The Cost Efficiency of Wild Dog Conservation in South Africa

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Abstract: *Aside from Kruger National Park, no other suitable reserves of sufficient size exist in South Africa that will hold a viable population of wild dogs (*Lycaon pictus*). Consequently, conservation efforts have been focused on creating a metapopulation through a series of wild dog reintroductions into isolated fenced reserves. Additional potential exists for conserving wild dogs on private ranch land. Establishing the metapopulation was an expensive process, accounting for approximately 75% of the US$380,000 spent on wild dog conservation in South Africa during 1997-2001. The principal goal of the metapopulation project was to reduce the risk of catastrophic population decline. Now that this has been achieved, we developed a uniform cost-efficiency index to estimate the cost efficiency of current and potential future conservation strategies in South Africa. Conserving wild dogs in large protected areas was predicted to be the most cost-efficient conservation strategy (449 packs/$100,000 expenditure). Establishing the metapopulation has been less cost efficient (23 packs/$100,000), and expansion of the metapopulation was predicted to be even less cost efficient if predation by wild dogs results in additional costs, as is to be expected if private reserves are used for reintroductions (3-13 packs/$100,000). Because of low logistical costs, conserving wild dogs in situ on private ranch land was potentially more cost efficient than reintroducing wild dogs (14-27 packs/$100,000). We recommend that donor funding be used to reintroduce wild dogs into transfrontier parks, when they are established, to maintain the existing metapopulation and to establish conservation programs involving wild dogs on private ranch land. Investing in the expansion of the metapopulation should be limited to state-owned nature reserves willing to carry predation costs without compensation.*

Key Words: donor funding, game ranching, *Lycaon pictus*, metapopulation, reintroduction

La Rentabilidad de la Conservación de Perros Salvajes en África del Sur

Resumen: *Además del Parque Nacional Kruger, en África del Sur no existen otras reservas de suficiente tamaño como para mantener una población viable de perros salvajes (*Lycaon pictus*). En consecuencia, los esfuerzos de conservación se han enfocado en la creación de una metapoblación por medio de una serie de reintroducciones en pequeñas reservas cercadas. Hay un potencial adicional para la conservación de perros salvajes en terrenos privados. El establecimiento de la metapoblación fue un proceso costoso, ~75% de US $380,000 que fueron gastados en la conservación de perros salvajes entre 1997 y 2001 en África del Sur. La meta principal del proyecto de metapoblación fue la reducción del riesgo de una declinación catastrófica de la población. Ya que esto se ha logrado, desarrollamos un índice de rentabilidad uniforme para estimar la rentabilidad de las actuales y potenciales estrategias de conservación en África del Sur. Se predijo que la estrategia de conservación de más rentable (449manadas/$100,000 de gasto) era la conservación de perros salvajes en áreas protegidas grandes. El establecimiento de la metapoblación ha sido menos rentable (23 manadas/$100,000), y se predijo que la expansión de la metapoblación sería aun menos rentable si la depredación*

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por perros salvajes resulta en costos adicionales, como se esperaría si se utilizan reservas privadas para las reintroducciones (3-13 manadas/$100,000). Debido a los bajos costos de logística, la conservación de perros salvajes in situ en terrenos privados fue potencialmente más rentable que reintroducir a los perros salvajes (14-27 manadas/$100,000). Recomendamos que el financiamiento de donantes sea utilizado para reintroducir perros salvajes en parque transfronterizos, cuando sean establecidos, para mantener a la metapoblación existente y para establecer programas de conservación que involucren a perros salvajes en terrenos privados. La inversión en la expansión de la metapoblación deberá limitarse a reservas naturales propiedad del estado que estén dispuestas a absorber los costos de la depredación sin ser compensadas.

Palabras Clave: crianza de especies cinegéticas, financiamiento de donantes, *Lycaon pictus*, metapoblación, reintroducción

Introduction

Cost efficiency in conservation can be gauged in terms of units of an environmental goods conserved per unit money spent. Examples of "environmental goods" in this context include recovery in numbers of a population or in area of a key habitat. With pressures on remaining natural habitats increasing and the number of threatened species rising (Guikema & Milke 1999) there is a worsening shortfall between the resources available and those required for conservation (Myers et al. 2000). For example, the recurrent cost of a globally effective reserve network encompassing terrestrial and marine habitats is estimated at $45 billion/year (Balmford et al. 2002), whereas current global spending on reserve networks is as little as $1–6 billion/year (James et al. 1999; Balmford et al. 2002). Expenditure on endangered species in the United States is only 20% of that required (Miller et al. 2002) and in developing countries the shortfall is substantially greater (Balmford & Whitten 2003).

Prospects for recovery in populations of threatened species generally improve with increased donor funding (Miller et al. 2002; Restani & Marzluff 2002), and cost efficiency potentially permits the conservation of more species per unit of funding. For individual species, designing conservation programs for cost efficiency increases the chances of financial support (Moran et al. 1997), and is becoming an important consideration in conservation prioritization (Balmford et al. 2003; Hughey et al. 2003).

Cost efficiency has been the focus of a number of studies on conservation planning (Moran et al. 1997; Ando et al. 1998; Balmford et al. 2003), and several studies have reviewed spending in relation to the U.S. Endangered Species Act (Baker 1999; Miller et al. 2002; Restani & Marzluff 2002). Research into the cost efficiency of conservation options involving single species, however, has been less common. Examples include cost estimates for wolf (*Canis lupus*) (Mech 1998) and Florida panther (*Felis concolor coryi*) (Main et al. 1999) conservation options. In developing countries, cost efficiency in conservation planning has received little or no attention, despite a desperate shortage of funds.

We adopted a novel approach to investigate the role of donor funding in the conservation of an endangered carnivore, the African wild dog (*Lycaon pictus*), by estimating the cost efficiency of current and potential future conservation strategies in southern Africa.

Current Wild Dog Conservation Efforts in South Africa

Despite a historical range comprising almost all of South Africa (Skinner & Smithers 1990), wild dogs are currently limited to a single viable population in Kruger National Park that has varied between 177 and 434 individuals in 21–32 packs in recent years (Maddock & Mills 1994; Davies 2000). Approximately 70% of South Africa is private land, with state-owned protected areas equaling <5% of the total land area (Cumming 1991). Aside from Kruger, no other suitable reserves of sufficient size exist in South Africa that will hold a second viable population of wild dogs. Consequently, conservation efforts became focused on creating a second viable population by reintroducing packs into several small (85–960 km^2), geographically isolated (mostly state-owned), fenced reserves, with the aim of establishing a minimum of nine packs linked through management during 1997–2007 (Mills et al. 1998).

A small population of wild dogs also occurs on private ranch land, comprising approximately 76 individuals in approximately 17 packs and dispersing groups (Lindsey et al. 2004). This population inhabits a fraction of available habitat on ranch land and is limited primarily to areas close to source populations (Lindsey et al. 2004). The increasing prevalence of game ranching in South Africa has resulted in increasing populations of wild ungulates and increased potential for conserving wild dogs on private land (van der Waal & Dekker 2000). The unprotected population on private land is a potentially important conservation resource as an additional genetic reservoir for wild dogs and insurance against environmental and demographic stochasticity. Improving the conservation status of wild dogs on ranch land, however, is likely to require significant efforts aimed at increasing tolerance among landowners (Lindsey 2005*a*).

Our objectives were threefold: (1) to document expenditure on wild dog conservation in South Africa during the first 5 years of the metapopulation management plan (1997–2001); (2) to assess the efficacy and cost efficiency of current conservation efforts; and (3) to compare the cost efficiency of current efforts with two potential future options: expansion of the metapopulation and conservation of wild dogs on private ranch land. Our assessment is expected to provide valuable objective information in support of future planning for wild dog conservation and a practical framework for analysis of conservation of other species or ecosystems.

Methods

Expenditure on Wild Dog Conservation in South Africa (1997–2001)

Wild dog stakeholders were asked for details about expenditure on activities related to wild dog conservation from 1997 to 2001. Stakeholders included agencies involved in the conservation of wild dogs within Kruger and the metapopulation reserves, provincial nature conservation representatives responsible for predators occurring outside state parks, and researchers. Information on expenditures by captive breeders associated with the provision of wild dogs for reintroduction programs was also obtained and documented. Budget records were obtained where possible; otherwise, the costs of activities conducted during the 5-year period were estimated. Expenditure records were converted into U.S. dollars (2002), based on Consumer Price Indexes published by the South African Reserve Bank and the mean US$/ZAR exchange rate for the first 6 months of 2002 (US$1 = ZAR 10.99).

Cost-Efficiency Indexes

The cost-efficiency index (CEI) is defined in this study as the number of packs maintained over a period of time per $100,000 spent on conservation efforts in present value terms. We used the following equation to calculate the cost efficiency of wild dog conservation under various scenarios:

$$\mathrm{CEI} = \frac{100,000}{7}\left[\frac{\mathrm{packs}_1}{\left(\frac{C_1}{(1+r)}\right)} + \frac{\mathrm{packs}_2}{\left(\frac{C_2}{(1+r)^2}\right)} + \frac{\mathrm{packs}_3}{\left(\frac{C_3}{(1+r)^3}\right)} + \frac{\mathrm{packs}_4}{\left(\frac{C_4}{(1+r)^4}\right)} + \frac{\mathrm{packs}_5}{\left(\frac{C_5}{(1+r)^5}\right)} + \frac{\mathrm{packs}_5}{\left(\frac{C_5}{r}\right)} + \frac{\mathrm{packs}_5}{\mathrm{SSC}}\right].$$

Packs_1–packs_5 represent the number of packs in a population resulting from a given strategy in years 1–5. Packs_5 also represents the predicted population size in perpetuity, assuming the number of packs remains constant or is managed to stay at this size. The costs of conservation in years 1 to 5 are represented by C_1–C_5, and C_5 also represents continuing annual costs in perpetuity. The costs of a conservation program are likely to vary for the first few years, but we assumed costs would stabilize after 5 years. The SSC is the sum of the startup costs of a conservation program, and r is the discount rate, based on the average long-term South African Government Bond rates for the first 6 months of 2002.

This formula averages an annual CEI for each of 5 years, a CEI for the costs of maintaining a stable wild dog population in perpetuity, and an index of the perpetual number of packs to initial costs. The average is then multiplied by 100,000 to yield an index expressed as packs per $100,000.

Costs of Conserving Wild Dogs within Kruger National Park

The cost efficiency of conserving wild dogs within a large protected area (Kruger) was calculated slightly differently. Wild dogs have been present in Kruger since the inception of the park; therefore, we excluded startup costs from the equation. In addition, significant costs are incurred every 5 years in Kruger when a photographic census is undertaken, so we modified the equation to account for this, assuming for tractability that one-fifth of the 5-yearly cost occurs each year. So, for wild dogs in Kruger,

$$\mathrm{CEI} = \frac{100,000}{6}\left[\frac{\mathrm{packs}_1}{\left(\frac{C_1}{(1+r)}\right)} + \frac{\mathrm{packs}_2}{\left(\frac{C_2}{(1+r)^2}\right)} + \frac{\mathrm{packs}_3}{\left(\frac{C_3}{(1+r)^3}\right)} + \frac{\mathrm{packs}_4}{\left(\frac{C_4}{(1+r)^4}\right)} + \frac{\mathrm{packs}_5}{\left(\frac{C_5}{(1+r)^5}\right)} + \frac{\mathrm{packs}_5}{\left(\frac{C_5+\frac{\text{five-year cost}}{5}}{\frac{r}{(1+r)^5}}\right)}\right].$$

We included other costs for monitoring and research (including researcher salaries equivalent to the 20% of time spent working on wild dogs by the resident scientist, aerial and ground tracking) and for snare removal at the rate conducted during 1997–2001. In this way the cost efficiency of conserving a viable population was estimated from expenditures made on wild dogs in Kruger from 1997 to 2001. We assumed that there were 28 packs throughout because this was the average number of packs

counted in the last three Kruger censuses (Maddock & Mills 1994; Wilkinson 1995; Davies 2000).

Costs of Establishing the Metapopulation

Costs associated with establishing and maintaining subpopulations within the metapopulation typically include upgrading of perimeter fencing and holding facilities, capture and transport of founders, veterinary care, feeding in holding facilities, equipment purchases, and monitoring. Wild dogs were reintroduced to Hluhluwe-iMfolozi Park and Madikwe Game Reserve in 1981 and 1994, respectively, and changing personnel prevented the collection of data on initial reintroduction costs. Consequently, costs of the initial reintroductions at these reserves were assumed to equal the average initial costs associated with reintroductions undertaken during 1997–2001. The costs of reintroductions at these reserves may have been lower because intensive monitoring as has been done during recent reintroductions was not undertaken. Adjusting the average costs for the removal of monitoring costs, however, did not affect estimates of cost efficiency. The costs of predation by wild dogs within the metapopulation were not estimated because no donor funding has been provided to compensate host reserves for these costs.

Records from the minutes of Wild Dog Advisory Group—South Africa meetings were used to document annual wild dog population sizes within each of the reserves in the metapopulation. The number of packs within the metapopulation increased from 3 in 1997–1998 to 10 in 2002. We assumed that the 2002 population size represents the stable population size for the five reserves into which wild dogs had been reintroduced by that year (additional reintroductions were undertaken at Marakele National Park and Shamwari Game Reserve in 2003 and Tswalu Kalahari Reserve in 2004).

Costs of Expanding the Metapopulation through Reintroductions into Nature Reserves

We assumed that establishment and annual maintenance costs would equal the mean costs incurred by existing metapopulation reserves. Reintroductions to date have typically involved intensive monitoring. An additional scenario was also presented whereby the monitoring costs were half of what had been spent on reintroductions to date to account for reduced monitoring intensity. In some nature reserves (especially if privately owned), predation may result in real costs because prey killed by wild dogs could otherwise be used for hunting or live capture and sale. In light of this, we estimated CEIs for expansion of the metapopulation by incorporating costs associated with predation if necessary.

We assumed that a reintroduced pack of 7 individuals would increase to the mean 2002 size of reintroduced subpopulations (~13 individuals in two packs) within the first year and then remain at that level. Although the number of dogs is likely to fluctuate, we used a fixed estimate of 13 dogs for the purposes of calculating costs.

We developed three cost scenarios to allow for variation in the extent to which predation would result in financial loss: (1) the value of all animals killed was compensated for fully; (2) half of prey killed was compensated for (given reduced intensity hunting); and (3) predation resulted in no cost. Recreational hunting for venison is the most common form of wildlife use in South Africa (van der Waal & Dekker 2000), so we assumed prey would be replaced at mean recreational hunting values for each species, as indicated from a survey of operators ($n = 15$).

Adult male wild dogs need to consume 3.04 kg of meat/day (Nagy 2001). We estimated the daily requirements of an average-sized individual based on 0.75 of mean adult mass (Coe et al. 1976). Typically, 61% of the body mass of ungulates is made up of flesh (Blumenschine & Caro 1986). Based on this, we adjusted the daily food requirement to provide an estimate of mass of prey killed/dog/day (3.2 kg), which is consistent with field estimates of 1.8-3.5 kg/dog/day (Fuller & Kat 1990; Mills & Biggs 1993; Creel & Creel 1995).

The costs of predation by wild dogs were based on prey profiles (Table 1) observed in southern Kruger (Mills & Gorman 1997) and Hluhluwe-iMfolozi Park (Kruger et al. 1999) and represent realistic prey profiles for two areas in which reintroductions are likely to occur: northeastern South Africa (north and northeastern Limpopo Province and probably most of North West Province) and eastern South Africa (northern Kwa-Zulu Natal), respectively.

Data on the sex and age breakdowns of prey species were unavailable for the northeastern prey profile and were thus extrapolated from data collected in similar habitat in southeastern Zimbabwe, adjacent to Kruger (Pole 1999). We estimated the number of individuals of each sex and age category and species killed annually by 13 wild dogs and then calculated cost estimates.

Costs of Conserving Wild Dogs on Private Ranch Land

If donor funding is used for the conservation of wild dogs on private ranch land, it is assumed that monitoring would be done to help prevent persecution and to assist with the allocation of compensation to landowners for losses from predation. Most negative attitudes among ranchers toward wild dogs are based on perceived or real costs associated with their presence (Lindsey 2005*a*), and we assumed that compensation for losses to predation by wild dogs is a sufficient incentive for landowners to tolerate them on their land. Wild dogs on ranch land may kill livestock, but because no data are available on livestock depredation by wild dogs on game ranch land in South Africa, cost estimates were made for prey profiles composed entirely of wild prey. This resulted in conservatively high cost estimates because of the high value of wildlife relative to livestock.

Table 1. Percent biomass of each prey species in two wild dog prey profiles.

Area and species	*Total (%)*	*Adult male (%)*	*Adult female (%)*	*Subadult (%)*	*Juvenile (%)*
Eastern South Africa[a]					
grey duiker, *Sylvicapra grimmia*	0.1	0.1	0.05	0	0
impala, *Aepyceros melampus*	16.2	4.2	5.6	1.2	5.2
kudu, *Tragelaphus strepsiceros*	0.7	0.1	0.1	0.3	0.3
nyala, *Tragelaphus angasi*	76.1	31.8	29.8	7.8	6.7
red duiker, *Cephalophus natalensis*	0.3	0.2	0.15	0	0
reedbuck, *Redunca arundinum*	0.9	0.3	0.3	0.2	0.1
waterbuck, *Kobus ellipsiprymnus*	2.2	0.2	0.3	0.9	0.8
wildebeest, *Connochaetes taurinus*	3.5	0.3	0.5	1.4	1.3
Northeastern South Africa[b]					
bushbuck, *Tragelaphus scriptus*	2.0	0.5	0.6	0.3	0.2
grey duiker, *Sylvicapra grimmia*	4.4	2.2	2.2	0	0
impala, *Aepyceros melampus*	81.0	18.6	25.7	13.0	8.6
kudu, *Tragelaphus strepsiceros*	8.1	0.3	0.6	2.2	4.1
reedbuck, *Redunca arundinum*	2.0	0.5	0.6	0.3	0.2
steenbok, *Raphicerus campestris*	2.5	1.3	1.3	0	0

[a] *Kruger et al. (1999).*
[b] *Mills and Gorman (1997).*

We obtained quotes for goods and services required for monitoring from recognized state agencies or from three private companies and used the intermediate quote. We assumed that three of the dogs would be radio collared initially, following helicopter-assisted capture. To be conservative we used the costs of expensive helicopter-assisted capture, although other methods of catching wild dogs such as using padded leg-hold traps or free darting at den sites may be possible, which would reduce costs. Following attachment of collars, we assumed that monitoring would be conducted at a rate equal to that done at Venetia-Limpopo Nature Reserve in the first year after release (4000 km/month). We also assumed that three dogs would be immobilized annually to replace radio collars and add collars to young individuals. With adequate habituation, wild dogs can be recaptured by darting from a vehicle, and the costs include vehicle usage, veterinary care, and capture drugs.

Natural habitat is highly fragmented in South Africa and there is a limit to the number of wild dogs that can be conserved in a given area on private ranch land. The average number of resident packs occurring in the two areas in which wild dogs are most regularly sighted on private land in South Africa is 2.5, and cost estimates were made for a stable subpopulation size of three packs of 7 dogs per pack, the average size observed on private ranch land (Lindsey et al. 2004). For the sake of cost estimates, we assumed that an average newly formed pack of 6 dogs colonizing an area of private ranch land with adequate prey availability would increase in numbers from 6 in one pack to 21 in three packs during years 1-5 (Fuller et al. 1992) and then remain at this level. It is assumed genetic management would not be necessary because of the wide distribution of naturally occurring dispersing groups of wild dogs on ranch land in the northern regions of South Africa (Lindsey et al. 2004). Predation costs were estimated as for reintroductions.

Results

Expenditure on Wild Dog Conservation (1997–2001)

An estimated $378,887 was spent on wild dog conservation in South Africa during 1997–2001, at an average of $75,777/year. Of this, $276,709 (73.0%) was spent on the metapopulation, $57,863 (15.3%) on the Kruger population, and $33,942 (9.0%) on wild dogs on ranch land (Table 2). The remainder was spent on wild dog research not related specifically to any of the three populations (Frantzen et al. 2001; Knobel & du Toit 2003).

Nongovernmental organizations (NGOs) provided the most funding for wild dog conservation in South Africa during 1997–2001 (41.1%), followed by South African state agencies (36.3%), private donors (20.5%), and universities (2.1%). Most expenditure on the Kruger population was provided by state agencies (65.8%) and NGOs (34.2%). Most of the money spent on the metapopulation was provided by NGOs (45.8%), followed by private donors (27.2%) and state agencies (26.2%). State agencies provided most of the money spent on wild dogs on ranchland (71.9%), followed by NGOs (24.4%).

Most of the money (64%) spent on the Kruger population was used for research, 34.1% was used for a photographic census, 1% for attending meetings, and the remaining 0.9% for capture and veterinary care, primarily for the removal of snares. For the metapopulation, most of the money was spent on monitoring and research (49.0%), upgrading holding facilities and feeding dogs in these facilities (12.7%), and upgrading perimeter fencing

Table 2. Expenditure on the conservation of the three subunits of the South African wild dog population during 1997–2001, in 2002 US$ (ZAR in parentheses).

Subunit	*1997*	*1998*	*1999*	*2000*	*2001*	*Total*
Kruger	7,505 (82,480)	7,305 (80,282)	24,820 (272,772)	9,829 (108,021)	8,404 (92,360)	57,863 (635,915)
Metapopulation						
Hluhluwe	18,479 (203,084)	11,464 (125,989)	10,909 (119,888)	14,130 (155,288)	8,687 (95,470)	63,669 (699,719)
Karongwe	-	-	-	-	29,295 (321,952)	29,295 (321,952)
Madikwe	9,719 (106,812)	4,321 (47,488)	4,408 (48,444)	7,735 (85,008)	14,375 (157,981)	40,558 (445,733)
Pilanesberg	-	-	39,783 (437,215)	3,278 (36,025)	4,860 (53,411)	47,921 (526,651)
Venetia	-	-	-	-	79,750 (876,453)	79,750 (876,453)
miscellaneous*	4,835 (53,137)	761 (8,363)	723 (7,946)	686 (7,539)	8,511 (93,536)	15,516 (170,521)
On ranch land	4,155 (45,663)	2,131 (23,420)	5,852 (64,312)	5,434 (59,720)	16,370 (179,906)	33,942 (373,021)
Total	44,693 (491,176)	25,982 (285,542)	86,495 (950,577)	41,092 (451,601)	170,252 (1,871,069)	368,514 (4,049,965)

**Miscellaneous costs associated with the metapopulation, including the workshop at which the metapopulation management plan was conceived (Mills et al. 1998), the costs of Wild dog Advisory Group-South Africa meetings, and the costs of purchasing founder dogs for reintroductions.*

(12.6%). Of money spent on wild dogs on ranch land, 39.7% was spent on removing "problem animals," 29.0% on research, 23.3% on nature conservation representatives attending to ranchers' complaints, and 8.0% on attendance at meetings.

Cost Efficiency of Wild Dog Conservation Strategies

KRUGER NATIONAL PARK

The estimated mean annual cost of conserving wild dogs in a large protected area was $11,573 (Table 3). Conservation of wild dogs within Kruger yielded the highest CEI, estimated at 449 packs/$100,000 (Table 4). This is more cost efficient than the metapopulation management plan by 20 times, more cost efficient than expansion of the metapopulation by 16–150 times, and more cost efficient than conserving wild dogs on ranch land by 17–32 times (Table 4).

METAPOPULATION ESTABLISHMENT AND EXPANSION

The metapopulation increased from 19 individuals in 3 packs in 1997 to 54 individuals in 10 packs before the denning season of 2002. Thus, the target for the metapopulation was achieved in just over half the time expected (Mills et al. 1998). The cost efficiency of establishing the metapopulation to date is 23 packs/$100,000.

The mean expenditure on initial reintroductions of wild dogs into metapopulation reserves was $36,880, and the mean annual maintenance expenditure was $10,753. Predicted annual costs of predation varied with prey profile and the proportion of prey for which compensation was provided (Table 3). The estimated CEIs of reintroducing and conserving wild dogs within a reserve ranged from 3 packs/$100,000 under the eastern prey profile with compensation provided for all prey to 18 packs/$100,000 with no compensation provided and 28 packs/$100,000 with compensation and reduced intensity monitoring (Table 4). Expansion of the metapopulation through reintroduction onto reserves where predation results in costs was predicted to be the least cost-efficient strategy of those considered.

CONSERVING WILD DOGS ON PRIVATE RANCH LAND

The estimated cost of establishing a conservation program involving wild dogs on ranch land was <10% of reintroducing a pack into a reserve (Table 3). The average annual costs associated with predation by a subpopulation of wild dogs were estimated to be 82.5% greater under an eastern prey profile than under a northeastern prey profile. The estimated CEIs of conserving wild dogs on ranch land varied from 14 packs/$100,000 under the eastern prey profile with all prey compensated for to 27 packs/$100,000 with no predation compensation costs (Table 4).

Discussion

After many years of being overshadowed by Africa's better-known carnivores, wild dogs have received increasing attention from researchers and donors in recent years

Table 3. Costs data used for the calculation of cost-efficiency indices for conservation of wild dogs, in US$2002 (ZAR in parentheses).

Costs[a]	*Amount*
Within a viable population	
average annual[b]	11,573 (127,187)
Reintroduction into a nature reserve	
initial[c]	36,880 (405,311)
initial with half monitoring	33,140 (364,208)
annual running[c]	10,753 (118,176)
annual running with half monitoring	6,887 (75,686)
predation[d]	
ESA prey profile, all prey compensated	101,762 (1,118,364)
ESA prey profile, half prey compensated	50,881 (559,182)
NESA prey profile, all prey compensated	17,761 (195,193)
NESA prey profile, half prey compensated	8,880 (97,594)
In situ on ranch land	
initial	
first (helicopter-assisted) capture	1,980 (21,760)
purchase of telemetry equipment	1,592 (17,496)
average annual running	
capture (darting from a vehicle)	1,012 (11,122)
purchase of additional radio collars	721 (7,924)
employee salary	4,648 (51,082)
vehicle devaluation and maintenance	9,001 (98,921)
predation	
ESA prey profile, all prey compensated	164,385 (1,806,591)
ESA prey profile, half prey compensated	82,192 (903,290)
NESA prey profile, all prey compensated	28,690 (315,303)
NESA prey profile, half prey compensated	14,345 (157,652)

[a] *Abbreviations: ESA, eastern South Africa; NESA, northeastern South Africa.*
[b] *Equal to the average annual expenditure on wild dogs in Kruger during 1997–2001.*
[c] *Equal to the average costs associated with the initial reintroduction and annual maintenance of wild dogs in the metapopulation to date.*
[d] *Assuming the number of dogs is equal to that in year 5.*

Table 4. Cost-efficiency indices (CEI) based on the discounted ($r = 0.1163$) costs of conserving wild dogs under three conservation scenarios in perpetuity.

Scenario[*]	*CEI (packs/ $100,000 spent)*
Within a viable population	449
Establishment of the metapopulation	23
Expansion of metapopulation	
ESA prey profile	
all prey compensated	3
all prey compensated, half monitoring	3
half prey compensated	4
half prey compensated, half monitoring	4
NESA prey profile	
all prey compensated	8
all prey compensated, half monitoring	9
half prey compensated	11
half prey compensated, half monitoring	13
zero predation costs	18
zero predation costs, half monitoring	28
In situ on ranch land	
ESA prey profile	
all prey compensated	14
half prey compensated	15
NESA prey profile	
all prey compensated	18
half prey compensated	21
zero predation costs	27

[*] *Abbreviations: ESA, eastern South Africa; NESA, northeastern South Africa.*

(Creel & Creel 2002). This interest is reflected in increasing expenditure on their conservation in South Africa during 1997–2001. Almost $380,000 was spent, with donors including a variety of NGOs, private companies, and state agencies. Funding received for wild dog conservation in South Africa is critically important, and for this support to continue, the use of funds must be shown to be effective.

Six years after the initiation of the metapopulation management plan (Mills et al. 1998) the target population of nine packs was exceeded, and wild dogs have now been successfully established and maintained in eight reserves. The Kruger population has remained viable, but has fluctuated widely, increasing by 17.8% during 1988–1995 and then declining by 59.2% during 1995–2000 (Maddock & Mills 1994; Wilkinson 1995; Davies 2000). These fluctuations stress the need for continued monitoring and continued investment in both the metapopulation and the unmanaged populations on private ranch land as an insurance policy for the conservation of the species.

Maintaining large protected areas represents the most important strategy for wild dog conservation (Woodroffe & Ginsberg 1997) and is the most cost-efficient way in which wild dogs can be conserved in South Africa. Little specific expenditure is required to conserve wild dogs in a large protected area and much of the expenditure in Kruger (e.g., the photographic census) is not vital for the persistence of a population, although it is seen by South African National Parks as an essential part of Kruger's monitoring program. Thus, the cost efficiency of this strategy is potentially even greater than we estimated.

The potential for conserving wild dogs in large protected areas in South Africa is likely to increase in the future, given plans to create large "transfrontier parks" through the amalgamation and expansion of existing parks on the national borders. This creates potential for expanding the Kruger wild dog population into Mozambique and joining it up with the southeastern Zimbabwe population (Great Limpopo Transfrontier Park) and establishing viable populations in the proposed Limpopo/Shashi and Lubombo transfrontier conservation areas.

The metapopulation management plan is substantially less cost efficient because of the logistical difficulty associated with reintroductions. Expansion of the metapopulation is likely to be even less cost efficient if predation after release results in costs related to the high value of wild ungulates used for hunting, live capture, and sale. Furthermore, most reserves into which dogs have been reintroduced to date have required little investment in infrastructure because of existing high-quality fencing and holding facilities. Upgrading standard game fencing to the specifications required for wild dogs is extremely costly (Lindsey 2005*b*), and if the metapopulation is expanded onto reserves without existing predator-proof fencing, cost efficiency would decline further.

Under certain conditions, however, nature reserve owners and managers could be encouraged to reintroduce wild dogs at their own cost. Ecotourism is the most profitable land use on reserves of sufficient size for wild dog reintroductions (Falkena 2000) and under these conditions the financial effect of predation is likely to be negligible. In addition, high-quality fencing and boma facilities are likely to be present already because of the importance of lions for attracting visitors (Vorhies & Vorhies 1993). Furthermore, as the methods for reintroducing wild dogs improve, the process is likely to become more efficient and costs will decline. Some of the costs incurred during reintroductions to date (e.g., holding dogs in captivity for longer than 6 weeks) are not vital and could be omitted. Other costs such as those for intensive monitoring and research could be reduced. Finally, the potential financial benefits associated with ecotourism based on wild dogs are substantial ($11,000-$64,000/pack/year) and may be sufficient to exceed the costs associated with reintroduction programs under certain conditions (Lindsey 2005*b*). In keeping with these potential benefits, the Wild Dog Advisory Group—South Africa has received several applications for wild dog reintroductions from private nature reserve owners.

We suggest that expansion of the metapopulation be limited to state-protected areas in which predation will not result in costs, with existing suitable fencing and where expenditure on after-release monitoring is limited. In addition, reintroductions should be encouraged by private nature reserves willing to cover the costs, particularly those that will allow the recovery of ecological processes involving wild dogs, enabling them to become an integral component of the ecosystem (Pyare & Berger 2003).

Conserving wild dogs on private ranch land was predicted to be more cost efficient than the metapopulation management plan under realistic scenarios and to be substantially more cost efficient than expansion of the metapopulation onto reserves where predation results in costs. Furthermore, the cost efficiency of conservation on private ranch land is likely to be similar to or higher than the upper estimates we have made (21–27 packs/$100,000) for two reasons.

First, impala and kudu (both relatively low value) (scientific names provided in Table 1) are the most common ungulates in most parts of northern South Africa. Conversely, nyala, a valuable species prominent in the eastern prey profile, are limited in distribution in South Africa, and the nyala predation cost scenario is likely to occur only in northern Kwa-Zulu Natal or when wild dogs occur on land where the breeding of rare antelopes is a priority.

Second, in some parts of South Africa, up to 33% of ranches have ecotourism-based land uses (Lindsey 2005*a*), where predation is likely to result in low or zero costs. Finally, there is potential to offset costs with ecotourism benefits, which reduces dependency on donor funding (Lindsey 2005*b*). There are difficulties associated with using compensation as a conservation management tool on private ranch land. Donor funding would be required indefinitely, and even to an increasing extent if wild dog numbers increased. Replacing compensation with educational programs and technical assistance to establish wild dog ecotourism operations would significantly increase the cost efficiency of this conservation strategy. This would be a significant challenge, however, because the negative mindset of many game ranchers toward wild dogs is still entrenched (Lindsey 2005*a*).

The conservation environment in South Africa differs from most African countries in that large areas of game ranching and small (<1000 km^2) fenced reserves do not generally occur elsewhere, except in Namibia and Zimbabwe. Despite this, a cost-efficiency approach to conservation planning is widely applicable, not least because other sub-Saharan countries are likely to have fewer resources available for conservation. Options for wild dog conservation elsewhere in Africa include large protected areas, wildlife management areas, community lands, and fencing medium-sized reserves to permit reintroductions into areas smaller than the threshold size below which extinction is predicted (Woodroffe & Ginsburg 1998).

Farther north, reserves are often larger than those used for reintroductions in South Africa and typically lack existing perimeter fencing. Consequently, the cost efficiency of a metapopulation management plan is likely to be unfeasibly low. Conserving wild dogs in community areas is analogous to conservation on ranch land in that the focus of conservation efforts would be increasing tolerance among local people. In community areas, the killing of wild prey is unlikely to cause as much conflict as it does on game ranches, and given sufficient wild prey wild dogs are unlikely to kill domestic stock (Woodroffe et al. 2005). Consequently, the cost efficiency of conserving wild dogs outside protected areas is likely to be higher in other African countries. The relative costs of conservation options are likely to differ from country to country. Nonetheless, a cost-efficiency approach has the potential everywhere to focus conservation efforts and ensure maximum gain for minimal expenditure.

The cost-efficiency approach we adopted has wide application for other threatened species. The design of cost-efficient conservation programs is likely to improve the chances of financial support, maximize productivity of conservation investment, and benefit other species by increasing availability of funds (Moran et al. 1997). An example of where cost efficiency in current conservation programs could potentially benefit other species is in North America. In 1995, of the $348 million spent on endangered species in the United States, more than 50% went to 10 species (Baker 1999).

We suggest that monitoring efforts be continued in Kruger and that donor funding be used to establish wild dog populations in proposed transfrontier parks as soon as they are established. In addition, we suggest that donor funding be directed toward the conservation of wild dogs on private ranch land and used for maintenance of the metapopulation. Expansion of the metapopulation should be limited to suitable state reserves, and private reserves willing to absorb the costs.

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