The impact of giraffe, rhino and elephant on the habitat of a black rhino sanctuary in Kenya

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Abstract

The habitat in an enclosed black rhino sanctuary, the Sweetwaters Game Reserve in Kenya, is being altered as populations of elephant, giraffe and black rhino increase. Height-specific browse impact data were recorded for 1075 trees of the dominant species, the whistling thorn, *Acacia drepanolobium*. Rhinos and elephants browsed 18% of these trees in 1 year, including 5% that were killed or removed. The remaining trees were subjected to high levels of giraffe browse and low rainfall and grew by only 7.5 cm in a year. A mathematical model has been constructed that predicts how the number of trees ha^{-1} will change with time under different browsing impacts. The model compares recruitment rate with removal rate and estimates that the number of trees ha^{-1} will fall by 2% per year under the current browsing impact of black rhino (0.27 per km^2), elephant (1.1 per km^2) and giraffe (1.9 per km^2). In 7 years, if the rhino and elephant populations continue to increase at the current rates, tree density will be falling by 5% per year and nearly one-third of the trees will have been removed. These conditions are unsustainable and will result in habitat change and may affect rhino breeding. Several ways of alleviating the problem are discussed.

Key words: Acacia drepanolobium, elephant, giraffe, habitat, rhinoceros

Résumé

L'habitat d'un sanctuaire fermé de rhinos noirs, la Sweetwaters Game Reserve, au Kenya, est en train de se transformer parce que les populations d'éléphants, de girafes et de rhinos noirs augmentent. On a relevé les données sur l'impact du broutage à chaque hauteur spécifique pour 1075 arbres de l'espèce dominante, *Acacia drepanolobium*. Les rhinos et les éléphants ont consommé 18% de ces arbres en un an, y compris 5% qui sont morts ou ont été arrachés. Les arbres restants ont été victimes du broutage en hauteur des girafes et de faibles chutes de pluie et n'ont poussé que de 7.5 cm en un an. On a construit un modèle mathématique qui prédit comment le nombre d'arbres par hectare va changer avec le temps en fonction de différents impacts de broutage. Le modèle compare le taux de repousse avec le taux de prélèvement et estime que le nombre d'arbres / ha va diminuer de 2% par an avec l'impact actuel du broutage des rhinos noirs (0.27/km^2), des éléphants (1.1/km^2) et des girafes (1.9/km^2). Dans 7 ans, si les populations de rhinos et d'éléphants continuent à augmenter au rythme actuel, la densité des arbres diminuera de 5% par an, et environ un tiers des arbres auront disparu. Ces conditions ne sont pas soutenables et aboutiront à une modification de l'habitat qui pourrait affecter la reproduction des rhinos. On discute de plusieurs façons de réduire le problème.

Introduction

When the last 5-year management plan for black rhinoceros (*Diceros bicornis*) in Kenya was drawn up (Brett, 1993) it was predicted that the Sweetwaters Game Reserve had a black rhino carrying capacity of 90. At this level, however, it was postulated that overcrowding and damage to the environment would begin to reduce the rhino breeding potential, and so the population would need to be controlled at a figure closer to a management level of 70, by periodic removals and resettlement. In this way the Reserve would become a donor site, with surplus rhino being used to restock areas formerly occupied by black rhino. However, the achievement of this capacity was contingent on reducing the elephant (*Loxodonta africana*) population to at most 40 (Brett, 1993). Since the

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creation of the Reserve in 1988, no elephants have been removed and, with an elephant population of 100 and a rhino population of 25, the habitat is already being threatened. Tree replacement is also being slowed by the browse impact of 150 giraffe (*Giraffa camelopardalis reticulata*).

A number of studies in the past have examined the effect of large herbivores on woodlands. Generally these studies have focused on elephant and fire impact (Dublin, Sinclair, & McGlade, 1990; Ben-Shahar, 1996; Van de Vijver, Foley & Olff, 1999) but some have also included the effect of giraffes (Pellew, 1983a; Ruess & Halter, 1990). Nearly all these studies have based their measurements on large-scale analysis of damage, but one studied the effect of giraffes on the growth rates of individually marked trees (Pellew, 1983a). In this study the combined impact of elephants, giraffes and rhinos on the habitat has been quantified by direct measurement of the growth rate and damage to individually marked trees over the period of 1 year. Some data is also presented on the impact of rainfall based on growth measurements taken over 2 years.

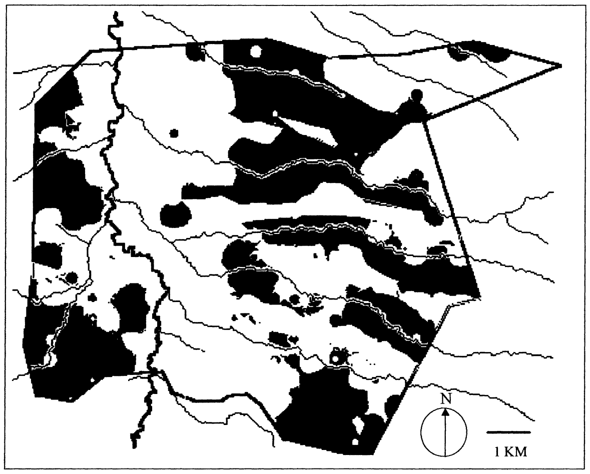

Fig 1 Sweetwaters Game Reserve. Areas dominated by *Acacia drepanolobium* are shown in black

Methods

Study site

Sweetwaters Game Reserve is located in central Kenya, 230 km north of Nairobi, near Nanyuki, on the equator at longitude 36°56′E. It is on the Laikipia plateau between Mt Kenya and the Aberdare Mountains at an altitude of 1800 m. The vegetation is a mosaic of grassland, *Acacia* woodland, *Euclea* scrub woodland and riverine woodland. The Reserve has a mean annual rainfall of 900 mm and a bimodal rainfall pattern giving long growth periods. The black rhino population comprised 25 known individuals. The rhinos occupy well-established home ranges (Tatman, Stevens-Wood & Smith, 2000).

Two species, the whistling thorn tree *Acacia drepanolobium* and the multistemmed shrub *Euclea divinorum* dominate the Reserve. These two species account for 71% of all the trees and shrubs sampled. Currently the whistling thorn is one of the principal foods of the black rhinoceros (Edwards, 1998), comprising more than 75% of its diet in this Reserve. This study was set up to quantify changes to the *Acacia drepanolobium* woodlands.

Based on the two dominant species, a habitat map has been prepared (Fig. 1) by inputting density data (trees ha^{-1}) to the Geographical Information System Idrisi (Eastman, 1997). The rivers were digitized in from a local map and open plains, fences and roads measured on foot or in a vehicle by recording locations on a Garmin GPS 12 Global Positioning System (Anon, 1998).

Tree measurements

Acacia drepanolobium tree growth and browse impacts were measured by setting up 21 plots randomly throughout the *Acacia* woodland areas of the Reserve. Located in the plots were 979 trees and 96 seedlings (height less than 0.5 m). Two additional plots (78 trees) were located in an area protected from elephants, rhinos and giraffes and acted as controls. Giraffe browse impact was estimated by comparing growth rates in the control area with those in the Reserve. In each woodland plot between 40 and 60 trees were selected to give a height-stratified sample. Trees were selected in two seedling and seven tree height classes. Each tree was identified with a numbered aluminium tag and each seedling by a plastic covered wire. The plot locations were recorded by GPS, accurate to 100 m and the individual tree locations by bearing and distance (in metres) from the first tree. Seedlings were located by recording bearings and distances from tagged trees.

Browsing was recorded only if it affected the main stem and hence affected growth or survival. Branch damage was not recorded. Browsing by herbivores can be differentiated easily in the field. Elephants either push over trees, or break the main stems and leave the bark hanging in strips; rhinos make a clean cut of the main stem; giraffes eat the leaves and growing tips of branches and main stems. Some trees died from 'natural' mortality agents such as disease, lack of water or old age. A tree may be 'reversed' when it is damaged so severely by an elephant or rhino that it regresses into a lower height class but does not die. The tree regrows eventually.

On each plot the heights of all tagged trees and seedlings were measured between June and October in 1998. The height and damage status of each tree and seedling were checked 1 year later (June–October 1999). Tree height was measured to an accuracy of 2 cm using a Dynamis Telescopic Measuring Rod (Stanton Hope, 1998) that could be extended to 7 m. Measurements were recorded in the field using a US Robotics 3Com PalmPilot Professional loaded with software supplied by the University of Kent (Pascoe, Morse & Ryan, 1998). Data was downloaded from the PalmPilot at the Research Centre into Microsoft Excel 97 spreadsheets.

Tree growth rates are given as means ± standard error. Growth rates were compared using two-tailed *t*-tests performed on Minitab Release 10.2.

In a pilot study, trees in the two protected plots and two in the Reserve were first measured in 1997. These trees were remeasured in 1998 and in 1999. The difference in annual growth rates between the 2 years was used to examine the impact of rainfall on tree growth.

The model

The model is based on the work conducted by Pellew (1983a) who measured the impact of giraffes on the rate of growth of *Acacia* trees and developed the first model to simulate the interaction between elephants and giraffes in the Serengeti. This model was modified by Dublin *et al.* (1990) to examine how the two stable states of woodland and grassland could have been created in the Serengeti-Mara by the interaction of elephants and fire. The model was then modified further by Ben-Shahar (1996) who looked at the interactions of elephants and fire on a Botswana woodland. In the current model the effects of fire have been excluded (because fire is not used to control habitat in this Reserve) but the impact of three herbivores – giraffes, elephants and black rhinos – has been incorporated. The effect of rainfall is included because it affects tree growth. In each tree height class, recruitment is determined by the number of new trees (or fresh seedlings) that enter it either by growth from the height class below or from height classes above when trees are 'reversed'. Elephants, rhinos and natural mortality agents remove trees from a class. Hence the difference determines how many trees there are in each height class at the end of each period for which the model is run.

Results

The 78 trees in the protected area had a mean annual growth rate of 19.1 $\pm$2.1 cm year^{-1}. The 879 trees in the unprotected *Acacia* woodland that were not reversed, killed or removed, had a mean annual growth rate of 7.5 $\pm$0.5 cm year^{-1}. Elephants retarded the growth of 44 of these trees, rhinos retarded the growth of 14 and the remaining 821 were subject to giraffe browse.

Growth rate varied with height class in the *Acacia* woodland (Fig. 2) and in the protected area (Fig. 3).

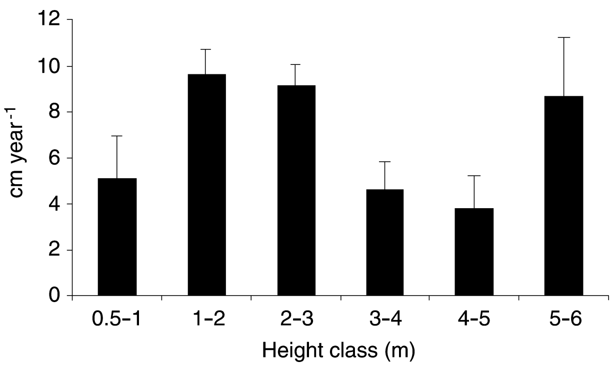

Fig 2 The mean ± SE annual growth rate of each height class of *Acacia drepanolobium* trees in the unprotected *Acacia* woodlands

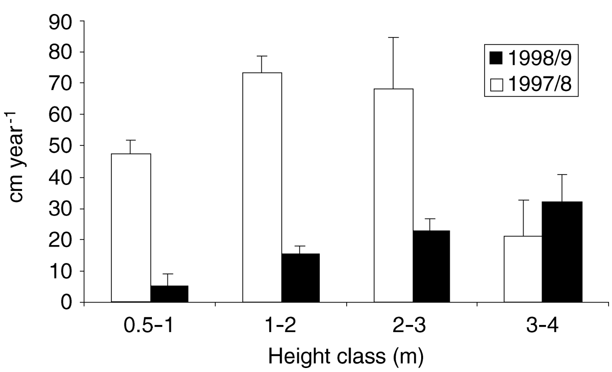

Fig 3 The mean ± SE annual growth rate of each height class of *Acacia drepanolobium* trees in the protected area in 1997/8 and 1998/9

Tree growth in the *Acacia* woodland was significantly lower in the 3–5 m height classes and in trees below 1 m than in trees in other classes ($t = 4.7$ $P < 0.001$). Mean annual growth rate in the 1–3 m height classes was 9.3 ± 0.6 cm, significantly lower than the mean annual growth rate of 17.9 ± 2.2 cm for the same height classes in the protected area (Fig. 3) ($t = 3.8$, $P < 0.001$). Mean annual growth rate of trees in the 3–4 m height class was 4.6 ± 1.1 cm, significantly lower than the mean annual growth rate of 31.8 ± 8.9 cm for the same height class in the protected area ($t = 3.0$, $P < 0.05$). However, there was no significant difference between the growth rate of the 0.5–1 m class in the protected area and the *Acacia* woodlands.

In the 12 months from mid 1998 to mid 1999 12% (129) of the 1075 tagged trees or seedlings were reversed or killed by rhinos, elephants or natural mortality agents. Damage varied with height class (Table 1).

Damage to the lower height classes was most severe. Over 52% of seedlings (<0.25 m) were lost in 1 year and 36% of the trees in the 0.5–1 m class were killed or reversed (Fig. 4).

Rhino damage and tree removal was confined to trees below 2 m (Fig. 5) whilst elephant damage was more evenly distributed.

Four plots, two in the protected area and two in the *Acacia* woodlands, were measured in 1997 as well as in 1998 and 1999. 1997/98 was an El Nino year with over 1200 mm of rain, whilst 1998/99 was one of the driest on record with 600 mm. In the El Nino year trees grew at 59.2 ± 3.8 cm in the protected area (but only 13.5 ± 2.3 cm in the two *Acacia* woodland plots). In the following year, growth in the protected area was limited to only 19.1 ± 2.2 cm (and in the two *Acacia* woodland plots was only 5.8 ± 1.5 cm).

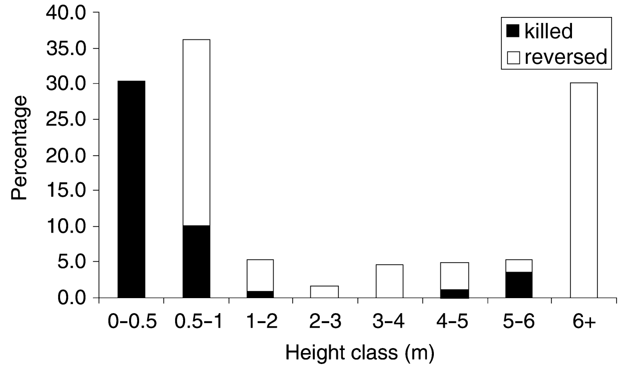

Fig 4 The percentage of *Acacia drepanolobium* trees in each height class 'reversed' or killed

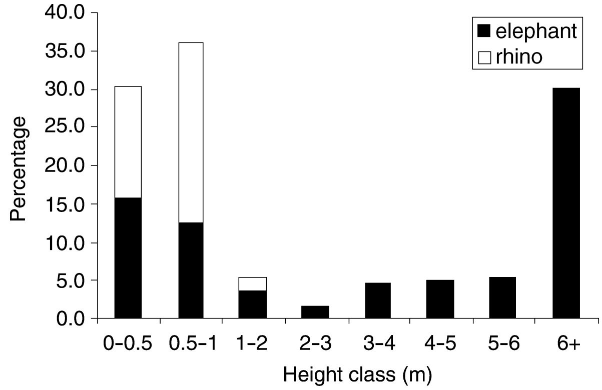

Fig 5 The percentage of *Acacia drepanolobium* trees in each height class damaged by rhinos and elephants

These were mean rates for all height classes. Rainfall affected each height class differently (Fig. 3). For trees less than 3 m in height mean growth rate was 61.9 ± 4.0 cm when rainfall was 1200 mm, significantly higher than

Table 1 *Acacia drepanolobium* trees killed or reversed in 1 year

Height class	Number of trees	%dead natural	%killed elephant	%killed rhino	%reversed elephant	%reversed rhino	% total
Seedlings	96		15.6	14.6			30.2
0.5–1 m	172		5.5	4.4	7.0	19.2	36.0
1–2	251		0.4	0.4	3.2	1.2	5.2
2–3	256	0.4			1.6		2.0
3–4	131	0.8			4.6		5.3
4–5	102		1.0		3.9		4.9
5–6	57	3.5	3.5		1.8		8.8
6+	10				30.0		30.0
Total	1075	0.4	2.6	2.1	3.5	3.4	12.0

the 17.0 ± 2.1 cm achieved when rainfall was 600 mm ($t = 9.9$, $P < 0.001$). In contrast, taller trees showed no significant difference in growth rate between the 2 years (Fig. 3).

The model was first used to predict what would happen to the habitat when subjected to the current browse levels. Under the combined impact of all three herbivores at the current animal densities the model predicts that tree density would fall by 2% per year. Assuming that in 7 years the rhino population doubles, the elephant population increases by 30% and the giraffe population can be stabilized by culling or translocation, the model predicts that tree density would fall by 5.0% per year. If tree removal rate increases from 2% per year at year zero to 5% per year after 7 years, tree density in the Reserve will then have fallen by 31.5%, although death by starvation may limit population growth before such extensive damage occurs.

The model was then run to simulate what the effect was of reducing the browse impact of species that compete with rhinos. If half the elephants were to be removed from the current population, the model predicts that there would be a 0.4% increase in the number of trees each year. If half the giraffe were removed, the model predicts that there would be an increase of 2% per year. If the Reserve were to be expanded in area by 50%, the overall effect would be to reduce the browsing impact of elephant, rhino and giraffe by 33%. The model predicts that this would lead to an increase in tree density of 3.4% per year.

If the rhino population were then allowed to double whilst keeping elephant and giraffe populations constant, the model predicts that after 7 years tree density would still be increasing but only by 0.2% per year in the expanded Reserve.

Discussion

Woodland–grassland ecosystems appear to be inherently dynamic (Dublin, 1995), with factors such as browsing, fire and rainfall being critical in determining whether the habitat will be stable or subject to rapid change. In this study the *Acacia* woodlands were exposed to conditions of low rainfall and high levels of browsing by elephants, rhinos and giraffes but were not subject to fire. These impacts appear to be sufficient to be causing a rapid reduction in tree density.

Giraffe browse and low rainfall reduced tree growth. In this study rainfall was only 600 mm per year and giraffe density was 1.9 per km^2, amongst the highest recorded in sixteen African game reserves reported by Pellew (1983c). In these conditions *Acacia drepanolobium* grew at 7.5 cm per year in the woodlands and 19.1 cm per year in the protected area. In comparison Pellew (1983a) measured annual growth rates for *Acacia tortilis* and *hockii* of 16.5 and 17.5 cm per year in the *Acacia* woodlands compared with 44.2 and 49.6 cm per year in a protected area. In the Seronera woodlands of the Serengeti, giraffe density was 1.47 per km^2 and mean annual rainfall was 811 mm (Pellew, 1983b).

Growth retardation was height specific. Growth rates in the protected area increased with height (Fig. 3) but in the *Acacia* woodlands were lowest in the 3–5 m height classes. In the 0.5–1 m class, growth rate was the same in the protected and unprotected areas. In the 1–3 m classes, growth rates were half and in the 3–4 m class, one-seventh of those in the protected area. Hence giraffe impact in this study was greatest at 3–5 m. Pellew (1983a) reported the maximum giraffe impact to be between 2 and 3 m. However, in the Serengeti the sex ratio in the giraffe population was biased towards females and subadults, only 19% being adult males. At Sweetwaters, during observation of 86 groups, Pinkney (1998) recorded 48% adult males and only 14% juveniles and subadults. The mean feeding height of giraffes in the Reserve on *Acacia drepanolobium* was 3.7 m for adult males and 2.6 m for adult females.

Tree damage rates at Sweetwaters were high. Elephants killed or reversed *Acacia drepanolobium* trees in all height classes, including 11% of the trees and seedlings below 1 m. Croze (1974b) reported that elephants did not feed on *Acacia* trees at heights below 1 m but Dublin (1995), based on direct close-up observations, determined that elephants, at a density of just less than 1 per km^2, killed 4% of all seedlings – defined as less than 1 m. In the *Acacia* woodlands at Sweetwaters nearly 60% of the trees and seedlings were below 1 m and this study supports the view that elephants do browse on small trees when available (Dublin, 1995). In another study, elephants, at a density of 3.2 per km^2, killed 10% of all *Acacia eriolaba* seedlings – defined as less than 1 m (Ben-Shahar, 1996).

Elephants killed 5.2% of trees above 5 m in height. This is similar to the figures of 5% for *Acacia tortilis* reported by Ruess & Halter, 1990) for a 10-year period prior to 1982 in the Serengeti. However, they did not kill any trees in the 3–5 m height classes. Croze (1974a) reported a significant difference in the way elephants damaged trees above and below 5 m. Taller trees were pushed over whilst the shorter ones had branches broken. In this study elephants reversed 4.3% of trees in the 3–5 m class, thus supporting the observation that they snap the tops off smaller trees but push over larger trees.

If tree density declined by a quarter, would rhino switch to other species? Black rhinos are known to eat an extremely wide range of plant species, ranging from trees to shrubs and herbs. Goddard (1968, 1970) listed 191 species eaten in the Ngorongoro and 102 in Tsavo; Muya & Oguge (2000) reported 34 species eaten in Nairobi National Park; Mukinya (1977) noted 70 species eaten in the Masai Mara; Oloo, Brett & Young (1994) recorded 103 food plant species eaten by black rhinoceros in the Ol Ari Nyiro Ranch. Therefore, it seems likely that black rhinoceros may compensate for loss of *Acacia* trees by switching to other species. However, in this reserve there are few other alternatives.

If both elephant and rhino populations are allowed to increase at their present rates, 32% of the *Acacia* trees will be lost in 7 years. There are several options available to the Reserve management. To prevent further tree loss, elephant or giraffe populations would have to be halved and other populations stabilized. This would mean exporting surplus rhinos now and removing 50 elephants or 75 giraffes. Studies are underway to assess both these options. Elephant translocation currently appears to be more feasible.

A better alternative would be to expand the area of the Reserve by 50% and then stabilize the elephant and giraffe populations. This would enable the tree population to be stabilized whilst enabling the black rhino population to double to 50.

Finally it should be noted that these measurements were taken in a dry year. Studies are continuing with the aim of collecting enough data to validate the model for a wide range of conditions.

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