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Arid and semiarid rangeland production systems of Southern Africa: Wildlife

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Abstract

Using data from state-funded and private conservation areas throughout South Africa, we explored the production of secondary herbivore biomass as a function of rainfall. We examined trends within the wildlife industry, including changes in the area of land under both state and private management, wildlife numbers, auction prices and hunting statistics. As a result of the availability of wild herbivores from formal conservation areas, there has been a dramatic increase in the biomass of wildlife on private conservation land. Rain use efficiencies for both formal and private conservation areas are at or below 2, suggesting that there is potential for increasing wild herbivore biomass throughout the country. The area of land under informal conservation management has increased to almost 14% of the surface area of South Africa, with the formal conservation agencies contributing a further 6.3%. We recommend that further stimulation of the wildlife industry should occur.

Key words: rangeland, parkland, arid and semiarid zone, wildlife, Southern Africa.

Résumé

Parcours arides et semi-arides d'Afrique australe : la faune

À partir des données provenant de sources étatiques ou privées et concernant les zones de conservation dans l'ensemble de l'Afrique du Sud, cet article cherche à définir la production secondaire de la biomasse d'herbivores en fonction de la pluviosité. Les tendances actuelles de l'industrie de la faune sauvage, en particulier la tenure des terres et diverses autres données, sont passées en revue : effectifs, prix de vente, enchères, statistiques de la chasse, superficies sous gestion privée et publique. La biomasse d'herbivores sous régime privé de conservation a considérablement augmenté ces dernières années. Le coefficient d'efficacité pluviale des parcours à la fois dans les systèmes publics et privés est de 2 kg de matière sèche (MS)/ha/an/mm, ou moins. Ce fait suggère qu'il y a un potentiel considérable d'amélioration de la productivité dans ce domaine pour l'ensemble du pays. La superficie des terres soumises à des systèmes informels de conservation a augmenté pour atteindre pratiquement 14 % du territoire national, les agences de conservation officielles couvrant en plus 6,3 % du territoire. Il est hautement souhaitable de multiplier les incitations destinées à stimuler encore plus l'industrie de la faune.

Mots clés : parcours, parcs, zone aride et semi-aride, faune sauvage, Afrique australe.

During the second part of the 1800s, wildlife was harvested intensively in South Africa and European settlers and their livestock occupied the interior of the country, further reducing indigenous wild herbivores to control trypanosomiasis and foot and mouth disease. The rinderpest epidemic of the 1890s also diminished herbivore numbers. The period of extermination was followed by concerted efforts during the twentieth century to increase the number of wild herbivores to levels where non-consumptive use was possible, and even to the point where consumptive use is necessary [1]. A key issue has been the legal ownership of wildlife, whereby private landowners have the power to harvest and dispose of wildlife populations, providing an incentive for the active management of wildlife and wildlife habitat [2]. Political stability and sustained economic growth has further encouraged wildlife use in the southern African rangelands. This increase can be attributed largely to two major driving variables: i) an increase in the availability of a range of wild herbivores for purchase; and ii) a resurgence in the ecotourism and hunting opportunities in the region. The former is a function of the effort of government and private conservation agencies to establish significant herds of wild herbivores on state-owned land, and to develop the capacity to capture and relocate these animals successfully. The latter was encouraged by improved political stability within the region (particularly countries such as Botswana, Namibia, and South Africa), and the marketing of luxury ecotourism and trophy hunting opportunities for tourists from Europe, the USA and Canada. In addition, cattle farmers in the marginal semiarid and arid regions of South Africa have been discouraged from pursuing livestock production by issues which include deregulation of the agricultural sector, increases in labour costs and stock losses due to theft, high costs of diseases control, as well as changes in rangeland condition, including encroachment of woody shrubs.

This trend has resulted in a transformation in land-use patterns across the subcontinent, with many farmers on freehold land converting their properties to "game farms", with the associated removal of livestock management infrastructures (fences, water points, and livestock handling facilities). Once "game farms" have been formed, these landowners form alliances with their neighbours to create larger continuous areas for wildlife, known locally as "conservancies". This pattern is accompanied by reductions in predator control programmes (particularly those for black-backed jackal, caracal/lynx and Cape hunting dog), making traditional livestock farming even less attractive. It is clear that this pattern of land use change is not slowing, and will continue unless the market for ecotourism becomes saturated. Of a total of 55,000 farms in South Africa, there are approximately 5,000 game ranches and more than 4,000 mixed game and livestock ranches in South Africa [3] covering some 170,000 km^2. These cover over 14% of the country's total land area, compared with 6.3% of all officially declared conservation areas.

Table I. Extent of formal (national parks and provincial) conservation areas for the 9 provinces of South Africa, representing some 6.3% of the total surface area (Source: Department of Environment Affairs, Pretoria).

Province	Proportion conserved	Area of province (km^2)	Area conserved (km^2)
Western Cape	0.07	129,315	8,703
Eastern Cape	0.03	169,857	5,049
Free State	0.02	129,833	2,476
Gauteng	0.2	16,943	2,851
KZN	0.09	92,337	8,087
Limpopo	0.12	122,945	14,529
Mpumalanga	0.19	79,583	15,232
Northern Cape	0.04	358,565	15,527
North West	0.04	116,240	4,373
Total	**0.07**	**1,215,622**	**76,828**

Methods

In order to quantify the contribution made by wildlife management to production in southern African rangelands, we assessed the distribution of formal (e.g. national parks and provincial nature reserves) and informal (e.g. game ranches, farms managed with broad conservation objectives) conservation areas relative to other agricultural activities (cultivation, commercial livestock farming). Using data from the records of wildlife agencies and commercial ranching operations, we have determined the standing biomass of wildlife in a wide range of conditions on state-owned and free-hold land. These estimates are based upon the results of annual wildlife census data and have been internally controlled for accuracy. The data provide the opportunity to compare wildlife standing biomass with those production figures obtained from commercial and communal livestock management scenarios. We extracted mean annual rainfall data for most of the study areas from the rainfall response surfaces for South Africa [4]. Where the areas were extensive (e.g. Kruger National Park), we used a raster-based GIS[1] to extract a mean for the entire area. Following Le Houerou *et al.* [5], we calculated the rain use efficiency for each system using a constant daily dry matter consumption of 11.5 kg per day for a 450kg steer and a 40% use factor.

There has been a rapid growth in the wildlife auction industry, with auctions events taking place within each province. We obtained data from sales and used these to describe trends in wildlife sales from the numbers and value of animals traded at commercial auctions over recent years.

Results

Wildlife population, biomass and economic value

Formal wildlife systems occur on less than 7% of the surface area of South Africa *(table 1)*, and this proportion is skewed by contributions from the two largest conservation areas (Kgalagadi Trans-Frontier Parks and Kruger National Park), located in the arid and semiarid savannas, respectively. South African National Parks manages twenty national parks, totalling approximately 43,000km^2 *(figure 1)* and contributes the largest component of wildlife standing biomass and production *(table 2)*. Provincial conservation authorities contribute a further 33,800 km^2 to the total state conservation initiatives. Although some private game reserves are included in national estimates of the area of land under conservation management *(table 1)*, this is a gross underestimate as many safari operations have

[1] GIS : geographic information system.

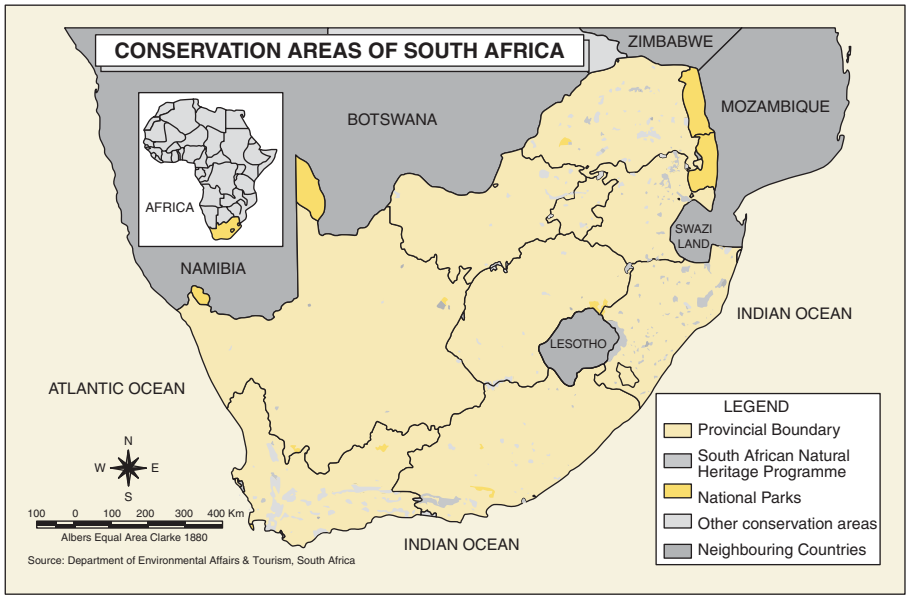

Figure 1. Location and extent of formal conservation areas in South Africa.
This figure does not reflect many of the newly-formed wildlife farms and conservancies.

yet to register as nature reserves and their properties are regarded as agricultural land in most databases. In the Limpopo Province, game ranching has been recognised as an agricultural enterprise and is a fast-growing sector in the agricultural economy. Here, cattle numbers have declined in favour of game. By August 1998 there were an estimated 2,300 game ranches in the Province (36,000 km^2 or 29% of the total area) [6]. These wildlife systems and their associated tourism industry, although contributing significantly to the gross domestic product (6% of GDP or US$6.5 billion in 1998) [3], remain an insignificant source of protein when compared to poultry beef, sheep and goat production *(figure 2)*.

There are efforts by provincial government to promote ecotourism, e.g. US$ 8 million has been allocated to the newly established Eastern Cape Parks Board during 2004/2005. Similarly, other provinces have allocated proportionally more resources to the development of ecotourism opportunities and promoted the privatization of the land under their control by issuing concessions for the establishment of private safari lodges.

Wildlife trading at auctions has grown rapidly in southern Africa and the numbers of animals traded in the Northern Cape province *(table 3)* and their US$ value *(table 4)* reflects part of the contribution of this sector to the economy. In 2000, 17,000 head of game was sold at 48 auctions at a value of US$10 million compared to 8,200 head of game in 1991 [3].Trends in live sales and relocation of game in the Northern Cape reflect an increase in value traded (US$) since 2002 *(table 3)*

Production

Early research on production in southern African wildlife systems [7] suggested that aboveground net primary production (ANPP) could be modelled using simple regression models between secondary herbivore production and rainfall. When investigating the principal driving determinants of vegetation structure and function in the Lowveld savanna, Peel *et al.* [8] show that the Coe model [7] gives conservative production estimates *(figure 3)*. These higher than predicted herbivore numbers are found on high potential areas with no apparent detrimental impact on the limiting grass layer. This is illustrated by a fodder flow model where the dry matter requirements of animals found on the different reserves, based on animal numbers, is related to the composition and standing crop of grass biomass found on the area. The results have implications for land users and policy makers in terms of setting animal stocking density guidelines.

Herbivore biomass, consumption and productivity were considered to be closely correlated with plant productivity [9], and it was suggested that the latter is a principal integrator and indicator of functional processes in food webs. With the advent of spatially explicit production models [10, 11] and the subsequent expansion to African wildlife systems [12], it became clear that production in African savannas is patchy [13]. This patchiness indicates a link between nitrogen mineralization and production. In order to define this synchronicity, Augustine and McNaughton [14] studied the temporal pattern of inorganic N turnover and plant growth in a semiarid savanna ecosystem in central Kenya. They evaluated the linkages between plant production and net N mineralization on nutrient-rich grazing lawns of *Cynodon* spp. and in nutrient-poor *Acacia* bushland. These are similar habitats to those encountered in the Lowveld savanna of Mpumalanga and Limpopo and could help explain the higher than expected herbivore biomass that this area sustains. There is a "distinct temporal asynchrony between plant production and soil N turnover and observed significant mineralization during plant senescence and dry season months" [14]. Combined with urine inputs in grazing lawns, the mineral N pool is recharged, and is ready for the next rainfall event. The African savanna can be viewed as a series of nutrient rich patches which provide seasonally high nutrient levels which sustain animal growth while being perceived as degraded. The link between mean annual rainfall and herbivore biomass remains tenuous given the high standing biomass associated with woody trees and shrubs. The challenge of successfully modelling production from herbaceous and woody components remains to be taken up.

The standing biomass in the Kruger National Park (3,931 kg/km^2) *(table 2)* equates to 90% of the "recommended stocking rate" for commercial ranches. This contrasts markedly with the earlier notion that African wildlife systems had lower standing biomass than commercial ranches. The rain use efficiencies (RUE) *(table 2)* of all the wildlife systems are lower (RUE<3) than those achieved by adjacent commercial ranches (RUE ranges from 3-4). These lower efficiencies should not be construed as evidence of system run-down as all of these systems reflect healthy rangeland condition and many have high standing plant biomass. This result is further evidence that production in South African wildlife system remains below potential.

The National Parks and Provincial nature reserves have relatively lower stocking densities compared to the private reserves of the eastern Lowveld *(table 2)*. This may be attributable to the objectives of the former organisations, whose primary focus is on the maintenance of ecological processes and preservation of genetic diversity. Private conservation areas focus on economic benefits while practising sustainable resource utilisation and this

Table II. Surface area (km^2) and current wildlife biomass (kg/km^2) for a range of areas in South Africa (2004/2005 unless stated).

Province	Type of protected area	Name of protected area	Size of area (km^2)	Total biomass for protected area (kg/km^2)	Mean annual rainfall (mm)	RUE (kg DM/ha/mm/y)
Kwa-Zulu Natal	Provincial	Hluhluwe Imfolozi	896	9,272	850	2.54
Kwa-Zulu Natal	Provincial	Emakhosini Opathe Heritage Park	240	1,152*	750	0.36
Kwa-Zulu Natal	Provincial	Ntinitin Field Training Centre	6	5,888	800	1.72
Kwa-Zulu Natal	Provincial	Entumeni Nature Reserve	8	432	1,200	0.08
Kwa-Zulu Natal	Provincial	Mhlathuze Community Conservation Reserve	4	8,062*	700	2.69
Kwa-Zulu Natal	Provincial	Matshenezimpisi	16	1,518*	800	0.44
Kwa-Zulu Natal	Provincial	Matshitsholo	5	2,542*	600	0.99
Kwa-Zulu Natal	Provincial	Fundimvelo	8	2,517*	800	0.73
Kwa-Zulu Natal	Provincial	Chelmsford	29	3,523	900	0.91
Kwa-Zulu Natal	Provincial	Spioenkop	40	6,585	730	2.10
Kwa-Zulu Natal	Provincial	Wagendrift	5	3,681	720	1.19
Kwa-Zulu Natal	Provincial	Weenen	39	6,940	750	2.16
Kwa-Zulu Natal	Provincial	Ukhahlamba Drakensberg Park	2,430	335	800	0.10
Mpumalanga	Provincial	All reserves	1,970	1,188	N/A	
Mpumalanga	Private	Exemption farms	2,715	4,230	N/A	
Northern Cape	Private	CAE – Diamantveld	2,953	2,680	350	2.08
Northern Cape	Private	CAE – Bo Karoo	1,457	3,794	420	2.28
Northern Cape	Private	CAE – Benede Oranje	2,054	1,781	360	1.15
Northern Cape	Private	CAE – Namaqua	290	995	120	1.93
Northern Cape	Private	CAE – Hantam	138	2,190	350	1.55
Northern Cape	Private	CAE – Kalahari	1,478	4,654	450	2.41
Gauteng	Provincial	Suikerbosrand	116	3,565	680	1.22
Gauteng	Provincial	Roodeplaat	8	3,951	660	1.40
Gauteng	Provincial	Abe Bailey	42	2,877	660	1.02
Gauteng	Provincial	Leeuwfontein	22	3,095	600	1.20
Gauteng	Provincial	Tswaing	20	2,296	650	0.86
Limpopo	Private	Combined Farms	29,200	2,543**	N/A	
Limpopo/Mpumalanga	National Park	Kruger National Park	19,500	3,931***	550	1.67
Limpopo/Mpumalanga	Private	Combined Farms	650	4,880	550	2.07
Total area			**66,347**			

CAE= Certificates of Adequate Enclosure; * - from estimated numbers; ** - estimated numbers of species from 1994 [6] and for 2004; *** - includes elephant and buffalo for 2004 as well as low density species (tsessebe, roan, and sable antelope).

includes allowing stocking densities to increase towards the upper limits of the areas potential.

Hunting

South Africa provides the greatest variety of animals available for hunting in any African country and regulations controlling the professional hunting industry are designed to protect both the resource and the industry. Hunting and associated activities contributed US$80 million and US$92 million to the South African economy for 2001 and 2002 respectively [15]. The potential for hunting is clearly illustrated for the Northern Cape province where number of hunters and trophies has increased in the past seven years

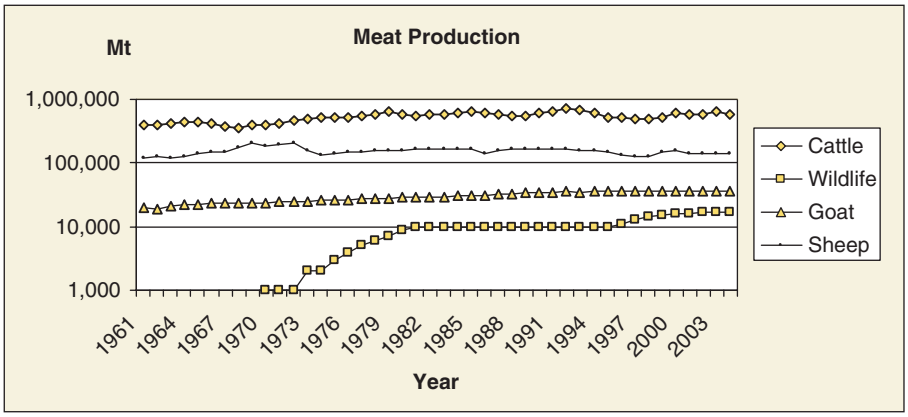

Figure 2. Meat (poultry, beef, wildlife, goat and sheep) production (Mt) for South Africa from 1961-2004 (Source FAOSTAT, http://faostat.fao.org).

Table III. Revenues raised from the sale of live game in the Northern Cape Province.

Financial year	Head of game traded (n)	Revenue generated (ZAR)	Revenue generated ($ US)
2002/03	30,754	91.15M	9.12M
2003/04	9,917	79.7M	9.96M
2004/05	23,699	85M	13.08M

Rand values converted to US dollars based on the rate R10 = $US 1, R8 = $US 1, and R6.50 = $US 1 for the years that are presented (*J.H. Koen, Northern Cape Province Department of Tourism, Environment and Conservation, pers. comm.*).

(table 5). During 2004, hunters from the following countries hunted in the Northern Cape: USA (46%), Spain (8%), Czech Republic (7%), France (6%), Austria (6%), Denmark (5%), and Belgium (5%) and the remainder from The Netherlands, Norway, United Kingdom, Greece, Saudi Arabia, Mexico, Canada, Germany, Italy, Switzerland, and Sweden. Although data are not presented here, similar trends are evident for other provinces in South Africa. The recent approval of five export permits *per annum* for hunted black rhino within South Africa under the CITES convention is sure to significantly boost the value of this industry as well as the demand for, and value of, this species.

Ostrich production

The South African ostrich industry was established in 1838 with the export of feathers to Europe to supply the fashion industry. Between 1900 and 1914 the industry flourished; however soon afterwards it collapsed as a result of changes in world fashion trends. During the 1960s the industry transformed to an intensively managed farming activity. The emphasis shifted from feather production to leather production. More recently, ostrich meat became popular because of its low fat content. Secondary products now include oil, feathers, eggs and ecotourism. The number of birds slaughtered in South Africa in 2002 was 350,000. Demand in Europe for ostrich meat remained strong during 2002 and the weak currency contributed positively to the total realisation per ostrich. However, since 2002 the price of ostrich leather dropped sharply. Income from leather varied significantly because of dramatic price differences between raw skin grades. In 2002, a producer earned approximately US$ 150 for a first-grade raw skin and around US$ 100 for a third-grade skin. The average price producers of ostrich meat received during 2002 was approximately US$ 2.5 per kg and US$ 11 for feathers per bird. On average, South African producers received approximately US$ 120 per raw skin. The improved South African currency has put further pressure on prices paid for ostrich products. During 2003, the slaughtering of ostriches in South Africa dropped back to the 2000 figure of approximately 300,000 units and income of producers was much lower. With the deregulation of the agricultural marketing in South Africa in the early 1990s, farming with ostriches spread from the Little Karoo region, where it had been strictly controlled, to other parts of South Africa and other countries. South Africa continues to supply approximately 67% of ostrich meat, leather and feathers to international markets. Today, all major stakeholders in the industry are affiliated to the National Ostrich Processors of South Africa and the South African Ostrich Business Chamber. Outbreaks of the avian flu virus during 2004 in the Eastern Cape have made direction in the industry uncertain. Although government acted quickly and prevented the spread of the virus from the infected farms, farmers remain reluctant to embark on further risky ventures, and the industry

Table IV. The mean value (US$) of wild herbivores at auctions in Limpopo Province during 2005 (Source: Nico Roux Wildveiling http://www.nicoroux.co.za).

Species	Value (US$) 2005*
African buffalo	20,000
Black rhinoceros	53,000
Blue wildebeest	430
Burchell's zebra	740
Eland	530
Giraffe	3,000
Greater kudu	410
Impala	150
Mountain reedbuck	240
Nyala	1,250
Roan antelope	3,500
Sable antelope	8,600
Warthog	80
Waterbuck	1,900
White rhinoceros	18,000

* Final price depends on the rarity, condition, size and gender of animals.

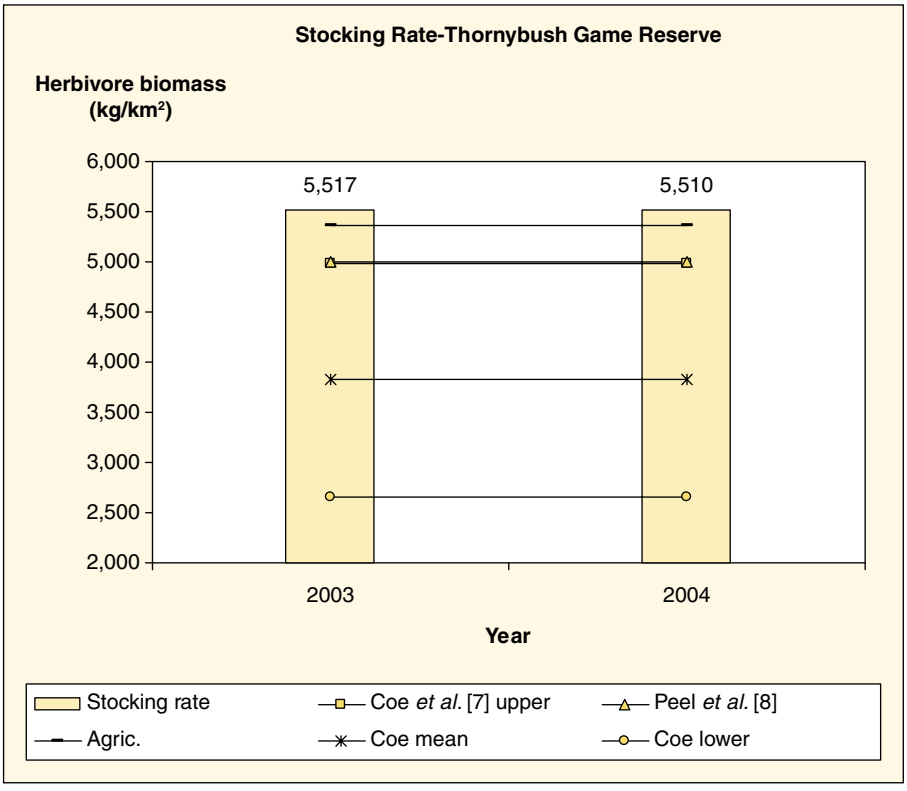

Figure 3. Comparison of observed herbivore biomass *versus* those predicted by Coe *et al.* [7], Peel *et al.* [8] and recommended by the National Department of Agriculture for the Thornybush Game Reserve.

Table V. Hunting data obtained from the Northern Cape Province[a].

Year	Hunters (N)	Trophies (N)	Estimated foreign income (US$)
1998	223	1,625	2,044,732
1999	377	3,371	4,355,233
2000	452	3,552	4,829,409
2001	538	4,133	5,145,777
2002	722	4,269	6,574,924
2003	645	4,203	5,125,118
2004	737	5,699	6,849,827

[a] J.H. Koen, Northern Cape Province Department of Tourism, Environment and Conservation.

continues to wait for an indication of future trends.

Management constraints

Growth of wildlife and ecotourism activities is constrained by the options available to managers to control herbivore numbers. This will have an impact on the future trends within the industry, and the possible impact of excessive wildlife numbers on the rangelands. After examining trends in wildlife auction prices, it appears that some charismatic species such as white rhinoceros have already reached a point where their value has decreased. The costs associated with the capture, transport and relocation of wild herbivores are increasing. Expensive equipment such as helicopters, drugs and experienced crew and vehicles are required. Activities are strongly seasonal, so the capital outlay for specialised equipment has to be recouped within the capture season (usually the dry, cool months). In addition, in line with international trends, there is mounting public pressure to reduce hunting and culling options on public land. This has resulted in a reduction in the options available for the management of megaherbivores. There is a limited local market for venison and wildlife products *(figure 2)* and restrictions on the import of wildlife products to developed countries make the expansion of these markets problematic.

Income and benefits of wildlife production systems through nature-based tourism

The growing interest in experiencing biodiversity, combined with the increased ease of global travel has led to an upsurge in nature-based tourism (of which ecotourism is a subset). Consequently, African wildlife operations have been able to focus very strongly on this market. In contrast to normal rangeland or wildlife productions systems, nature-based tourism is a non-consumptive use of wildlife through game viewing. However, unless the park or reserve in question has the full suite of carnivores able to maintain herbivore numbers within carrying capacity, such nature-based tourism operations will be forced to remove excess wildlife in order to avoid exceeding the carrying capacity. These excess animals are culled for the venison market or captured and sold live. Given the apparent conflicts between game viewing and hunting (particularly as this affects marketing opportunities), it is unusual for hunting to take place on a wildlife operation that focuses on the tourism market.

The economic impact and financial income of nature-based tourism can be relatively large and is increasingly being recognised. Within the Eastern Cape Province of South Africa, the Addo Elephant National Park (AENP) is one of the few operations for which there are comprehensive data on the economic value. In 1996, the AENP had an annual recreation value or consumer surplus value of over US$ 60 million, based on a travel cost approach [16]. This figure reflects the *pro rata* expenditure on travel, accommodation and onsite costs of visitors to the AENP, and was an order of magnitude higher than the financial income obtained by the AENP. Clearly, this shows that much of the value of these wildlife-based systems is provided through economic activity taking place elsewhere.

Table VI. Total gross income per hectare (TGI/ha) of alternative land use types compared with wildlife systems offering nature-based tourism.

Land Use	TGI/ha	Source
Private Game Reserve Ecotourism	ZAR 1,605	Sims-Castley *et al.* [17]
Mohair	ZAR 155	Sims-Castley [18]
Boer goats	ZAR 45	Sims-Castley [18]
Livestock	ZAR 100	Sims-Castley [18]

The economic status of seven large privately-owned wildlife-based ventures (private nature reserves) in the Eastern Cape was assessed [17]. Although some of these operations were still in a development phase, it could be shown that gross income generated per hectare was significantly higher than that of pastoral rangeland operations *(table 6)*. This does not take into account the fact that the operating costs of such private nature reserves are also significantly higher than comparable pastoral rangeland operations. Although such data are for commercial reasons not currently available, it is known that the establishment upcosts of private nature reserves tourism ventures are high, averaging in the region of US$ 6 million per venture. These costs include land purchase, construction and renovation of buildings, interior décor, wildlife purchases, infrastructure, equipment and rangeland rehabilitation [17]. Despite these high costs, the number of such private nature reserves is increasing *(figure 4)*, suggesting that market forces perceive them to be a good investment.

Another aspect of wildlife-based systems is that of job creation. Given the service demands of the nature-based tourism industry, it is not surprising that such operations employ more staff and pay higher wages than comparable pastoral operations in these rangelands. In 1994, the AENP employed twice as many staff at an average of four times the salary than a comparable pastoral operation [19]. These figures were later re-confirmed [16]. More recently, Sims-Castley *et al.* [17] provided similar figures for privately-owned reserves, which increased employment numbers by 3.5 times that of comparable pastoral operations, and on average paid salaries that were 5.7 times greater than the comparable pastoral operations.

In the Eastern Cape Province, private nature reserves cover an area of 1,523 km^2 ([2]). This represents approximately 30% of the formally conserved area of this province, and given the non-consumptive nature of these operations they can fairly be considered to be contributing to conservation estate. A limitation of the contribution to conservation by these private nature reserves is that many are small (<50 km^2), which restricts the populations and ecological processes that can be maintained on these properties. In addition, over 90% of these operations maintain populations of extralimital herbi-

[2] Graham Kerley, unpublished data.

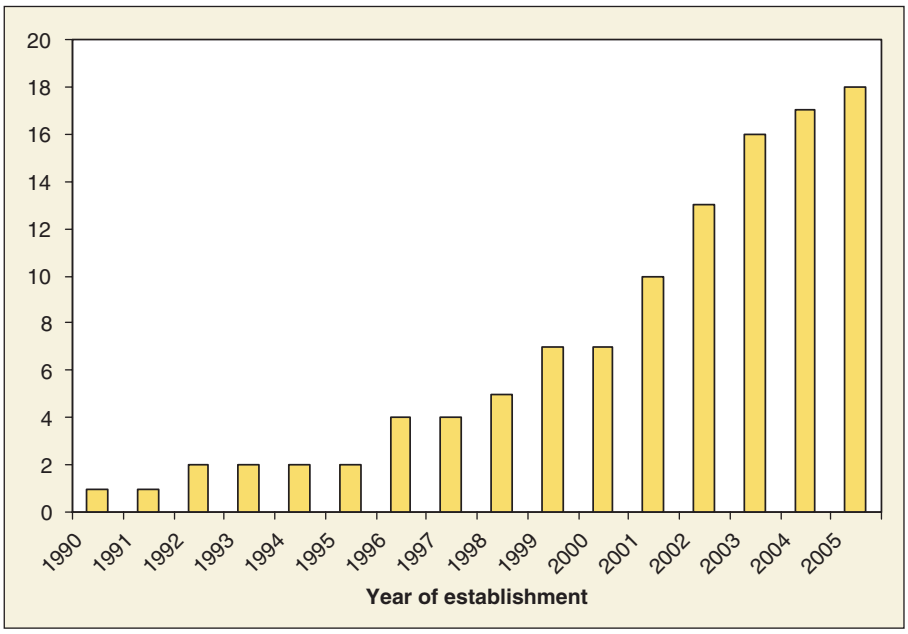

Figure 4. Rate of establishment of private nature reserves in the Eastern Cape Province, South Africa, including only operations that focus on nature based tourism operations.

vores[3]), potentially compromising the indigenous fauna and flora [20].
From the above, it can be concluded that the non-consumptive use of wildlife through nature-based tourism is attracting significant investments, while providing substantial socio-economic benefits in rural landscapes.

Conclusions

A positive outcome of the process of privatization and commercialization of wildlife resources is that conservation of South Africa's wildlife resources and biodiversity is no longer solely within the hands of government. It is encouraging to note that many rare or endangered herbivores *(table 7)* are now secure on private ranches and state-owned conservation areas (e.g. elephant, black rhinoceros, white rhinoceros, sable antelope, oribi; see *box 1* for scientific nomenclature). One disadvantage is that control over the mixing of inappropriate combinations of sibling species (e.g. bontebok and blesbok, bushbuck and nyala, black and blue wildebeest) has diminished, and the threat to genetic purity from hybridization has increased [20]. To date hybridisation has been recorded between blesbok and bontebok (which are separated at the subspecies level), blue and black wildebeest, as well as red hartebeest and blesbok. These hybridisations represent a conservation threat to the respective populations as a well as a decline in the commercial value of the progeny as there is little demand for these hybrids [20]. Another risk is that extra-limital and alien species are permitted within private conservation areas, often to the detriment of the indigenous elements that may have remained. Although limited research has been undertaken in this area, it has been shown that introduced nyala lead to a decline in indigenous, naturally occurring populations of bushbuck [22].
It is obvious that simple production models, based on direct relationships with rainfall, do not account for the high production levels achieved on commercial livestock ranches in southern African rangelands. We argue that southern Africa's potential for wildlife and commercial livestock production from arid and semiarid rangelands is greater than previously suggested. The current wildlife production levels, achieved in conservation areas after substantial initiatives to restore historical wildlife populations, remain below sustainable production from commercial ranches. The secondary production estimates for both wildlife systems and commercial livestock ranching remain below those achieved in communal grazing systems. System run-down, reflected as an ever declining level of net carbon gain, is only achieved in production simulations when extreme stocking rates (>2xs recommended by conventional wisdom) are applied [23]. These modelled stocking rates are well above those currently recorded for any wildlife or commercial ranching operation. In concurrence with Peel *et al.* [8], we maintain that South African rangelands have yet to achieve their full production potential for secondary production of wildlife. This is further confirmed by the low rain use efficiency levels achieved by wildlife systems.
South Africa's wildlife commands a high value both regionally and globally. However, this value is often ignored because it is difficult to quantify and the depletion of wildlife and natural resources is not generally seen as an economic cost to society [24]. The value of wildlife is not fully represented in economic decisions and wildlife-based activities are often viewed as being less profitable than activities that generate more easily quantifiable benefits and outputs to society [25]. By demonstrating wildlife values and expressing them in monetary terms, wildlife is placed on an equal footing with other sectors of the economy. This provides important information for justifying and financing wildlife conservation, for using wildlife as a means of economic development and for setting in place economic activities that promote sustainable resource use [25].
Conservation authorities, through their stimulation of animal production, have provided an enormous resource base of wild herbivores for distribution throughout the country. This, together with the philosophy of sustainable use of natural resources (e.g. culling and hunting) has seen the development of some 9,000 privately-

Table VII. Wildlife of critical conservation status [21] which currently receive conservation attention on both state-owned and private conservation efforts.

Vernacular name	Scientific name	Status
Black rhinoceros – arid ecotype	*Diceros bicornis*	Critically endangered
Hartmann's mountain zebra	*Equus zebra hartmannae*	Endangered
Oribi	*Ourebia ourebi*	Endangered
Tsessebe	*Damaliscus lunatus lunatus*	Endangered
African elephant	*Loxodonta africana*	Vulnerable

[3] Graham Kerley, unpublished data.

Box 1
Wildlife species mentioned

Vernacular names	Scientific names	Authorities
African elephant	*Loxodonta africana*	Blumenbach
African buffalo	*Syncerus caffer*	Sparrman
Black rhinoceros	*Dicornis bicornis*	L.
Black wildebeest	*Connochaetes gnou*	Zimmerman
Blesbok	*Damaliscus dorcas*	Pallas
Blue wildebeest	*Connochaetes taurinus*	Burchell
Brontebok	*Damaliscus pygargus*	Pallas
Burchell's zebra	*Hippotigris burchelli*	ray
Bushbuk	*Tragelaphus scriptus*	allas
Cape eland	*Taurotragus oryx*	Pallas
Giraffe	*Giraffa camelopardalis*	L.
Greater kudu	*Tragelaphus strepsiceros*	L.
Hartmann's mountain zebra	*Equus zebra hartmannae*	L.
Impala	*Aepyceros melampus*	ichtenstein
Mountain reedbuk	*Redunca fulvorufula*	Afzelius
Nyala	*Tragelaphus angasi*	Gray
Oribi	*Ourebia ouribi*	immerman
Ostrich	*Struthio camelus*	L.
Roan antelope	*Hippotragus equines*	Desmarest
Sable antelope	*Hippotragus niger*	Harris
Springbok	*Antidorcas marsupialis*	Zimmerman
Tsessebe	*Damaliscus lunatus lunatus*	Burchell
Warthog	*Phacochaerus aethiopicus*	Pallas
Waterbuk	*Kobus ellipsiprymnus*	Ogilvy
White rhinoceros	*Ceratotherium simum*	Burchell

owned game farms, covering 17 million hectares and generating substantial foreign earnings from ecotourism. With our results showing that production potential is yet to be achieved, the supply of herbivores to the commercial wildlife sector should continue to be encouraged by State-funded authorities, further stimulating the wildlife industry within South Africa.

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