in Eastern Cape reserves following reintroduction in 2001. Hi relates to the peak in population size that year and Lo the lowest.

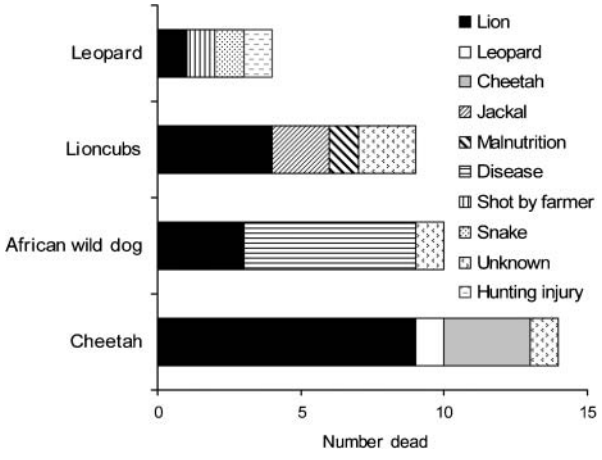

Fig. 4 Causes of mortality of reintroduced predators in the Eastern Cape.

and Darlington sections of the Park. Wild leopards have also been observed at Blaauwbosch.

Shamwari's reintroduced servals have only occasionally been sighted, although a population still persists in the reserve (Fig. 2). Similarly, at least one of the servals released into Kwandwe escaped and the existing population size is unknown. Servals have been observed on farms adjacent to the eastern boundary of Addo Main Camp in 2000 and 2005.

Shamwari's brown hyaenas have only been occasionally observed but the 2004 estimate (15) indicates their numbers have increased (Fig. 3). The current size of Kwandwe's brown hyaena population is unknown. Individual brown hyaenas have also been reintroduced *ad hoc* to the Great Fish River Complex. They are still sighted although monitoring has not been conducted and the current population is unknown. Addo released two separate clans of spotted hyaenas that have produced several cubs. Pumba and Kariega also have spotted hyaenas.

African wild dogs reintroduced to Shamwari have undergone regular increases, with the birth of each litter followed by subsequent declines as many of the pups died (Fig. 3). Kwandwe released a pack of African wild dogs that bred in 2005. Aardwolf, caracal and black-backed jackal still occur on each of the studied reserves and have not been reintroduced.

Further reintroductions are planned in the Eastern Cape. Cheetahs are to be released into the Mountain Zebra National Park and the Darlington section of Addo in 2007. African wild dogs will also be released into Darlington in 2007. Contractual agreements between South African National Parks and private concessionaires mean lions are required to be released to the Nyathi and Darlington sections of Addo when adequate prey densities are attained. Amakhala currently has three lions and three spotted hyaenas in bomas awaiting approval for release. The Great Fish River Complex is also planning to reintroduce spotted hyaenas soon.

Carnivore populations in 2005

Lions have been the most successful species reintroduced to the Eastern Cape (Fig. 2). The population of lions in 2005 was 56 individuals, with 35 reintroduced and 49 cubs known to have been born. The African wild dog population doubled to 24 in 2005, from 11 founders and 27 pups. Cheetah reintroductions have been less successful, with 36 reintroduced and at least 23 cubs born, but only 41 surviving by 2005. Spotted hyaenas have only been present in the Eastern Cape for 2 years but their numbers have increased to 13 with the birth of two cubs. Brown hyaenas have been poorly monitored but the 2005 population in the Eastern Cape reserves was at least 18. There have been no records of leopard cubs, although mating has been observed at Shamwari. The ability of this secretive species to persist despite human persecution (Skead, 1987; Hayward *et al.*, 2005) suggests populations are at least stable in the Eastern Cape conservation areas, with nine having been reintroduced.

Reproduction and mortality

Reproductive rates observed in the Eastern Cape are equivalent to other reintroduced carnivore populations in Africa. In Phinda Private Game Reserve 7.2 lion cubs and 8.0 cheetah cubs were born per year for the first 6 years following reintroduction (Hunter, 1998b). In the Eastern Cape lions have produced either 4.7 or 7.3 cubs per year after release (excluding and including the Scotia lions) and cheetahs have produced 5.8 cubs per year.

Cheetahs have suffered the highest mortality since reintroductions began (14 recorded mortalities from 41 individuals; Fig. 4). Wild dog mortality has also been high (10 deaths from 24 individuals; Fig. 4), although these mostly arose through disease (with diarrhoea presenting as a symptom) affecting pups. Only two adult lions have died since reintroductions began, and lions have been the cause of most deaths of other species (17 of 37; Fig. 4).

There was a strong linear relationship ($y = 2.26x - 0.56$, $n = 7$, $r^2 = 0.88$) between the female:male ratio of founding lion populations and the overall rate of increase at a site, although this is not significant ($0.20 < P < 0.50$). This relationship was not related to the size of the founder population but was caused by the effect of the sex ratio on the reproductive success of lionesses. Although there were no differences in the number of litters born between sites with male biased sex ratios and those at parity or more female biased (Mann-Whitney $U = 0.289$, $df = 1$, $P = 0.767$), male biased sites had fewer cubs born or surviving to adulthood, although these differences were not significant ($U = -1.73$, $df = 1$, $P = 0.083$).

There was a strong linear relationship ($y = 0.02x - 0.02$, $n = 9$, $r^2 = 0.56$) between lion population density and cheetah annual adult mortality rate, although this was not significant ($P = 0.09$). Density-dependent factors may limit cheetah populations in the presence of lions and spotted hyaena and this may be the cause of the inherent rarity of cheetahs in intact ecosystems.

Discussion

There are a variety of ways to define successful reintroductions (Table 2) but the applicability of the

Table 2 Criteria and assessment of the success of the large carnivore reintroductions to 11 sites (Table 1) in the Eastern Cape. S, success; F, failure; U, uncertain at this stage due to inadequate monitoring or insufficient time lapsed since reintroduction took place to assess success.

Definition of success	1. Breeding by 1st wild born generation[1]	2. 3-year breeding population with natural recruitment > death rate[1]	3. Unsupported population of ⩾500[1]	4. Self-sustaining population[1]	5. Red List status
Addo					
Leopard	F	F	F	F	F
Lion	U	U	F	F	F
Spotted hyaena	U	S	F	F	F
Amakhala					
Cheetah	U	U	F	F	F
Blaauwbosch					
Cheetah	S	S	F	F	F
Fish River					
Brown hyaena	S	S	F	F	F
Leopard	U	U	F	F	F
Kariega					
Lion	U	U	F	F	F
Spotted hyaena	U	U	F	F	F
Kwandwe					
Brown hyaena	U	U	F	F	F
Cheetah	U	S	F	F	F
Leopard	U	U	F	F	F
Lion	U	S	F	F	F
Serval	U	U	F	F	F
African wild dog	U	S	F	F	F
Lalibela					
Cheetah	F	F	F	F	F
Lion	U	S	F	F	F
Pumba					
Leopard	U	U	F	F	F
Lion	U	U	F	F	F
Spotted hyaena	U	U	F	F	F
Samara					
Cheetah	S	S	F	F	F
Scotia					
Lion	S	S	F	F	F
Shamwari					
Brown hyaena	U	S	F	F	F
Cheetah	F	F	F	F	F
Leopard	U	F	F	F	F
Lion	S	S	F	F	F
Serval	U	U	F	F	F
African wild dog	U	S	F	F	F

[1]Griffith *et al.*, 1989

[2]Where a species categorized locally as Critically Endangered according to IUCN Red List criteria (IUCN, 2001), as are all the species here, is regarded as a reintroduction failure, Endangered as uncertain, and vulnerable or more secure as a success (Breitenmoser *et al.*, 2001).

definitions varies with a species' life history, and they are limited by time (Seddon, 1999) and the carrying capacity of the reintroduction site. Several of the definitions cannot apply to small, isolated populations of large predators. The length of time since reintroductions began limits the number of sites that can be defined as successful with breeding by the first wild-born generation (Definition 1). Given there are few extant populations of large carnivores >500 individuals anywhere (Nowell & Jackson, 1996), Definition 3 seems unrealistic. Similarly, the IUCN Vulnerable category (Definition 5) requires >1,000 mature individuals (IUCN, 2001) and therefore few individual sites could ever satisfy this criterion. It is too early to determine whether the Eastern Cape populations are self-sustaining (Definition 4) as this can only be determined retrospectively. The most realistic definition of success for the Eastern Cape reserves is a 3-year breeding population with recruitment exceeding adult death rate (Definition 2). Overall, by this definition, the reintroduction of large predators in the Eastern Cape appears successful (Table 3). Young

Table 3 Assessment of the overall success of the large carnivore reintroductions in the Eastern Cape. S, success; F, failure; U, uncertain at this stage because of inadequate monitoring or insufficient time lapsed since reintroduction took place to assess success.

Definition of success (Table 2)	Lion	Cheetah	Leopard	Serval	Wild dog	Spotted hyaena	Brown hyaena
1	S	S	U	U	U	S	S
2	S	S	U	U	S	S	S
3	F	F	F	F	F	F	F
4	F	F	F	F	F	F	F
5	F	F	F	F	F	F	F

have been observed for all reintroduced species except leopard, and all species have increased from the number initially reintroduced.

Lions have rapidly become over abundant, suggesting that competitively dominant carnivores are more resilient to the reintroduction process than more threatened species because they are free from competitive persecution. Only lions exceed the 50 breeding individuals considered necessary to protect from genetic problems (Frankham, 2005), and continued population mixing will be essential for the long-term conservation of all species of reintroduced carnivore. The Shamwari and Kwandwe lion reintroductions are successful (Table 2). The six lions in Addo have been unable to raise successfully three of the four litters born and so must tentatively be described as unsuccessful. However, given the original aim of having a slow population increase this may also eventually be classed as a success. It is too early to evaluate the success of the other lion reintroductions.

Wild dog reintroductions appear successful (Table 2). It has been suggested that areas $<$1,000 km^2 were too small to conserve African wild dog populations and would lead to dogs ranging beyond reserve boundaries and suffering persecution (Woodroffe & Ginsberg, 1997). Wild dogs are difficult to translocate due to their complex social interactions and susceptibility to domestic dog diseases (Hofmeyr *et al.*, 2003) but they have been successfully reintroduced to Madikwe Game Reserve (550 km^2) and Pilanesberg National Park (500 km^2). The issue of the African wild dog's ranging behaviour beyond reserves is alleviated when they are contained within fenced reserves.

Spotted hyaenas are difficult to reintroduce and releasing two or three clans simultaneously has previously been recommended to avoid mortalities resulting from agonistic encounters, as seen at Madikwe (Hofmeyr *et al.*, 2003). The reintroduction into Addo, despite reintroducing two clans sequentially, may have been successful because a stronger clan (i.e. more adult females) was released after the first clan.

Reintroductions of cheetah have been less successful when dominant predators are present. At Blaauwbosch and Samara cheetah increased in the absence of threats from lions and/or spotted hyaena. Given the lack of historical records of cheetahs from the Eastern Cape (Skead, 1987) it is possible that many reintroductions reported here are to areas outside the original distribution of the cheetah.

Although widely distributed, serval are habitat specialists, preferring moist, tall grasslands associated with wetlands (Bowland, 1997). Such habitat is uncommon and disjunct in the Eastern Cape, which explains the paucity of records of serval from early explorers away from the coastal belt (Skead, 1987). This may also explain the difficulty in retaining reintroduced serval on reserves. As with brown hyaena, inadequate monitoring has prevented a full assessment.

Although reviews a decade ago concluded that reintroductions of large predators were not viable (Wemmer & Sunquist, 1988; Mills, 1991), an increase in knowledge and technical expertise has since made reintroduction common practice. The data from the Eastern Cape shows that every species of large African carnivore can be reintroduced and translocated successfully within fenced reserves, and data from Phinda Private Game Reserve in KwaZulu-Natal (Hunter *et al.*, 2006) also demonstrates that lions can be successfully translocated. To date, the Eastern Cape reintroductions have generally been adequately monitored and this report is the first step in satisfying the recommendation to publish monitoring results (Chivers, 1991).

Ultimately all reintroduction programmes aim for population persistence without intervention. However, this is a state, rather than a result, and it is assessable only in the long-term via continued monitoring (Seddon, 1999). The inherent low density of most top predators means that there are few criteria for measuring reintroduction success but we believe that, in the early stages of predator reintroduction, a 3-year breeding programme with natural recruitment exceeding deaths (Definition 2) should be used to assess success. By 10 years post-reintroduction, successful breeding by wild born generations (Definition 1) should then be used to assess success.

The use for reintroduction of areas previously under agriculture has yielded benefits for biodiversity conservation in the Eastern Cape but there are high management requirements associated with small reserves. The ability of private organizations or individuals to own wildlife in South Africa provides an economic impetus to private game reserves to retain ownership and management rights of their wildlife and promotes the continued separation, and thereby isolation, of these reserves. The clumping of a number of relatively small conservation reserves (Fig. 1), however, provides an opportunity to remove partitioning fences and consolidate this conservation estate into one large, contiguous unit. Such multiple owner conservancies are one way that sites could maintain their own identity while being part of a single, large conservation unit. This would greatly reduce the need for excessive management and allow natural evolutionary processes to occur. Nonetheless, management is likely to be a permanent requirement for the conservation of most large terrestrial predators whether they are enclosed by electric fences, as in southern Africa, or by uninhabitable land as elsewhere.

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References

Bauer, H. & Van der Merwe, S. (2004) Inventory of free-ranging lions *Panthera leo* in Africa. *Oryx*, **38**, 26–31.

Bowland, J.M. (1997) Serval *Felis serval*. In *The Complete Book of African Mammals* (eds M.G.L. Mills & L. Hes), pp. 190. Struik, Cape Town, South Africa.

Breitenmoser, U., Breitenmoser-Wursten, C., Carbyn, L.N. & Funk, S.M. (2001) Assessment of carnivore reintroductions. In *Carnivore Conservation* (eds J.L. Gittleman, S.M. Funk, D.W. Macdonald & R.K. Wayne), pp. 241–280. Cambridge University Press and Zoological Society of London, Cambridge, UK.

Castley, J.G., Knight, M.H., Mills, M.G.L. & Thouless, C.R. (2002) Estimation of the lion (*Panthera leo*) population in the southwestern Kgalagadi Transfrontier Park using a capture-recapture survey. *African Zoology*, **37**, 27–34.

Chivers, D.J. (1991) Guidelines for reintroductions: procedures and problems. *Symposium of the Zoological Society of London*, **62**, 89–99.

Frankham, R. (2005) Genetics and evolution. *Biological Conservation*, **126**, 131–140.

Griffith, B., Scott, J.M., Carpenter, J.W. & Reed, C. (1989) Translocation as a species conservation tool: status and strategy. *Science*, **245**, 477–480.

Hayward, M.W., Adendorff, J., Moolman, L.C., Hayward, G.J. & Kerley, G.I.H. (2007) The successful reintroduction of leopard *Panthera pardus* to the Addo Elephant National Park. *African Journal of Ecology*, **45**, 103–104.

Hayward, M.W., White, R.M., Mbandla, K.M. & Bukeye, P. (2005) Mammalian fauna of indigenous forest in the Transkei region of South Africa, an overdue survey. *South African Journal of Wildlife Research*, **35**, 117–124.

Hofmeyr, M., Davies, R., Nel, P. & Dell, S. (2003) Operation Phoenix - the introduction of larger mammals to Madikwe Game Reserve. In *Madikwe Game Reserve: A Decade of Progress* (ed. M. Brett), pp. 8–20. North West Parks & Tourism Board, Rustenberg, South Africa.

Hofmeyr, M. & van Dyk, G. (1998) Cheetah introductions to two north-west parks: case studies from Pilanesburg National Park and Madikwe Game Reserve. In *Cheetahs as Game Ranch Animals* (ed. B.L. Penzhorn), pp. 60–71. Wildlife Group of the South African Veterinary Association, Onderstepoort, South Africa.

Hunter, L.T.B. (1998a) Early post-release movements and behaviour of reintroduced cheetahs and lions, and technical considerations in large carnivore restoration. In *Cheetahs as Game Ranch Animals* (ed. B.L. Penzhorn), pp. 72–82. Wildlife Group of the South African Veterinary Association, Onderstepoort, South Africa.

Hunter, L.T.B. (1998b) *The behavioural ecology of reintroduced lions and cheetahs in the Phinda Resource Reserve, KwaZulu-Natal, South Africa*. PhD thesis, University of Pretoria, Pretoria, South Africa.

Hunter, L., Pretorius, K., Carlisle, L.C., Rickelton, M., Walker, C., Slotow, R. & Skinner, J.D. (2006) Restoring lions *Panthera leo* to northern KwaZulu-Natal, South Africa: short-term biological and technical success but equivocal long-term conservation. *Oryx*, **41**, 196–204.

IUCN (1998) *Guidelines for Re-introductions*. IUCN/SSC Re-introduction Specialist Group, Gland, Switzerland.

IUCN (2001) *IUCN Red List Categories and Criteria: Version 3.1*. IUCN, Gland, Switzerland and Cambridge, UK [http://www.redlist.org/info/categories_criteria2001.html, accessed 16 February 2007].

IUCN (2006) *2006 IUCN Red List of Threatened Species*. IUCN, Gland, Switzerland [http://www.redlist.org, accessed 16 February 2007].

Kerley, G.I.H. & Boshoff, A.F. (1997) *A Proposal for a Greater Addo National Park: A Regional and National Conservation and Development Opportunity*. TERU Report No. 17, Terrestrial Ecology Research Unit, Department of Zoology, University of Port Elizabeth, Port Elizabeth, South Africa.

Low, A.B. & Rebelo, T.G. (1996) *Vegetation of South Africa, Lesotho and Swaziland*. Department of Environmental Affairs and Tourism, Pretoria, South Africa.

Mills, M.G.L. (1991) Conservation management of large carnivores in Africa. *Koedoe*, **34**, 81–90.

Nowell, K. & Jackson, P. (1996) *Wild Cats: Status, Survey and Conservation Action Plan*. IUCN/Species Survival Commission Cat Specialist Group, Gland, Switzerland.

Rowe-Rowe, D.T. (1992) *The Carnivores of Natal*. Natal Parks Board, Pietermaritzburg, South Africa.

Seddon, P.J. (1999) Persistence without intervention: assessing success in wildlife reintroductions. *Trends in Research of Ecology and Evolution*, **14**, 503.

Skead, C.J. (1987) *Historical Mammal Incidence in the Cape Province. Volume 2: The Eastern Half of the Cape Province, Including the Ciskei, Transkei and East Griqualand* Chief

Directorate Nature and Environmental Conservation of the Provincial Administration of the Cape of Good Hope, Cape Town, South Africa.

Stuart, C.T. (1981) Notes on the mammalian carnivores of the Cape Province, South Africa. *Bontebok*, **1**, 1–58.

Vlok, J.H.J., Euston-Brown, D.I.W. & Cowling, R.M. (2003) Acocks' Valley Bushveld 50 years on: new perspectives on the delimitation, characterization and origin of subtropical thicket vegetation. *South African Journal of Botany*, **69**, 27–51.

Weber, W. & Rabinowitz, A. (1996) A global perspective on large carnivore conservation. *Conservation Biology*, **10**, 1046–1054.

Wemmer, C. & Sunquist, M.E. (1988) Felid reintroductions: economic and energetic considerations. In *Proceedings of the 5th International Snow Leopard Symposium* (ed. H. Freeman), pp. 193–205. International Snow Leopard Trust & The Wildlife Institute India, Delhi, India.

Woodroffe, R. & Ginsberg, J.R. (1997) Measures for the conservation and management of free-ranging wild dog populations. In *The African Wild Dog: Status, Survey and Conservation Action Plan* (eds R. Woodroffe, J.R. Ginsberg & D.W. Macdonald), pp. 88–99. IUCN/Species Survival Commission Canid Specialist Group, Gland, Switzerland.

Appendix

The Appendix for this article is available online at http://journals.cambridge.org

Biographical sketches

The majority of the authors are members of Indalo, a collective of conservation managers and owners of private game reserves and national parks in the Eastern Cape of South Africa that acts as a support network for members and a lobby group to ensure their interests are addressed from a political, social, economic and environmental perspective. All authors are interested in the practical side of reintroductions and measures to manage, limit over-population and conserve top order predators. Matt Hayward, Graham Kerley, Charlene Bissett & John O'Brien are conducting research into these issues.