Productivity indexing of wild herbivores on Lewa Wildlife Conservancy and Ol Pejeta Ranch in northern Kenya

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Abstract

A selected set of wild herbivores on Lewa Wildlife Conservancy (LWC) and Ol Pejeta Ranch were evaluated for their utility value by productivity indexing based on a computer bio-economic model, Prying Livestock Productivity (PRY). PRY derives productivity of species based on feed energy efficiency (FEE). The respective FEE indices (Kenya shillings, Ksh, per kilogram dry matter, Ksh kg^{-1} DM) for consumptive use only on LWC and Ol Pejeta Ranch for zebra, buffalo, impala, giraffe and eland were 9.23 and 9.20; 4.70 and 4.74; 4.05 and 3.42; 7.34 and 7.24; 6.21 and 6.06. With non-consumptive use included in productivity assessments on LWC and Ol Pejeta Ranch, the respective indices for zebra, buffalo, impala, giraffe and eland were 15.52 and 9.98; 21.10 and 6.34; 9.85 and 4.69; 14.41 and 9.92; 12.72 and 16.05. The buffalo and eland were the most productive species on LWC and Ol Pejeta Ranch respectively, while the impala was the least productive on the two units. Most herbivores on LWC were more productive than the same species on Ol Pejeta Ranch when touristic value was included in the indexing. However, without tourism, species in the two units had similar index values, except for the impala. It was concluded that tourism provides the main economic justification for utilization and conservation of the herbivores.

Key words: cropping, productivity, species mix, valuing, wildlife

Résumé

Un ensemble sélectionné d'herbivores sauvages de *Lewa Wildlife Conservancy* et du *Ol Pejeta Ranch* a été évalué pour leur valeur utile au moyen d'un index de la productivité, en se basant sur un modèle bio-économique informatisé, PRY. Le PRY fait dériver la productivité des espèces sur la base de l'efficience énergétique alimentaire (FEE). Les indices FEE respectifs (Ksh/kg MS), pour la consommation uniquement, à LWC et à Ol Pejeta Ranch, étaient pour les zèbres, buffles, impalas, girafes et élands, de 9,23 et 9,20; 4,70 et 4,74; 4,05 et 3,42; 7,34 et 7,24; 6,21 et 6,06. Usage non alimentaire inclus dans les évaluations de la productivité, ces indices étaient respectivement de 15,52 et 9,98; 21,10 et 6,34; 9,85 et 4,69; 14,41 et 9,92; 12,72 et 16,05. Les buffles et les élands étaient les espèces les plus productives aux deux endroits, tandis que l'impala était la moins productive de chaque côté. La plupart des herbivores de LWC étaient plus productifs que la même espèce au Ol Pejeta Ranch lorsque la valeur touristique était incluse dans l'index. Mais sans le tourisme, les espèces des deux unités avaient des index de valeur similaire, excepté l'impala. On en a conclu que le tourisme représente la justification économique principale pour l'utilisation et la conservation d'herbivores.

Introduction

Both livestock production and wildlife management have environmental costs. Comparative evaluation of these costs and returns depends on species of herbivores considered (FAO, 1978). The implication is that different species have different environmental costs. Indeed, bigger animals have lower energy requirements, weight for weight, than smaller ones; hence, bigger animals consume less from the environment when compared with smaller animals of equivalent weight. This implies that smaller animals have a higher potential of causing damage to the environment than bigger animals. For ecological balance, therefore, bigger herbivores should be mixed with smaller ones.

The basis of establishing the wildlife opportunity costs in any ecosystem is the value of mixed herding (Thresher,

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1976). Deliberate efforts are always required to have some desired combinations, particularly where wild herbivores are involved. Such efforts according to FAO (1978) include providing an incentive element equal to or exceeding the amount of money which ranchers would receive had they harvested the migratory herds grazing on their land. Some form of incentive may also be needed to encourage ranchers to protect species with high viewing value. In this context, valuing of wildlife herbivores is of utmost importance.

Productivity indexing of wild herbivores is performed by a number of microcomputer models like Texas A and B, HerdEcon, Productivity Efficiency Calculator and Prying Livestock Productivity (PRY) (Baptist, 1990). These models unlike PRY are not species and systems independent, do not optimize culling strategy, and do not have validated modules of stationary-state population dynamics (Baptist, 1990). PRY uses a single input, dry matter, which is determined by feed energy requirement. This dispenses with the difficulty of pricing input. Reducing inputs to feed energy is supported by the fact that in most economically significant production systems in developing countries, feed energy is the most limiting input, the one which accounts for the greatest part of total production cost and the one which is more difficult to price because it is mostly procured from labour-intensive roughages (Baptist, 1990). This does not mean that an in-depth analysis of overall productivity is to be restricted to the sole input of feed energy. Once PRY has been used to determine total offtake value (TOV) and the required dry matter intake (DMI), pen and pencil exercises or high level modelling could try to account for other input if their intensity level is expressed in terms of dry matter consumption. This paper reports on the valuation of wild herbivores in Lewa Wildlife Conservancy (LWC) and Ol Pejeta Ranch in Kenya.

Materials and methods

Description of the study area

The study was based in Laikipia and Meru Central districts. Ol Pejeta Ranch is located in the central division of Laikipia District. The ranch covers an area of 90,000 acres (36,423 ha). It is divided into wildlife and livestock blocks that cover areas of 23,000 acres (9308 ha) and 67,000 acres (27,115 ha) respectively. LWC is located in Timau division of Meru Central District. The conservancy covers an area of 45,000 acres (18,211 ha).

The oldest rocks in central and Timau divisions of Laikipia and Meru Central districts are the Precambrian metamorphics of the Mozambique Belt (GoK, 1987). The soils of central division have been developed on various volcanic materials, mainly of pyroclastic rocks and ash. According to Ahn & Geiger (1987) the soils of this division can be divided into the Chromic Vertisols, Pellic Vertisol with Chromic Vertisols and Luvic Phaezems and Pellic Vertisols with Chromic Luvisols. Timau Division, on the other hand, is dominated by the fertile dark loams derived from volcanic turf (GoK, 1997).

The climate of LWC and Ol Pejeta Ranch is mainly governed by their positions across the equator and their positions to the north and west of Mt Kenya respectively (Thouless, 1995; Mwangi, 2000). They receive relief rainfall that ranges between 400 and 800 mm annually. Ol Pejeta Ranch has a trimodal rainfall distribution, while LWC has bimodal distribution. On the habitats, annual rainfall distribution shows a great disparity both over space and time (Flury, 1987; Thouless, 1995). The total precipitation and its distribution correlate highly with relief. The high altitude (1800–2600 m) of the two units results in temperatures between 15 and 20°C (Flury, 1987; GoK, 1994). It is, however, hotter in the low-lying areas of Timau Division, where temperatures reach 45°C (GoK, 1997). Most of central and Timau divisions fall in moisture availability zone V, in which annual rainfall received is only equivalent to between 25% and 40% of evaporation (Sombroek, Braun & van der Pouw, 1982). The tributaries of Ewaso Ng'iro River dominantly drain both central division of Laikipia District and LWC (Mwololo, 2002).

The relatively high rainfall on Ol Pejeta Ranch have given rise to an extensive vegetation cover of mostly open grassland with scattered bushy trees consisting mainly of *Acacia drepanolopium* on heavy soils and *A. gerradii*, *A. tortilis* and *A. seyal* on the flat to very gently undulating land (Wakhungu *et al.*, 2002). The grasses on the range include *Themeda triandra*, *Pennisetum straminium*, *P. mezianum* and *Cynodon dactylon* (Wakhungu *et al.*, 2002). LWC, on the other hand, forms a transition from a semi-arid highland to arid lowlands. Most of the area can be described as dry bush savanna (Pratt & Gwynne, 1977). The conservancy is covered with grass and tree vegetation with varying amount of *A. drepanolopium* (GoK, 1997; Wakhungu *et al.*, 2002). Wetlands and indigenous forests are also present. The detailed description of these two study sites in terms of human population, land use, infrastructure and ecology has been provided by Wakhungu *et al.* (2002) and Olukoye *et al.* (2003).

Productivity indexing and sensitivity analysis

Quantitative data collected from both primary and secondary sources were inputted into the PRY model for productivity indexing for the selected wild herbivore species (Buffalo, Zebra, Giraffe, Eland and Impala) in the two units. The whole population of selected herbivores on the two sites between 1996 and 2002 was studied. Interviews, focus group discussions, observations and a review of relevant literature provided demographic parameters and yield levels of selected wildlife and livestock species on both LWC and Ol Pejeta Ranch.

The productivity indices were used to determine the utility value of the herbivores on the two units. Sensitivity analysis based on changes in the productivity indices due to a shift in the cropping rates helped to determine the most optimal cropping rates which would coincide with the maximum index value of each species at stationary-state equilibrium.

Prying Livestock Productivity is a time- and species-independent, herd and flock dynamics microcomputer package that makes use of inherent fitness traits (characteristics), yield levels, energy flow, unit produce values and culling practices to derive productivity indices of each species. The package as described by Baptist (1990) consists of two inputting procedures, demographic program input constant (DIC) and produce-related program input constant (PIC) and four deterministic modelling components consisting of animal population emulator, stationary-state animal demographic model (SAM), find optimal culling practice (FOC) and breakdown of offtakes and intake (BOI). Tasks that were performed by PRY to obtain productivity indices and sensitivity analyses were as described below.

Demographic program input constants (DIC)

DIC is a routine for inputting the demographic parameters (inherent fitness traits). Parameters inputted in this routine include survival rates, selective culling rates, age at first parturition, parturition interval and litter size. After inputting, parameters were formatted and saved to a work file (*.dic) from where they were retrieved by the simulation and derivation routines.

Stationary-state animal demographic model (SAM)

SAM was run using fitness characteristics of each herbivore species saved on DIC work file. It was used to establish whether the populations being modelled were at stationary-state (breeding female replacements are adjusted to keep the population size constant). This was to ensure that the populations of each species modelled were sustainable populations.

Produce-related program input constants (PIC)

PIC is a routine for inputting the produce-related traits. Traits inputted include growth traits, yield levels, metabolic constants and unit produce values. Yields inputted included touristic income for each study site. When PIC was run, fitness traits were retrieved from the work file saved earlier on with DIC. The in-loaded DIC-constants are used for consistency checks of the inputted PIC-constants. Entries were formatted and saved to a work file (*.pic) for future retrieval by FOC or BOI. Where data were missing, default parameters generated from within the PIC routine were used.

Find optimal culling practice (FOC)

The productivity of wild herbivores not only depends on inherent fitness and yield traits but also on the cropping strategy. FOC automatically varies the cull-for-age threshold of breeding females and the disposal age of male and female young stock respectively. Stationary-state feed energy efficiency (FEE) (the productivity index of gross return on DMI) is calculated for each combination of cropping ages. The best cropping strategy was then identified, where FEE was highest.

Breakdown of offtakes and intake (BOI)

When the best culling strategy was identified and the resulting optimal culling ages inputted using PIC, a more detailed analysis of FEE was obtained from BOI. Lifetime expectancies per kind of offtake and animal category (breeding female, surplus female and male young stock) are given separately. The weighted mean constitute TOV per animal-year. Similarly, feed energy requirement, converted into DMI requirement, was assessed per animal-year. The ratio of TOV and DMI is FEE. This is the overall productivity index. It represents gross return on DMI requirement, which can be expected for the set culling ages at the stationary state of population dynamics.

Sensitivity analysis for cropping rates in each species was accomplished by varying cropping rates and determining the magnitude of change in FEE obtained in the BOI module. The cropping rates expressed in decimal scale were altered on the DIC work file and the BOI module was run. If the magnitude of change in FEE was positive then the cropping strategy was favourable for the species utilization. However, a negative magnitude of change in FEE showed that the cropping strategy being practiced was unfavourable and should be revised to reduce wastage of species in the particular habitat.

Results

Consumptive output of species

The productivity of wild herbivore species on LWC and Ol Pejeta Ranch when only consumptive outputs were used in productivity indexing are shown in Table 1.

Without factoring in tourism, the zebra with FEE of 9.23 and 9.20 Ksh kg^{-1} DM on LWC and Ol Pejeta Ranch respectively, was the most productive species in both habitats, while the impala with FEE of 4.05 and 3.42 Ksh kg^{-1} DM on LWC and Ol Pejeta Ranch respectively was the least productive. Similar species ranked the same in the two habitats (Table 1). However the FEE values for the species were slightly lower on Ol Pejeta Ranch than on LWC. The highly priced skin of the zebra made it to have the highest productivity in absence of tourism.

Consumptive and nonconsumptive output of species combined

Productivity of wild herbivore species on LWC and Ol Pejeta Ranch when both consumptive outputs and income from tourism were used in productivity indexing are shown in Table 2.

Breeding females on LWC with a mean FEE of 19.32 Ksh kg^{-1} DM had the highest productivity, while the surplus females with a mean FEE of 9.24 Ksh kg^{-1} DM had the least productivity (Table 2). Similar pattern of results were observed for the eland on Ol Pejeta Ranch, while for the other wildlife species *and livestock*, the male young stocks were the most productive and the breeding females least productive (Table 2). The buffalo with FEE of 21.10 Ksh kg^{-1} DM was the most productive species on LWC, while the eland with FEE of 16.05 Ksh kg^{-1} DM was the most productive species on the Ol Pejeta Ranch. The impala with FEE of 9.85 and 4.69 Ksh kg^{-1} DM on LWC and Ol Pejeta Ranch respectively was the least productive species in both habitats (Table 2). Considering the overall productivity ranges of species on LWC and Ol Pejeta Ranch, the zebra (15.52 Ksh kg^{-1} DM on LWC; 9.98 Ksh kg^{-1} DM on Ol Pejeta Ranch) and giraffe (14.41 Ksh kg^{-1} DM on LWC; 9.92 Ksh kg^{-1} DM on Ol Pejeta Ranch) had relatively high productivity.

Optimal cropping rates

Sensitivity analysis of the species in response to cropping rates on LWC and Ol Pejeta Ranch are shown in Tables 3 and 4 respectively.

Changes in productivity were minimal (less than one unit) when cropping rates were varied between zero (species not cropped) and the highest possible cropping rates

Table 1 Productivity (Ksh kg^{-1} DM) of species on Lewa Wildlife Conservancy (LWC) and Ol Pejeta Ranch when only consumptive outputs are used in productivity assessments

Species	Breeding females		Surplus females		Male young stock		Value per animal-year (overall FEE index)		FEE ranking of species on LWC and O l Pejeta
	LWC	Ol Pejeta	LWC	Ol Pejeta	LWC	Ol Pejeta	LWC	Ol Pejeta	
Zebra	8.67	8.68	10.05	10.05	10.29	10.29	9.23	9.20	1
Giraffe	5.72	5.74	9.94	9.94	10.49	10.49	7.34	7.24	2
Eland	3.82	3.85	9.41	9.41	10.17	10.17	6.21	6.06	3
Buffalo	2.77	3.02	7.55	7.55	8.16	8.16	4.79	4.74	4
Impala	2.15	2.23	9.26	8.18	10.00	8.89	4.05	3.42	5

Table 2 Productivity (Ksh kg^{-1} DM) indices (feed energy efficiency, FEE) of different animal categories and overall productivity of selected species on Lewa Wildlife Conservancy (LWC) and Ol Pejeta

	Breeding females		Surplus females		Male young stock		Value per animal-year (overall FEE index)		FEE ranking of species	
Species	LWC	Ol Pejeta	LWC	Ol Pejeta	LWC	Ol Pejeta	LWC	Ol Pejeta	LWC	Ol Pejeta
Buffalo	33.17	5.06	7.56	7.56	8.16	8.16	21.10	6.34	1	4
Zebra	20.38	9.81	10.05	10.05	10.29	10.29	15.52	9.98	2	2
Giraffe	17.55	9.66	9.94	9.94	10.49	10.49	14.41	9.92	3	3
Eland	15.69	20.98	9.41	9.41	10.17	10.17	12.72	16.05	4	1
Impala	9.82	3.83	9.26	8.18	9.99	8.88	9.85	4.69	5	5
Mean	19.32	8.39	9.24	8.20	9.82	8.75	14.72	8.28	–	

Table 3 Overall productivity indices at different simulated cropping rates for selected species on Lewa Wildlife Conservancy

	Cropping rate in percentage (%)				
Species	0	6	15	16	19
Zebra	15.52	15.53	–	**15.53**	–
Buffalo	21.10	21.46	–	–	**21.66**
Impala	9.85	**9.85**	–	–	–
Giraffe	14.41	14.43	**14.52**	–	–
Eland	12.72	12.78	**12.83**	–	–

–, Denotes productivity indices not determined.
Bold productivity values are at maximum viable cropping rates of species.

Table 4 Overall productivity indices at different simulated cropping rates for selected species on Ol Pejeta Ranch

	Cropping rate in percentage (%)								
Species	1	3	6	10	15	16	19	32	33
Zebra	10.02	10.00	9.98	9.99	–	**9.98**	–	–	–
Buffalo	6.75	6.75	6.34	6.59	–	6.62	**6.58**	–	–
Impala	5.63	5.55	**4.69**	–	–	–	–	–	–
Giraffe	9.97	–	9.92	9.95	**9.93**	–	–	–	–
Eland	–	16.01	16.05	16.10	**16.13**	–	–	–	–

–, Denotes productivity indices not determined.
Bold productivity values are at maximum viable cropping rates of species.

that could maintain the population viable (last cropping rate with value in Tables 3 and 4). Species with the highest differences in productivity when the cropping rates were varied were the buffalo (0.56 Ksh kg^{-1} DM) on LWC and the impala (0.94 Ksh kg^{-1} DM) on Ol Pejeta Ranch. This implies that other factors must be considered to determine the most appropriate cropping rates of the species in the habitats. For example, on LWC and Ol Pejeta Ranch, the pressure exerted by herbivores on the range resources could be used to determine the right cropping rates of different species on these habitats.

Discussion

The buffalo on LWC and the eland on Ol Pejeta Ranch had high productivity because of their tourism value. The relatively high productivity of giraffe could be associated with its viewing value. For the zebra, the good performance is mainly due to its high quality hide that fetches high returns. This is in agreement with the findings of Wakhungu *et al.* (2002), who reported that the heavy cropping of Burchell zebra in Laikipia District is due to the readily available market for its skin in South Africa and Canada where each untanned skin fetch about US$80–100. The poor performance of the impala was due to its low viewing value and low prices of its by-products.

The buffalo, which had the highest productivity on LWC (21.10 Ksh kg^{-1} DM), had relatively low productivity on Ol Pejeta Ranch (6.34 Ksh kg^{-1} DM). The same is true for the eland, which had the highest productivity on Ol Pejeta Ranch (16.05 Ksh kg^{-1} DM) but had relatively low productivity on LWC (12.72 Ksh kg^{-1} DM). Apart from the eland, the wild herbivores of LWC had higher productivity when compared with the same species of Ol Pejeta Ranch. This implies that LWC was more productive when compared with Ol Pejeta Ranch.

The productivity of species, therefore, depends on the type of economic activity on the habitat. For example, the high productivity of species on LWC was due to the promotion of tourism through wildlife conservation, while the relatively low productivity of species on Ol Pejeta Ranch could be associated with the emphasis on production of consumptive products. This reinforces the findings of Wakhungu *et al.* (2002) who reported that eco-tourism has higher economic returns when compared with consumptive use only. In addition, Elliot & Mwangi (1997) reported that wildlife tourism provides the main economic justification for wildlife on the ranches either alone or mixed with livestock.

The consumptive use of wild herbivores alone led to low productivity while the inclusion of nonconsumptive use increased productivity of each species drastically. Thus multiple utilization of wild herbivores would make the enterprise more attractive and ensure better management of the range. This implies that wildlife conservation, as a land use in the drier environments is economically and ecologically sustainable. The two habitats, however, had unsuitable species mix and their cropping rates were not optimized at the 6% level that was being enforced by the Kenya Wildlife Service (KWS) at the time. This scenario led to competition for resources among herbivores in the two range units.

Species on LWC were not cropped and this led to high population densities that were degrading the habitat. On this strength, some cropping could be necessary to support the animal translocation activities on the conservancy. Each species could viably be cropped at different rates as shown in Table 3. Therefore, zebra, buffalo, giraffe and eland could be cropped at the 6% level to reduce the pressure on the basic range resources. The 6% was the cropping rate that had been recommended by KWS for this region, but had led to imbalances between vegetation biomass and animal biomass in other habitats in the region. It is therefore, expected that a combination of cropping at the 6% level and the translocation could lead to animal population densities that would maintain the desired ecosystem health.

Cropping on Ol Pejeta Ranch was carried out at the rate of 6% across the species as recommended by KWS for all ranches in the Laikipia region. However, this rate failed to reduce species to desired densities on the ranch. To improve the ecosystem health, zebra, buffalo, giraffe and eland could be cropped at rates between 6% and 10%. The 6% cropping rate was found to lead to animal populations densities that are unsustainable, while 10% was found to lead to rapid decline in animal numbers. The impala on this habitat as well as on LWC need to be cropped at 5% as 6% is the critical rate beyond which the species die out (Tables 3 and 4). The rate of 5% is recommended for impala because it should be sustained at the lowest density as it was found to be the least productive species.

Optimization of herbivore species mix

Lewa Wildlife Conservancy and Ol Pejeta Ranch sustain different animal species on the same range. The challenge to the ranchers is, therefore, to have a species mix that assures excellent range conditions and high economic returns. For this to be attained, competition among species should be reduced while complementarity is promoted. This can be achieved through species substitutions where some species are used to replace others. Wakhungu *et al.* (2002) reported that ranchers raising wildlife could use substitution of one species of wild herbivore interchangeably to suit market and changing economic policies or circumstances without causing degradation on the ranch.

From the results it is expected that LWC and the wildlife unit of Ol Pejeta Ranch need to maintain the impala at its lowest sustainable level as it had the lowest productivity (LWC: 9.85 Ksh kg^{-1} DM; Ol Pejeta Ranch: 4.69 Ksh kg^{-1} DM). It could be substituted by the more productive species, for example on LWC by the buffalo (21.10 Ksh kg^{-1} DM), while on Ol Pejeta Ranch by the eland (16.05 Ksh kg^{-1} DM). Giraffe, which is a high browser, could be increased in numbers to utilize the very high browse. Giraffe population needs to be increased in the two habitats because it has few competitors and therefore, it is a good complement to the other species.

The less productive species like the impala on LWC and Ol Pejeta Ranch could be substituted by the more productive species. Animals that play complementary roles like giraffe need to be increased in population for proper utilization of range resources. The substitutions need to maintain or improve the existing biodiversity, as this is crucial for ecological balance and tourism. The less productive species need to be cropped at high rates to reduce the herbivory pressure and competition on the habitats. Within the framework of these findings, the Kenya Wildlife Service would need to re-think the current ban and implementation strategies of wildlife cropping in Kenya.

Acknowledgements

We wish to acknowledge financial support received from Kenya Agricultural Research Institute (KARI) through Agricultural Research Fund (ARF). We are grateful to the

Department of Animal Production University of Nairobi for providing PRY and working space. Finally we thank all people in LWC and Ol Pejeta Ranch who contributed to this study.

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(Manuscript accepted 1 December 2006)

doi: 10.1111/j.1365-2028.2006.00749.x