8

LETHAL MANAGEMENT OF ELEPHANTS

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INTRODUCTION

FOR THE purpose of this chapter, we define two broad circumstances under which elephants are killed for management purposes. The first, which we will term culling, is where a significant fraction of the elephant population are killed with the objective of reducing the population size or controlling its growth rate. The second is when specific individuals are killed to prevent them from causing further damage or threatening human lives (hereafter referred to as 'problem animal control') (DEAT, 2008). Decisions on the implementation of problem animal control are relatively uncontentious. When an individual poses a threat to human life, or persistently causes damage to infrastructure or agriculture, that identified individual is dealt with according to set decision-making norms and procedures, which may include lethal management (DEAT, 2008). Culling for population management is much more complex and is at the root of much of the elephant debate (Caughley, 1976).

Imposed population control may be necessary when natural mechanisms of population regulation are not operating, for whatever reason (Chapter 2). Besides controlling population numbers, manipulation of age-sex class composition may be necessary to correct historical effects, e.g. populations founded by young elephants only (Garaï *et al.*, 2004).

The purpose of this chapter is to provide a resource for decision-making around culling of elephants and problem animal control and to evaluate our current understanding, knowledge, and gaps regarding lethal management of elephants. Culling has been applied as a management tool for elephants since elephants have been managed, and we have a good understanding of certain aspects. However, increased accountability to the broader community has necessitated that all aspects are well considered.

The specific objectives of this chapter are to: (1) describe the history of culling, (2) briefly describe and evaluate the methods for culling, (3) describe the various management contexts and objectives for culling as a viable intervention, (4) highlight the constraints and consequences of culling, and (5) define gaps in our knowledge.

THE HISTORY OF CULLING

Zimbabwe and other southern African countries

An overview of culling in southern Africa is provided to place the South African experience in context. Although this assessment focuses on elephant management in South Africa, numerically, most culling that has taken place to date has occurred in Zimbabwe, where culling to control population numbers was first implemented in 1966. By August 1996, a cumulative total of almost 50 000 elephants had been culled in Zimbabwe (Martin *et al.*, 1996; see also Cumming & Slotow, 2003 cited in Cumming & Jones, 2005). The estimated elephant population in Zimbabwe in 1996 was 68 000 (Martin *et al.*, 1996).

Culling of family groups also occurred in the Luangwa valley in Zambia in the 1960s and 1970s (Cumming & Jones, 2005). Culling to reduce numbers also took place in Etosha, Namibia in 1983 and 1985 (Cumming & Jones, 2005). Culling to reduce population size has not been undertaken in Botswana or Mozambique. Poaching, however, has resulted in a major reduction in population size in Mozambique (and Zambia) since the 1960s (Cumming & Jones, 2005).

The first culling within national parks took place in Hwange in 1966 and 1967, and then in Mana Pools in 1968 and 1969 (Cumming, 1981). Culling was scaled up in 1971 with 1 300 elephants removed from Hwange, and 665 elephants from Gonarezhou (Cumming, 1981). Culling was initiated in Chizarira and Matusadona in 1972 (Cumming, 1981). Full details of removals in Zimbabwe up until 1979 are included in Cumming (1981); by 1979 18 216 animals had been removed. Details of culling after that time are provided in Martin *et al.* (1996).

Kruger National Park

The decision to cull elephants in Kruger is dealt with as a case history in Chapter 1, and is not repeated here. A policy of elephant population control by culling and live removals was implemented from 1965 until 1995.

A total of 14 629 elephants were culled between 1967 and 1997 in the Kruger (Whyte, 2001; table 1). The highest number of elephants culled in any year was 1 846 in 1970, the median number for years in which more than 100 were culled was 348. The median percentage of the existing population that was culled per year was 5.35 per cent.

Addo Elephant National Park

The attempt in 1919 to eradicate the population of elephants in the Addo bush near Port Elizabeth in the Eastern Cape was one of the earliest specific management attempts to cull elephants. This population of about 120 elephants represented what was then the largest elephant population in South Africa (Whitehouse, 2001), but these animals were in conflict with local farmers due to the elephants causing destruction of dams and other infrastructure (see Chapter 1 for details). Pressure by the local farmers led the then Cape Provincial administration to contract Major P.J. Pretorius to eradicate this population (Hoffman, 1993). Pretorius, who described the habitat as a 'hunter's hell' (Pretorius, 1947), managed to shoot about 120 animals and sold the meat and ivory. He also sold some specimens to the then South African Museum. Pretorius later petitioned the Administrator of the Cape to be released from his contract when an estimated 16 elephants remained, pleading the need for their conservation. This was granted in 1920, and the remaining animals became the basis for the now famous Addo elephants. After the establishment of the Addo Elephant National Park (Addo) in 1931, further culling of some problem animals occurred. This included one bull shot in self-defence in 1931, a second shot in 1932 to protect a windmill, a third in 1937 in retaliation for the death of a ranger (Whitehouse & Kerley, 2002) and a fourth bull in 1968 (the well-known Hapoor) who had escaped from the fenced park (Whitehouse, 2001).

The population was ultimately reduced to 11 animals. This strong bottleneck effect has been expressed at a genetic level, with the Addo elephants being genetically impoverished compared to the parent population (i.e. the pre-Pretorius Addo population) or the Kruger population (Whitehouse & Harley, 2001). The current social structure of the Addo population (seven family groups) reflects the presence of five cows in the founder population (Whitehouse, 2001). Finally, the culling of the three bulls in the 1930s left the Addo population without any mature breeding bulls for nine years (until a bull calf matured), hindering the population's recovery from low numbers (Whitehouse & Kerley, 2002).

Year	Census total	Culling quota	Total culled	Juveniles translocated	Family units translocated	Adult bulls translocated	Total removed after census
1966	No census	–	–	26	–	–	26
1967	6 586	650	355	–	–	–	355
1968	7 701	1 230	460	–	–	–	460
1969	8 312	1 408	1 160	–	–	–	1 160
1970	8 821	2 093	1 846	–	–	–	1 846
1971	7 916	889	602	–	–	–	602
1972	7 611	618	608	–	–	–	608
1973	7 965	738	732	–	–	–	732
1974	7 702	853	764	–	–	–	764
1975	7 408	601	567	–	–	–	567
1976	7 275	350	285	–	–	–	285
1977	7 715	663	544	26	–	–	570
1978	7 478	392	348	35	–	–	383
1979	–	380	322	48	–	–	370
1980	7 454	395	356	55	–	–	411
1981	7 343	71	16	0	–	–	16
1982	8 051	555	427	46	–	–	473
1983	8 678	2 229	1 290	66	–	–	1 356
1984	8 273	1 890	1 289	88	–	–	1 377
1985	6 887	369	268	101	–	–	369
1986	7 617	495	404	94	–	–	498
1987	6 898	305	245	59	–	–	304
1988	7 344	367	273	83	–	–	356
1989	7 468	367	281	85	–	–	366
1990	7 287	367	232	132	–	–	364
1991	7 470	367	218	140	–	–	358
1992	7 632	350	185	150	144	–	479
1993	7 834	577	308	74	8	–	390
1994	7 806	600	177	31	146	2	356
1995	8 064	0	44	0	83	0	127
1996	8 320	0	18	0	52	6	76
1997	8 371	0	5	0	12	34	51
1998	8 869	0	0	0	13	18	31
1999	9 152	0	0	0	0	12	12
2000	8 356	0	0	0	22	27	49
Total	–	20 169	14 629	1 339	458	72	16 520

Table 1: Annual elephant census totals and culling quotas in the Kruger National Park since the initiation of the census and culling programmes in 1966, and numbers removed from the population (from Whyte, 2007)

Tembe Elephant Park – KwaZulu-Natal

Tembe Elephant Park houses one of the original (non-introduced) populations in South Africa. The park was proclaimed in 1983, and the south, west and east boundaries were fenced to protect the local population from elephants. The northern boundary with Mozambique was fenced in 1989, until which time elephants could move freely in and out of the park.

A number of individuals had been injured by people in Mozambique, resulting in human-elephant conflict within the park. Nineteen elephants have been culled in Tembe to date, and four males were hunted in Tembe in 1996 (table 2).

Reserve	Problem males	Problem females	Hunted	Source
Marakele	2			Hofmeyr, SANParks
Ithala	10			Conway, EKZNW
Mkhuze	1	1		Conway, EKZNW
St. Lucia				Conway, EKZNW
Tembe	19[a]		4	Matthews, EKZNW
Hluhluwe-Umfolozi	10			Conway, EKZNW
Pilanesberg	?		24[b]	Nel, NWP&TB
Madikwe	?	2	22[b]	Nel, NWP&TB
Fish River Complex	1			Kerley, NMMU
Songimvelo [c]	?		7[b]	Steyn, MPB
Mthethomusa	?		3[b]	Steyn, MPB
Kwa Madwala			2	Steyn, MPB
Private reserves 2001 data [c]	8	1	9	Slotow, UKZN

[a] 3 animals were culled because of wounds received in Mozambique.

[b] Some of the hunted males were problem animals. A ? is inserted in that column to indicate that there were some problem animals on those reserves.

[c] Based on the database from a survey done by the Elephant and Owners Association in 2001 ($N = 56$ reserves with wild elephants), extracted by Slotow. Here we present the number of reserves which had killed elephants as problem animals or had hunted elephants.

Note: See text for details from Addo, which last culled an animal in 1968. Whether animals have been hunted or culled in Limpopo provincial reserves is unknown.

Table 2: Killing of problem animals and hunting in small reserves (data up to 2007 except for private reserves)

Small populations in South Africa

Elephants had been introduced to 58 small, fenced reserves (<1 000 km^2) by 2001 (Garaï *et al.*, 2004; Slotow *et al.*, 2005), and the number of small reserves with elephants probably exceeded 80 in 2007 (see Chapter 6). Two reserves have to date instituted culling as a means of population control. In both cases a family group was culled (Steyn, pers. comm.; Van Altena, pers. comm.).

A number of these reserves have removed elephants alive. These capture and removal events, while not resulting in elephant deaths, present an opportunity to learn about the effects of population reduction on the remaining population. Elephant groups have been translocated from Madikwe Game Reserve (five groups), Hluhluwe-Umfolozi Park (three groups), Phinda Private Game Reserve (five groups), Weenen Biosphere (one group) and Magudu Game Reserve (one group). These elephants were relocated to other reserves to form new populations.

Hunting has taken place in a large number of small reserves (table 2), but the effects on the population have been comprehensively studied only in Pilanesberg National Park (Burke *et al.*, 2008). See the relevant section below for key conclusions.

Problem animal control

A large number of small reserves have experienced problems with elephants, to the extent that at least 15 reserves have shot problem animals (table 2) (also see Chapter 4). At least six small reserves (Tembe, Pilanesberg, Hluhluwe/Umfolozi Park, Madikwe, Phinda, Greater St. Lucia Wetland Park) have destroyed both male and female elephants that killed people (unpublished information provided to Slotow by reserve management staff). In all cases involving females, the particular individual female was killed rather than the whole group. Elephants have been hunted in at least 15 small reserves (table 2).

Controlling problem elephants in and around the Kruger National Park has been ongoing since large-scale culling of elephants was stopped in 1994. In 2006/2007 fewer than 20 elephants were destroyed in and around Kruger (data extracted from Kruger internal diaries and reports housed at Skukuza archives by M. Hofmeyer). All of these animals were killed because they were deemed problem animals, because of threat to outside communities when they broke out of the park, damage to property inside the park, or a threat to guests or staff in the park. Some animals were destroyed because they had sustained serious injuries such as snare wounds.

Elephant that are shot on communal land around Kruger are given to the communities to salvage the meat and other products. Tusks are removed for safekeeping by the provincial conservation agency. In Kruger, the carcasses are left to scavengers in the areas far away from the wildlife products plant

Box 1: Proposed management of problem elephants at KNP (extracted from SANParks standard operating procedure by Hofmeyr):

Inside KNP: When an elephant (usually it is an individual) causes problems in staff villages or enters tourism facilities, it must be chased out/away. If an individual displays aggressive behaviour over an extended period, then a decision is taken on whether to destroy the animal or to capture and translocate it.

Elephants leaving KNP: The decision on the actions to be taken against elephants that left the park will be the responsibility of the relevant Provincial Environmental Authority. The first option will be to chase herds back to the park, and if this cannot be achieved the next consideration should be capture (in the case of family groups) and lastly to destroy them. Individuals and bulls that cause problems will most probably have to be destroyed, as it is not viable to capture and translocate these animals. Translocation of elephants is an expensive exercise and the areas for translocation in South Africa are limited (Chapter Six). It is therefore not a viable option to deal with problem elephants in this manner; they also often become repeat offenders and subsequently break out of their new locality.

in Skukuza, otherwise the carcass is transported to the plant and as much is used as possible (skin and meat mainly). The meat is sold internally to staff or restaurants. Skins and tusks are securely stored at Skukuza. At the time of writing (2007) the wildlife products plant is not fully functional due to limited usage since 1994. It is estimated that it will cost in excess of R14 million in repairs and maintenance to restore the plant to the required standard (internal report – Kruger National Park). The economics and broader consequences of this are dealt with in Chapter 10.

CULLING METHODS

Shooting methods

In Zimbabwe elephants to be culled were located using a fixed-wing aircraft, and a ground crew of three to five marksmen (Thompson (2003) suggests only three should be used because of safety concerns) were directed to the target group (Bengis, 1996; Thompson, 2003; Cumming & Jones, 2005). Elephants were brain-shot with heavy-calibre weapons (FN 7.62 mm automatic rifles were used on sub-adult animals, Conway pers. obs.), with up to 50 animals being killed within two minutes (Thompson, 2003; Cumming & Jones, 2005). A helicopter was used on only one occasion in Gonarezhou, and was discarded because the sound of the blades disturbed the elephants and caused them to run (Thompson, 2003). Details of the culling procedures used in Zimbabwe are provided by Thompson (2003: 272). Bulls in the breeding herds were generally shot first, and then the older females, generally the matriarch, in order to anchor the group (Thompson, 2003). Large trophy bulls were generally spared in most of these culling operations. In East Africa a helicopter was used to herd the animals to the 'killing ground' and to pursue any escapees, but they were shot from the ground as per the Zimbabwe method (Bengis, 1996).

Culling of elephants in Kruger was always conducted from a helicopter that herded the elephants until all in the group had been targeted (Bengis, 1996). Initially, Kruger elephants were immobilised using Scoline-loaded darts fired from a helicopter (see below) followed up with lethal brain-shots from a ground team (Bengis, 1996). However, this technique was shown to be physiologically stressful and inhumane, and was discontinued (Bengis, 1996). In an attempt to reduce the time interval between motor paralysis ('going down') and the administration of the lethal brain-shot, the technique was modified as follows: as soon as the animal went down following darting with Scoline, it was brain-shot from the helicopter. Inevitable delays and the wider scattering of carcasses of the target group meant this was not ideal (Bengis, 1996).

After the discontinuation of the use of Scoline, all elephants culled in Kruger were brain-shot at close range from a helicopter using heavy calibre rifles (.375 or .458) to cull bulls, and a semi-automatic rifle firing .308 (7.62 mm) brass monolithic solid bullets for females and other age classes. The advantage of the latter rifle was low recoil, large magazine capacity and rapid repeat fire if necessary. The helicopter continuously circled the herd, keeping them within the confines of the identified 'killing zone'. Shooting of the matriarch first anchored the rest of the family group, allowing all to be quickly shot in a small area (Bengis, 1996). For details see box 2. This technique was also used briefly in Etosha, Namibia, during the early 1980s (Bengis, 1996).

In Kruger, the processing of the carcasses constrained the culling rate and thus the total number of elephants culled. Between 1968 and 1970 two separate culling operations were conducted in Kruger, one in the southern half which supplied carcasses to the permanent abattoir in Skukuza, and one in the north which supplied carcasses to a temporary facility on the Shingwedzi River near the western boundary. The latter facility collected the ivory, treated the skins and cooked the meat in large cast iron pots, for sale at a low price to communities neighbouring the park. Cooking of the meat before sale was necessary due to the uncertainty at the time regarding the possibility that elephant might be carriers of FMD. This has subsequently been found not to be the case. The temporary northern facility allowed increased culls in the years 1968–1970 (see table 1). In Hwange, Zimbabwe, up to 5 000 elephants were killed over the three-month winter period in the 1980s (Cumming & Jones, 2005). A target of 50 animals per day could be achieved if the animals were breeding herds, but even half that would be difficult to reach if bull groups were targeted (Thompson, 2003).

Chemical methods with specific reference to Scoline

For reasons of safety to operators and the public, the culling of elephants in Kruger was initially conducted using the drug Scoline (succinyldicholine chloride). This compound paralysed the animal, rendering it immobile and harmless once it was recumbent until it could be dispatched by means of a brain-shot. It was shown by Hattingh *et al.* (1984a; 1984b; 1990a; 1990b) that the use of Scoline for culling elephants was inhumane. These authors showed that in elephants the locomotory muscles are immobilised initially, rendering the animal recumbent yet totally aware of its surroundings. A while thereafter the diaphragm is affected, stopping respiration. The heart muscle continues to function for several minutes thereafter and the animal eventually dies of asphyxiation if it is not brain-shot. The use of Scoline was therefore discontinued and is not approved in the Norms and Standards (DEAT, 2008) or SANParks Standard Operating Procedures for either culling or euthanasia.

Financial assessment of culling

Culling, if humanely conducted, and with recovery of the animal products, can be a complicated process. It needs specialist equipment and personnel, and is distracting to management (Owen-Smith *et al.*, 2006). 'Culling of elephants whether on a small or large scale is expensive' (Martin *et al.*, 1996). The costs in KNP for culling approximately 800 elephants and processing them was calculated in year 2005 values as ZAR5 298 260 (table 3), about ZAR6 600 per elephant. The field costs alone (excluding salaries) were ZAR1 761 per elephant. The non-field costs excluded the commissioning of the abattoir facilities, and some of the processing costs such as canning (Grant, 2005).

Box 2: Proposed management of problem elephants at KNP (extracted from SANParks standard operating procedure for elephant culling by Hofmeyr):

Elephants are culled using rifles. The procedure differs slightly for bulls compared to breeding herds. For bulls, single animals or small groups (2–4) are selected. The helicopter slowly herds the animal(s) to a selected work site, which is chosen for its distance from the tourist road system, proximity to a patrol or firebreak road, heavy vehicle access, and terrain. At the selected site, the helicopter flies low and at slow airspeed, lining up the marksman over and behind the target, in a direct line with the animal's direction of movement. This is more easily accomplished with a 'right door off' helicopter for a right-handed marksman, and for a 'left door off' helicopter for a left-handed marksman. It is essential that the marksman is brought over the midline of the elephant, in line with its direction of movement. For opposite-handed marksmen, it may be necessary for the pilot to 'crab' the helicopter slightly to give the marksman the correct approach and aiming angle.

Elephants have a very smooth gait with little head movement and generally move in a straight line. As the helicopter flies above the elephant, approaching from behind, the marksman shoots the animal in the midline, aiming at the lower part of the back of the skull. Excellent landmarks for this aiming point are the two large longitudinal muscle masses, clearly visible on the back of the neck. As the helicopter overflies the elephant, the marksman needs to aim between these two muscle masses at a forward angle of between 30° and 45°. It is important to note that an elephant's brain lies very deep, and a shot at the skull (rather than neck) from behind, frequently passes over the top of the brain cavity. If the shot placement is too far back on the neck or at too steep an angle, as long as it is in the midline, it should strike the cervical spinal chord, which is also instantly effective. For lateral brain-shots from the side of an elephant, the aiming point should be at the angle between the ear-slit and the cheekbone.

The elephant should collapse instantly at the shot, frequently in sternal recumbency with tusks ploughed into the ground. If falling in lateral recumbency, the spasmodic jerking of one or both of the hind legs is frequently indicative of a good brain-shot.

If more than one bull elephant is to be culled, the second (or more) bull(s) is herded by the helicopter to the proximity of the first carcass, and then shot. A minimum calibre of .375 inch firing a monolithic solid bullet must be used in the culling of elephants. Only shots to the brain should be used and once the animal has collapsed a second shot (insurance shot) should be administered to make sure that it is dead. In the rare event of an elephant only being stunned by a shot close to the brain, this animal may regain consciousness and be dangerous.

In the case of elephant breeding herds, the helicopter separates a family group out of the breeding herd, and then slowly herds this group to the working site. The selection of family group depends on its size (relative to the day's quota) and direction of movement (towards the selected working site). At the working site, the matriarch is shot first, which anchors and confuses the rest of the group. The rest of the group can then be quickly dispatched, as they mill around or are herded around the fallen matriarch.

Shooting of elephants from the ground is usually done in the case of solitary injured or problem animals, in the absence of helicopter back-up. When firing frontal brain-shots in elephants, one should take cognisance of the fact that an elephant's brain is also located low down in the skull. Good landmarks for the brain level are the bilateral protuberances caused by the 'cheek bones' (zygomatic arches). When aiming from the frontal position, another important factor is whether the head is in the neutral position or lifted alert/aggression position. In the neutral position, the aiming point is on a level with the eye line, whereas when the head is in the lifted alert/aggression position, the aiming point is lower, approximately on the second or third crease of the trunk. From a lateral position, the angle where the ear slit meets the cheekbone makes a good landmark for the position of the brain. For an oblique rear or rear shot, the back of the neck or behind the ear, at ear slit level, are good aiming points.

Elephant products are potentially valuable. In KNP only the blood and intestines were left in the field, and the rest used (Whyte, 2001). The ivory is the most valuable single product, but if the hides are properly treated they represent an almost equivalent value. All meat was used either for biltong or for a canned meat product. Biltong and canned meat were sold to tourists while the cans were also issued to field staff as rations. Excess carcass fat was rendered and sold to the cosmetic industry, while all other parts of the carcass were made into carcass meal for sale to the agricultural industry. Taking into account all of the potential income excluding ivory, 800 elephants would generate about

ZAR10 976 000 per year. This provides a profit of ZAR5 677 740, or just over ZAR7 000 per year per elephant (excluding recapitalisation of the abattoir). The addition of ivory to the income would effectively double the profit. Note that these figures have not been externally audited, and should be regarded as approximate.

North West Parks and Tourism Board conducted a feasibility study for culling of elephants in Madikwe Game Reserve. Based on their investigations, there is no local market for the elephant products, and carcasses would have to be transported to a major centre for processing (Pieter Nel, NWP&TB, pers. comm.). Based on transport of carcasses to Gauteng, and on culling groups of 10 elephants, the costs per culling were calculated at about ZAR4 000 per elephant (table 4). If a suitable processing plant could be found closer, in Mafikeng or Rustenburg, the costs would be reduced to about ZAR3 578 per elephant. The potential income from culls was not calculated.

THE VARIOUS MANAGEMENT CONTEXTS FOR CULLING

Overpopulation and population control

Elephants, being large, have populations limited by bottom-up effects (*sensu* Sinclair, 2003). In other words, their population number is expected to be limited by some underlying resource, most likely food. Top-down control, i.e. from predators such as humans, has been proposed as a historical elephant number-limiting mechanism by some (Cumming, 2007). Bottom-up control of population size manifests through density-dependent effects, where as the population increases, the per capita population growth declines (Sinclair, 2003; see also Coulson *et al.*, 2004; Owen-Smith *et al.*, 2006). Such density dependence has been found for elephants in the Serengeti (Sinclair, 2003). There is some evidence for density dependence in Kruger National Park (Van Aarde *et al.*, 1999), but it is tenuous. Errors in the population estimates can lead to spurious regressions of population change against population density, and migration between subpopulations may further confuse the results. Nevertheless, Van Aarde *et al.* (1999) concluded that: 'The method has small flaws, but it is contended that these will not obscure the general results.'

While it is inevitable that elephant numbers within a confined area must eventually reach a limit (Owen-Smith *et al.*, 2006), and thus that the net population growth rate must decline to zero at some maximum density, it is not certain that elephants in all areas will show a smoothly declining population growth rate as a function of population density, commencing at moderate elephant densities. For example, there is no evidence yet for density dependence in elephants at Addo (Gough & Kerley, 2007). The issue of density dependence is explored in greater depth in Chapter 2.

Costs (based on an annual cull of 800 elephants in Kruger):	
Item	**Per year costs (ZAR)**
Average daily helicopter costs (1.5 hours per day @ 2 200 per hour = 3 300 per day)	440 000
Transport truck @ 62 200 per month	311 000
Trailer for transport truck @ 21 000 per month	105 000
Tractor (x2) costs @ 38 826 per month each	388 260
Trailer (x2) @ 620 per month each	6 200
Mobile crane @ 21 160 per month	105 800
Ground crew transport @ 10 600 per month	53 000
Staff salaries (if all staff are SANParks)	3 009 000
Operating costs: salt, spices, cleaning materials, PPE, etc.	100 000
Abattoir costs: water, electricity, etc.	420 000
Abattoir maintenance	360 000
Hidden costs not included: operating costs of processing (e.g. canning); commissioning and capital costs.	??*
Total costs (excluding hidden costs)	**5 298 260**
Income (based on an annual cull of 800 elephants in Kruger):	
Item	**Per year income (ZAR)**
Meat products @ 4–11 per kg ('average ZAR5.00')	1 200 000
Hides (average 200 kg per elephant: last sold at 60 per kg dry salted)	9 600 000
Front feet (220 for front feet per elephant)	176 000
Carcass meal (sold at 'break even' prices)	0
Total income	**10 976 000**
Potential profit (income – cost, excluding some processing and capital costs)	**5 677 740**

* Commissioning and capital costs for the meat processing plant estimated at ZAR14 000 000 (see text).

Note: Above calculations exclude the sale of ivory (average of 5 kg per tusk per elephant, sold at an average price of ZAR750 per kg) = ZAR6 000 000

Table 3: Estimated costs and income from culling 800 elephants per year in Kruger National Park (Grant, 2005: 315)

The absence of natural density-dependent population controls at moderate population densities (i.e. densities lower than those which result in dramatic habitat transformation and starvation of the elephants and other species) may necessitate management intervention if such scenarios are to be avoided. Culling by removal of the annual population increment results in population numbers remaining approximately constant from year to year. Culling in excess of the population growth rate is the only viable mechanism by which populations can be reduced in size in the short term. The 'short term' means up to 5–15 years, depending on whether the animals in the population are mostly old or young. Because of the high cost of capture and translocation, and the increasing scarcity of receiving habitat (Chapter 5), this is not a viable alternative to culling where a near-immediate reduction in the population size is the objective. Contraception is a potential alternative to culling if population size reduction *per se* is not required (Chapter 6).

Item	Units	Cost per unit (ZAR)	Units	Total costs (ZAR)
Veterinarian travel	1	4	710	2 840
Pilot's travel	1	4	710	2 840
Helicopter costs	1	4 500	3	13 500
Equipment and drugs	2	500	2	2 000
Park staff				Not included
Veterinarian	1	350	5	1 750
Assistants	2	200	5	2 000
Tractor and trailer	1	8	60	480
Heavy duty truck and trailer	2	15	355	10 650
Bakkie 1 ton		4	60	720
Bakkie 1 ton (Gauteng return)		4	710	2 840
Total cost for 10 elephants				39 620
Cost per elephant				3 962
Note: Total cost/elephant if carcasses are transported to Mafikeng/Rustenburg = ZAR 3 578				

Table 4: Estimated costs of culling a group of 10 elephants at Madikwe Game Reserve, North West Province, with carcasses transported to Gauteng for processing (source: unpublished estimates provided by Pieter Nel, North West Parks and Tourism Board)

The key issue involves how to define 'overpopulation' and ensure management actions are triggered by ecological indicators rather than elephant numbers (see Owen-Smith *et al.*, 2006). Historically, elephant target densities were set arbitrarily (Van Aarde & Jackson, 2007, Chapter 1).

Decision-making around elephant numbers has moved away from a simple maximum density-based approach to one using indicators from the environment (there is a historical review in Chapter 1, and see current examples of such decision-making processes in Chapter 12 and Slotow *et al.* (2003)). The main reasons for abandoning a single, constant maximum elephant density (sometimes characterised as a 'carrying capacity') are that (1) carrying capacity is not a constant in environments with a highly varying climate (McLeod, 1997); (2) a coupled plant–herbivore system, especially one involving long-lived plants and animals, may not smoothly reach a maximum, but may oscillate or alter to a new state at high herbivore density; (3) herbivore numbers are probably constrained by the availability of spatially or temporally restricted key resources rather than general conditions; and (4) there is insufficient quantitative information relating to elephants at high densities to set density-based estimates with any reliability in most circumstances.

The use of ecological indicators to drive decisions requires them to be spatially explicit. For a reserve the size of Kruger such indicators will vary regionally, and as such management may be implemented only in specific areas – that is, the total population size may not be relevant. Even for small reserves, population density *per se* presents a weak indicator for management intervention when it is based on extrapolation from other situations because elephant effects are governed by the specific ecology of each reserve (see Chapter 3). It is therefore preferable that local ecological indicators be used to trigger management interventions.

Population control should have specific objectives, and depending on the objectives, different approaches can be used to achieve them. The longevity of elephants should always be considered. There may be effective short-term approaches that have long-term negative consequences.

Approach 1: Culling adult males

The culling of males is an extremely inefficient and usually ineffective way of reducing the population size or growth rate. The reason is that the breeding herds continue to produce young at a rate faster than adult males can be culled (even if nearly all males are culled – Martin *et al.*, 1996). Removal of adult males should therefore occur for specific objectives unrelated to population size or growth, such as preventing crop-raiding, fence-breaking or excessive damage to trees. The adult bull elephants are disproportionately linked to the pushing over of large trees (see Chapter 3, and Midgley *et al.*, 2005), but not necessarily to ringbarking, another important cause of tree death. Tree-pushing is widespread among bull elephants, therefore there is reasonable cause to believe that a reduction in bull density will lead to a reduction (but not elimination) of tree damage. On the other hand, breakouts are not necessarily dependent on the *number* of males, since some individuals have a greater propensity to break out, so specific individuals would have to be targeted to reduce breakouts, or fencing would have to be improved/maintained (Chapter 7). Male elephants are more valuable in terms of trophy hunting (see Chapter 10, and consumptive use below), because of the larger size of their tusks, but trophy hunting, by itself, is an ineffective means of population control.

Targeting of adult males would, therefore, be warranted when an objective is to reduce the probability of a particular action that is most commonly attributed to adult male elephants, rather than to reduce the population *per se*. In the first comprehensive aerial census in Kruger in 1967, adult bulls comprised 15 per cent of the total population (Whyte, 2001). In order to maintain this proportion, the prescribed culling quota for bulls was always 15 per cent of the total cull, with the balance from breeding herds (Whyte, 2001). Selection of bulls for any particular cull was a random process and was based on location, group composition and individual characteristics (large tuskers were excluded from culls) (Whyte, 2001). Usually only two or three bulls were culled per day (Whyte, 2001), due to the limited capacity of the processing plant (Whyte, pers. obs.). The bull quota in Kruger was frequently used to address the problem of break-out elephants and other problem elephants (which were mainly bulls), as well as to reduce the numbers of tree-breaking individuals in designated 'botanical reserves' in the KNP (Bengis, pers. comm.).

Removal of individuals or small groups of males is relatively simple, and they can be shot from the air (Whyte, 2001) or the ground (Burke *et al.*, 2008). Such removals do affect the local population, but for a relatively short time (Burke *et al.*, 2008), and the elevated stress that results in the remaining animals is deemed acceptable (Burke *et al.*, 2008; and in the opinion of the authors).

There are a number of concerns about targeting only adult males. Firstly, larger (older) adult males are the more spectacular tourism animals, and may be the most important contributors of genes to following generations (Martin *et al.*, 1996). Secondly, selective removal of adult males over an extended period will result in a compression in age of the adult male population in the future due to simple numerical effects (see Milner *et al.*, 2007 for review). Such a compressed age-group is relatively young, and may swamp the dominance hierarchy within the adult male population. Distorted male age hierarchies have been implicated in abnormal behaviour in these younger males, such as elevated aggression, killing people, and killing rhino (Bradshaw *et al.*, 2005; Slotow *et al.*, 2000; Slotow *et al.*, 2001; Slotow & van Dyk, 2001). Thirdly, older males have greater reproductive success, and longevity may reflect fitness (Hollister-Smith *et al.*, 2007). Because of the above, any significant manipulation of the adult male population needs to be carefully considered, and should be a truly random process across all age classes if skewing of the age structure and the associated problems are to be avoided. Martin *et al.* (1996) also point out concerns over selective removal of males.

Approach 2: Removal of entire family groups (and associated males)

The only feasible manner of culling to reduce population growth rate (and thus population size, in the long term) is by removal of females. Where the total population size must be significantly and rapidly reduced, in practice this is best achieved by culling entire family groups, along with their associated young males (Whyte, 2001; Cumming & Jones, 2005). It has the further advantage of leaving no traumatised family members, although nearby (and possibly related) family groups may still be disturbed. Because of the complex social system of elephants, removal of entire family groups is considered the most ethical approach to population reduction (DEAT 2008; Martin *et al.*, 1996). In Kruger, all members of the selected group were culled regardless of sex or age class, unless young animals were to be translocated. This practice was terminated in 1994 (Whyte, 2001). Usually a daily cull would have comprised about 15 animals, with carcass recovery to a centralised abattoir being the limiting factor (Whyte, 2001). In Zimbabwe, up to 50 animals were killed by a team per day (Thompson, 2003), and carcasses were processed *in situ*, with the meat and skins taken to a temporary base in the protected area for cleaning and drying.

The approach is not, in fact, completely age and sex neutral, because the proportion of juvenile to older individuals tends to increase in harvested populations (see Gordon *et al.*, 2004 and references therein). In a modelling exercise, even if herds are removed randomly, the average age of the matriarch leading the group may decrease (Mackey & Slotow, unpublished manuscript).

Some degree of disruption of the complex social network is inevitable (McComb *et al.*, 2001; Wittemyer *et al.*, 2005; Wittemyer & Getz, 2007) with culling as it is with live removals. The consequences include long-term stress to the population (Gobush *et al.*, 2007). It is possible to remove female groups from relatively small populations. Family groups have apparently been successfully culled from small reserves in two cases (Steyn, pers. comm.; Van Altena, pers. comm.), although the consequences were not studied in detail. Groups have been successfully removed live from Phinda on four occasions and Hluhluwe-Umfolozi Park on three occasions (Slotow pers. obs.). In all cases there were no major disruptions to the animals that remained behind (Phinda: H. Druce (Elephant Monitor), pers. comm.; K. Pretorius (Reserve Manager), pers. comm.; Slotow, pers. obs.; Hluhluwe-Umfolozi Park: T. Burke (Elephant Monitor), pers. comm.; Slotow, pers. obs.). Five groups (Hofmeyr, pers. obs.; Slotow, pers. obs.) have been removed from Madikwe, but the consequences were not systematically studied.

Approach 3: Selective removal within family groups

Natural mortality from droughts or predation would in the first instance be just-weaned calves (Moss, 2001; Dudley *et al.*, 2001; Leggatt, 2003; Woolley *et al.*, 2008). Simulation studies, based on southern African data, indicate that episodic droughts with about a five-year frequency that resulted in 100 per cent mortality of just-weaned calves, or about a eight-year frequency that resulted in 85 per cent mortality of infants and weaned calves (0–7 years old), would lead to a zero net population growth (Woolley *et al.*, 2008). Mimicking natural processes by selective removal of young elephants has not been attempted (Cumming & Jones, 2005), although it has been considered in a number of reserves (Goodman, pers. comm.).

The most efficient means of reducing future population growth is removal of young adult females (Van Aarde *et al.*, 1999; Woolley *et al.*, 2008), where efficiency is defined as minimising the total number of individuals that need to be culled to achieve a given reduction in the population growth rate. Population models indicate that removing an annual number of prepubertal females equivalent to just 2 per cent of an elephant population would stop its growth (Whyte *et al.*, 1998; Van Aarde *et al.*, 1999), compared to the 6 per cent that would need to be removed if an age-and-sex neutral approach were to be used.

Removal of selected young individuals (as opposed to other herd members) from a herd on a periodic basis would simulate 'natural mortality' of elephants from drought or predation, and could be relatively easily implemented from the ground using a rifle (possibly silenced) or a lethal dose of drugs. The stress caused to the remainder of the family is unknown. It could cause major gaps in age classes (Martin *et al.*, 1996), and there are ethical considerations (Chapter 9). This approach precludes natural selection from acting on particular individuals; it would disrupt more different herds than removal of entire herds, and like contraception, would not lead to a significant immediate reduction in elephant impacts.

The Norms and Standards precludes removal of individuals from a breeding herd: 'an elephant may not be culled if it is part of a cow-calf unit unless the entire cow-calf unit, including the matriarch and juvenile bulls, is culled' (DEAT, 2008), so this is no longer an option for management.

Synthesis of approaches

The relative effectiveness of the different approaches to solving particular management problems are summarised in table 5. Each approach has merits, depending on the objective. Note that culling is generally not the only potential management intervention to solve a particular problem. The process of evaluating the relative merits of various alternatives is dealt with in Chapter 12.

Elephant population age–sex structure

The age–sex structure of a population is important for two reasons (see also Milner *et al.*, 2007 for further discussion). Firstly, when specific age classes are missing from a population, behavioural abnormalities can occur (e.g. Slotow *et al.*, 2000). Secondly, future population growth is governed by the current population structure. A relatively young population displays a higher growth rate than an older population, and this effect persists for an extended period, while the population comes to a stable-state distribution (e.g. Mackey *et al.*, 2006; Mackey & Slotow, unpublished manuscript). What might be considered a normal age–sex structure is dealt with separately in Chapter 2.

The tendency of culled populations to 'overshoot' their natural limits once culling has been discontinued is termed 'eruptive growth'. An eruptive population temporarily exceeds its ecological carrying capacity – that is, the long-term limit imposed by its key limiting resource (Caughley, 1970) – causing a decline in that resource, and subsequently in the population itself (Caughley, 1970). Density dependence does not act to constrain an eruptive population as it would a population with a stable age-structure (Mackey & Slotow, unpublished manuscript). Eruptive growth is related to the population response inertia introduced by the age-structure distortions discussed above. There is no field-based evidence that eruptive growth does or does not occur in elephant populations, since this question has not been adequately addressed for any post-culling elephant population.

There is also no reason why elephants should behave differently from other herbivores, where eruptive growth has been widely observed (see for example Forsyth & Caley, 2006 for population models of several species showing eruptive growth). What is evident is that the formerly culled populations in both Kruger and Zimbabwe have grown at near-maximum rates since culling was suspended (Van Aarde & Jackson, 2007).

It must also be noted that the elephant population in Kruger is still in a growth phase from the deep reductions at the end of the nineteenth century, and thus the age structure was probably not a stable one during the period of culling. Although there is currently no compelling evidence available to assess this, the possibility of eruptive growth, either from the 'founding' effects of the Kruger population, or as a consequence of culling, cannot be eliminated. The relatively high population growth rates recorded in Kruger in the decade since culling ceased may simply be because this population is far from its resource limitation level (see Owen-Smith *et al.*, 2006 for a discussion of the ecological carrying capacity of elephants in Kruger).

Many of the problems associated with skewed age-sex structure have manifested in small populations. Many of the smaller reserves have a population structure clearly biased towards young adults (Slotow *et al.*, 2005), and do display abnormally high growth rates (Mackey *et al.*, 2006), which may in time show the characteristics of eruptive growth. Until 1993, the founder populations in all the elephant reintroduction areas consisted of young (<8 years old) elephants (Slotow *et al.*, 2005; Whyte, 2001). Since 1993, elephants have been moved as family groups including adult females, and since 1998 large adult males (>35years old) have been included as well (Slotow *et al.*, 2005; Whyte, 2001).

The best-known behavioural abnormality resulting from a skewed age-structure was the killing of white and black rhino by young male elephants in Pilanesberg, Hluhluwe-Umfolozi, and other reserves (Slotow *et al.*, 2000; Slotow & van Dyk 2001; Slotow *et al.*, 2001). These males had matured in the absence of an older male hierarchy, and were entering musth much earlier, and for much longer, than normal (Slotow *et al.*, 2000). This problem was corrected by the introduction of older males into the population at Pilanesberg in 1998 (Slotow *et al.*, 2000) and Hluhluwe-Umfolozi in 2000 (Slotow *et al.*, unpublished data). Subsequently, older males have been introduced to most populations founded by young elephants, and the problem of elephants killing rhino has been largely negated, although there are occasional mortalities from time to time in various reserves (Slotow, unpublished data).

Female elephants have been displaying an abnormal amount of aggression in circumstances where they would normally retreat (Slotow, unpublished data). This has resulted in human deaths in at least five small reserves in South Africa (Slotow, unpublished data). This behaviour may be due to female elephants maturing in the absence of an older experienced matriarch, and thus not learning how to behave in threatening circumstances. These females show abnormal responses when experimentally tested relative to females from a normally age-structured population (Shannon *et al.*, unpublished data). Alternatively, the behaviour may reflect long-term (>12 years) effects of elevated stress levels associated with capture and introduction into a new environment. Learnt abnormal behaviour related to social disruption will almost definitely require lethal control of those individuals responsible.

The problems displayed in smaller reserves may also be present in larger populations such as Kruger National Park, where the age-structure may have been somewhat affected by long-term culling despite the policy of age- and sex-specific neutral removals (see above), although there is little evidence to suggest that this is the case. In the past 10 years there have on average not been more than one incident of elephant–human conflict per year in the Kruger, with three incidents in 2007, and three elephants being culled after charging staff in the 12 months prior to October 2007 (data extracted from Kruger internal diaries and reports housed at Skukuza archives by M. Hofmeyr). No culling-related significance can be attributed to the recent apparent increase; it may simply be a result of increased numbers of elephants and tourists.

It is very difficult to define a 'normal' population age–sex structure, as the population structure varies somewhat under natural circumstances. However, the complete absence of a particular age–sex class (e.g. older male or female elephants) is definitely abnormal and results in problems. The preponderance of young breeding individuals, for example 10- to 20-year old females, will cause above-average growth rates until that age class stops breeding (i.e. only after >50 years; see discussion of population consequences below).

Problem animal control

Problem animal control occurs both inside and outside of reserves, although the focus tends to be on elephants that have broken out of reserves (DEAT, 2008). The traditional method of control is to shoot the culprits (Hoare, 1995). This represents symptomatic relief rather than a long-term solution to the problem (Hoare, 1995). Ongoing killing of problem animals on the periphery of protected areas may erode the quality of the remaining animals in terms of trophies (Hoare, 1995) and genetic diversity (Martin *et al.*, 1996). A number of alternatives to problem animal control are being investigated (e.g. better fencing, *Capsicum* repellents – Osborne & Rasmussen, 1996).

Male problem animals outside reserves tend to be alone or in small groups, and can be relatively easily controlled (Chapter 4). However, when the animal is still within the reserve, identification of the offending individual can be difficult because of the lag between reporting the incident and locating the elephant.

Such uncertainty has resulted in more than one animal being killed in order to ensure the culprit was killed (e.g. at Pilanesberg when three males were killed to ensure that the one that was killing rhino was eliminated – Slotow & Van Dyk, 2001). Alternatively, the culprit is not killed because the specific elephant could not be identified (e.g. at Hluhluwe-Umfolozi, from a group of four elephants that killed rhino, Slotow, pers. obs.).

Management objective	Random removal across population		Random removal of complete family groups		Selective removal of young individuals from family groups		Selective removal of males	
	Effectiveness		Effectiveness		Effectiveness		Effectiveness	
	Short	Long	Short	Long	Short	Long	Short	Long
Reduce impact on large trees	2	1	3	3	4	4	1	2
Reduce biomass removal	1	3	2	2	4	1	3	4
Problem animal control	2	2	2	2	4	4	1	1
Population reduction (for whatever reason)	2	3	2	2	3	1	4	4
Correcting eruptive growth	4	4	4	4	1	1	4	4
Correcting age–sex problems (too many males)	4	4	4	4	4	4	1	1
Correcting age–sex problems (population young)	4	4	4	4	3	2	4	4
Correcting age–sex problems (too many breeding females)	4	4	4	3	4	4	4	4

Rankings: rank 1 = most effective; rank 4 = least effective.
Short-term indicates a period up to 5 years. Long-term indicates a period >5 years.

Table 5: Relative effectiveness of different culling approaches in achieving specific management objectives

Problem animal behaviour has been observed to escalate within an individual over time, as the elephant becomes habituated to humans and their infrastructure (Slotow, pers. obs., from Pilanesberg, Hluhluwe-Umfolozi, Mkhuze). Individuals progress from pulling up pipes, to damaging cars, to killing people. Accordingly, one approach that is being used in populations where each individual can be identified is to create 'rap sheets' (records of 'bad' behaviour that can be attributed to identified individuals in the population) of problem animals, and to identify repeat offenders for subsequent removal (Slotow, unpublished information).

Not all problem animals are male, and particularly within some reserves, female elephants may be posing a greater risk than males. It is very difficult to remove a single female from the population, either because of difficulties of identification, or because of the stress placed on the remaining animals. This has been successfully done in Greater St. Lucia Wetland Park, where a number of female elephants were suspected of being responsible for an unprovoked attack on a vehicle, which resulted in the death of people. All the adult females in the group were sequentially immobilised and the culprit identified by metal scrape marks and chips on the tusks (Conway, pers. obs.).

Inside Kruger, problem elephants are rare, usually animals that have attacked people or consistently broken into rest camps (Whyte, pers. obs.). Culprits are sometimes identified by the tear patterns of ears or tusk shape or marked with paint ball guns. Where the individuals can be positively identified, they are usually brain-shot using heavy calibre rifles from a helicopter, or else shot by the local Ranger on foot from the ground (Whyte, pers. obs.).

When elephants break out of Kruger, or other protected areas, attempts are usually made to drive them back inside (Whyte, pers. obs.). However, once outside of a National Park, legislation dictates that they become the responsibility of the provincial conservation agencies (see Chapter 11). Often they are shot from a helicopter or from the ground by staff of these agencies (Whyte, pers. obs.).

The situation around Kruger (and potentially at Mapungubwe, Madikwe, Pongola and Tembe) is complex because the boundaries of the park stretch across international and provincial borders. The control and management of problem animals is covered by different legislation in each jurisdiction (Chapter 11). Currently, if an elephant leaves the Kruger boundaries, ranger staff from Kruger will respond only when specifically requested by the provincial authorities of Limpopo Province or Mpumalanga Province (Hofmeyr, pers. obs.). In Mpumalanga most problem animal cases are handled directly by Provincial staff. In Limpopo Province the ranger staff are frequently asked to help out with destroying elephants that are causing problems in community areas. The situation is more distinct with the international boundaries, and Kruger staff do not follow up elephants that leave the park into Mozambique or Zimbabwe. Only if there was a direct request, and in collaboration with the relevant authorities in those countries, would Kruger staff help with elephant problems. The human population is very sparse along both the Zimbabwe and Mozambique boundaries so such requests have not been made.

Smaller reserves in South Africa have well-maintained fences and there have been relatively few break-outs from such reserves (Slotow, pers. obs.). Within these reserves problem animal control will be primarily to protect humans, other species, and infrastructure on the reserve. There have been no break-outs of elephants in North-West Province, but there have been break-outs from at least eight small reserves in KwaZulu-Natal and three in Limpopo Provinces (Slotow, unpublished data). Ezemvelo KwaZulu-Natal Wildlife routinely either chased elephants back, or immobilised and transported them back into the reserve (Slotow, pers. obs.).

Disturbance culling to move elephants around the landscape

One possible application for culling is to reduce the density of elephants in a particular sub-area of the range. The effect could be direct (by removal of animals) or indirect (by making an area less attractive to elephants through the culling-related disturbance). Such disturbed elephants – that is, elephants with experience of a cull – may move out of the area, resulting in a lower localised density. The trade-off between risks and benefits of disturbance culling need to be carefully evaluated.

In Kruger, when culls were compartmentalised into sections of the park, regional population totals varied in response (Whyte *et al.*, 1999). The year after a cull in a region, population totals declined more than could be accounted for by culling alone, while a year later, regional population totals increased in excess of that possible by reproduction alone. Movements in and out of these regions in response to culls must have been responsible for the trends (Van Aarde *et al.*, 1999; Whyte *et al.*, 1998). These results imply that localised culling results in some movement out of the affected area by the remaining elephants. The regional culling boundaries in Kruger did not conform to the elephant clans' home range boundaries, and such movements could have been within the normal home range of those elephants (Whyte, 2001). Elephants may return to the culling area at a later stage, and an analysis based on home ranges rather than on arbitrary logistical boundaries might have yielded rather different results (Whyte, pers. obs.).

In Hwange, elephant numbers remained low in areas where culling had taken place for up to two to three years after a cull (Cumming, 1981), indicating that there may have been some localised disturbance effect. These culls were in areas towards the edge of the park. There is no indication that elephants moved out of the area, but the implication was that elephants did not move into the area, at least over the medium term. Elephants have home ranges which they will defend against non-clan members with certain antagonistic behaviours (Moss, 1988). Thus one would expect that where a decline (but not complete removal) of a 'clan' has been effected, a replacement of the population through immigration is unlikely. When the western boundary fence of the KNP was removed, there was little or no increase in the elephant populations of the Klaserie and Timbavati Private Nature Reserves, where established populations of elephants already existed. In the Sabi-Sand, however, only a small population was present (mainly bulls with a small translocated herd of young females and males). This area was quickly colonised once the fence was removed (Whyte, 2007).

Prior to the erection of the game fence in Sebungwe (Zimbabwe), massive culling in 1968 in the area to the south of the fence caused 250 animals to move north of the fence (Cumming, 1981).

In Kasungu (Malawi), poaching occurred along one side of the park, which acted as a sink (Bell, 1981). Most of those killed were males (Bell, 1981), and the implication is that additional males were continually moving into the area. A radio-collared male elephant that was near an animal killed in agricultural fields adjacent to a national park in Zimbabwe returned to the agricultural fields within five days (Hoare, 2001). This 'disturbance culling' was clearly not discouraging elephants from moving into the area of risk.

During the 1960s (particularly after 1966), attempts were made to keep elephants out of the Bunyoro Forest (Uganda) through disturbance culling ('chasing elephants out of young regeneration areas' or 'keeping elephants out of the forest' (Laws, 1974)). Although initially successful, the programme failed because elephants modified their behaviour by entering the forest at night to simply avoid the disturbers working during the day (Laws, 1974). 'As well as causing considerable disturbance, the control shooting over the years has been wasteful, uneconomic and grossly inhumane' (Laws, 1974).

It may be that elephants do not avoid areas of high risk, but rather change their behaviour in response to the risk. Elephants in Tarangire, Tanzania, adopted different day-time (high-risk) and night-time (low-risk) behaviour, foraging while walking slowly at night, and 'streaking' through dangerous communal farming areas during the day (Douglas-Hamilton *et al.*, 2005).

Hunting elephants

Consumptive use is normally a by-product of culling or problem animal control. Although sustainable use is part of the mission statement and governing legislation of most conservation agencies in South Africa, the use of elephants (or any other species) is not a primary management objective in national parks administered by SANParks. However, elephants have been hunted in the Makuleke region (a community-owned area within the greater Kruger boundary, and co-managed by SANParks) and Pilanesberg National Park, which is managed by North West Parks and Tourism Board (table 2). Hunting has also occurred in the Tembe Elephant Park (owned by the Tembe people, but managed by EKZN Wildlife) and in Mpumalanga Parks Board reserves. Hunting also occurs in some privately owned reserves (table 2).

Hunting of bull elephants is a straightforward process when conducted professionally by experienced personnel, and has only a minor effect on the elephants that remain behind (Burke *et al.*, 2008). The Norms and Standards (DEAT, 2008) prescribes the manner in which elephants may be hunted, and excludes females from being hunted unless vagrant. 'Green hunts' (in which a client pays to fire a non-lethal immobilising dart into the elephant) are prohibited in terms of the Threatened and Protected Species Regulations (2008).

SHORT- AND LONG-TERM CONSEQUENCES OF CULLING

Short-term effects on remaining elephants (stress)

Disturbance causes stress, and an important consideration prior to culling is an assessment of the impact that culling will have on the animals that remain behind. 'It is naive to believe that, if an entire herd is killed, the remainder of the population know nothing about the event' (Martin *et al.*, 1996). This must also apply to translocations, as the disturbance and impact on animals remaining will be almost identical. Herds may be able to signal their distress over considerable distances using infrasound. Radio-collared elephants in Sengwa, Zimbabwe, occasionally visited cull-sites shortly after the event (Martin *et al.*, 1996). Elephants in an area adjacent to Hwange were inferred to have responded to culling 150 km away by disappearing into the bush, and were later found at the opposite end of the reserve, bunched up (Moss, 1988).

Cumming & Jones (2005) indicate that culling does result in disturbance, and conclude that major interventions involving 'more than one team operating in a culling season may result in unacceptable levels of disturbance'. They do not provide the basis for this statement, but the implication of the quote is that such disturbance is unacceptable because of the stress imposed on the elephant population. After major culling operations, elephants in Hwange may spend less time at waterholes during the daytime, but their behaviour towards tourists appeared not to alter (Martin *et al.*, 1996). Further, Whyte (1993) initiated a study of the effects of culling on elephants in Kruger because of concerns based on reports from rangers that after culls elephants 'disappeared from the area'. This effect was not based only on the helicopter actions, because Whyte (1993) noted that when elephants were immobilised from helicopters they did not react in the same manner.

Whyte (1993) observed the behaviour of collared female elephants that were within 7 km of a culled group. Four out of the 10 females 'reacted to the cull by undertaking significant movements', including, for example, direct movement of 23, 25, and 30 km overnight or within two days of the cull (Whyte, 1993). Such movements even took the elephants outside of their previously determined home ranges (Whyte, 1993), but subsequent observations suggest that they had moved to another part of their home range (Whyte, pers. obs.). The response was not consistent among all females studied – the other six showed a weak or no response.

The above results suggest that there is substantial short-term stress on the elephants, but none of the studies quantified stress directly. The effect of hunting on stress in the elephants that remain behind was studied in Pilanesberg, using both behavioural and hormonal assays (Burke *et al.*, 2008). The effect of immobilisation of a single female from 12 different herds was also examined (Burke, 2005). There were physiological and behavioural stress effects lasting about four days from any hunting or immobilisation event. The effect was apparent in corticosterone levels for longer than from behavioural assays (Burke *et al.*, 2008). Although there was increased stress throughout the population during these disturbances, the levels of corticosterone were still much lower than those associated with natural stress events, for example during thunderstorms (Millspaugh *et al.*, 2007).

Long-term elephant behavioural consequences

It is uncertain how the observed short-term responses may translate into longer-term consequences (but see Bradshaw & Schore, 2007). Very little information on the longer-term consequences of culling is available. Although some reports were received from staff and tourists that elephants were aggressive in areas where elephants had been culled in Kruger, no quantified data exist to support or refute this (Whyte, 2001). The statement in Cumming & Jones (2005) about the disturbance of culling clearly implies short-term consequences, but it is not clear if there are longer-term consequences. Whyte (1993) concluded that Kruger elephants react more to helicopters during culling events than during translocation events, but the sample was small and the study was prematurely discontinued as culling was terminated in 1994. Elephants in Chizarira (Zimbabwe) now associate aircraft with danger, and flee (Martin *et al.*, 1996).

Gobush *et al.* (2007) represents the only study to assess the long-term consequences of poaching and culling. The elephants at Mikumi National Park (Tanzania) experienced heavy poaching prior to the ivory ban, but pressure has declined since then (Gobush *et al.*, 2007). These elephants still show elevated stress levels over a decade later, potentially from a loss of kinship in the socially complex matrilineal network (Gobush *et al.*, 2007; see also McComb *et al.*, 2001; Wittemyer *et al.*, 2005).

Culling results in a loss of cultural information and experience from the population, especially if older individuals are targeted (McComb *et al.*, 2001). It also results in trauma associated with the culling (Bradshaw *et al.*, 2005). 'Calves witnessing culls, and those raised by inexperienced mothers are high-risk candidates for later disorders, including an inability to later regulate stress-reactive aggressive states' (Bradshaw, 2005). The Norms and Standards (DEAT, 2008) does not allow for capture of juveniles during culls. This is considered inhumane: juveniles should not witness the culling of their families. There have been human deaths from young female matriarchs in five small reserves in South Africa (Slotow, unpublished data), and younger matriarchs respond differently and less appropriately than older females (both in Pilanesberg and Amboseli) to unfamiliar elephant calls or lion roars (Shannon *et al.*, unpublished data). The effects of human-caused disruptions on neuro-endocrinological development of elephants, and subsequent non-normative behaviour, has been recently reviewed by Bradshaw & Schore (2007).

We should not expect elephants to live a completely stress-free life, and they have evolved to deal with a certain degree of stress. Top predators, including humans, hunted elephants throughout their evolutionary history, but modern technology allows humans to impose a more intensive disturbance event, of a scale unlikely in the evolutionary history of elephants. This generates concern about long-term effects on elephants from both a welfare and human risk perspective. There is a need to differentiate between evolutionary and ecologically selected stress responses (i.e. to which an animal such as an elephant is adapted), and artificial disturbances (such as mass culling) to which elephants would not have had the opportunity to adapt (Bradshaw, pers. comm.). In terms of the latter, there may not be adequate coping mechanisms to diffuse or ameliorate stress (Bradshaw, pers. comm.), and such unnatural trauma may have fundamental consequences.

Long-term elephant population consequences

When culling is implemented in strict proportion to the existing population age-sex structure, as has been the general practice to date (Whyte, 2001; Cumming & Jones, 2005), the intention is to retain the current structure, albeit in lower numbers. The reduction in population size will depend on the number of animals removed. The problem occurs once culling stops. Once a population is released from culling, even if the culling is age-and-sex neutral, it enters a growth phase that inevitably leads to an age distribution somewhat skewed toward younger individuals (e.g. Red Deer – Coulson *et al.*, 2004; Pronghorn antelope – White *et al.*, 2007; see also Mackey & Slotow, submitted manuscript). There are a number of reasons for this. The reduction in density leaves the underlying resources on which the population depends intact, thereby increasing the amount of resources available to each individual (Caughley, 1983), which then grows and breeds at a maximal rate. Culling automatically boosts the potential population growth rate of the population (Caughley, 1983). This effect persists for at least one generation (all newly born animals age and die), after which a new stable age-structure will gradually establish itself. The consequences of culling Red Deer included demographic and spatial effects that persisted for 30 years – almost four generations – after culling halted (Coulson *et al.*, 2004). Although the long-term consequences of culling have only been modelled in elephants, given their very long intergeneration times, the possibility exists that such effects may at least in theory persist up to a century. They could potentially be mitigated by applying age-and-sex neutral culling. Eruptive growth is exacerbated if older individuals are selectively targeted.

Eruptive growth overshoot could be minimised by artificially 'aging' the population, for example by contraception or selective culling of younger age-sex classes (Mackey & Slotow, unpublished manuscript). If the age-class distortion is effectively countered, the mechanism of density dependence may prevent population overshoot (Mackey & Slotow, unpublished manuscript). There are ethical and practical concerns about culling specific age-sex classes from within breeding groups (Martin *et al.*, 1996, see section above on selective culling), and such an approach is specifically excluded in the Norms and Standards (DEAT, 2008).

GAPS IN OUR KNOWLEDGE

Key gaps in our knowledge that emerge from above are:

1. Incomplete information on the population structure and dynamics of important elephant populations as they approach high-density limits. Such information would allow robust predictions of the population consequences of culling or not culling.
2. A lack of systematic information regarding problem animals. Monitoring and assessment of incidents will allow the identification of patterns and underlying causes, which will provide the basis for any management interventions.
3. Uncertainty as to what indicators should be used to trigger management intervention to reduce population numbers, and what the critical thresholds are.
4. The consequences of selective removal of particular age or size classes from the population from demographic, behavioural, social, economic, and genetic perspectives, particularly in small reserves, and how to mitigate undesirable outcomes.
5. The long-term viability and practicality of low-density areas created by disturbance culling.
6. Scientific studies, preferably including both behavioural and hormonal assays, on the disturbance effects and consequences of culling, e.g. for elephant social networks.

CONCLUSIONS

The shooting of identified individual elephants is the main means to control problem animals in the short term, but avoidance of problem-creating situations is a better long-term strategy. Culling is the only realistic mechanism to reduce population size in the short term if this is necessary to achieve specific management objectives. The technical aspects of culling and problem animal control are well understood and it is feasible in South Africa to cull on whatever scale may be needed.

There are, however, a number of issues that have emerged from this assessment relating to the elephants that remain behind after culling.

Firstly, possible resultant elevated population growth rates resulting from skewed age and sex structures could create long-term problems requiring ongoing management. Secondly, the behavioural consequences are uncertain, but this assessment indicates that they are potentially substantial, raising welfare concerns.

Our current understanding of culling relates mostly to what has happened in Kruger and Zimbabwe. There may be a more immediate need for culling intervention on smaller spatial scales and in smaller populations, for which our understanding is less developed.

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