Factors affecting black rhino monitoring in Masai Mara National Reserve, Kenya

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Abstract

The black rhino in Africa is slowly recovering from poaching. This has been achieved in part by maintaining ongoing monitoring as part of intensive protection and biological management. However, the efficacy of population monitoring methods has not been assessed. Rhino surveillance records and rainfall data were used to determine which ecological and operational factors affected monthly rhino sightings by vehicle patrols in Masai Mara, Kenya. Comparisons of sightings capture rates using different ground-based and aerial methods were also conducted. Stepwise multiple regression revealed a model (adjusted $R^2 = 0.66$) predicting monthly rhino sightings with four significant factors; number of patrols, rhino population size, rainfall over the previous 2 months and a dummy variable for the month of August. The latter two variables represent the negative effects of long grass growth and the annual wildebeest migration on rhino sightings, and result in seasonal deficiencies in monitoring. During vehicle patrols, 51% of sightings were made whilst moving, and 49% were made whilst stationary and scanning with binoculars, although sightings capture rate was an order of magnitude higher when stationary. Equally, sightings capture rate from hot air balloons was twice that during vehicle-based patrols, although with less accuracy of identification. The introduction of foot patrols would increase patrol cost-effectiveness and fill seasonal troughs, thereby providing better all-round surveillance.

Key words: Black rhinoceros, population, monitoring, seasonality, Kenya

Résumé

Le rhino noir d'Afrique récupère peu à peu des méfaits du braconnage. Ceci est le résultat, en partie, de la poursuite des contrôles constants visant une protection intensive et une gestion biologique. Pourtant, on n'a pas évalué l'efficacité des méthodes de surveillance de la population. On a utilisé les rapports de surveillance des rhinos et les données sur les chutes de pluie pour déterminer quels facteurs écologiques et opérationnels influençaient le nombre de fois que les véhicules des patrouilles apercevaient des rhinos chaque mois dans le Masai Mara, au Kenya. On a aussi fait des comparaisons des taux de captures visuelles selon différentes méthodes, au sol et aériennes. La méthode de régression multiple a fait apparaître un modèle (R^2 ajusté = 0,66) pour prédire les observations mensuelles de rhinos avec quatre facteurs significatifs; le nombre de patrouilles, la taille de la population de rhinos, les chutes de pluie au cours des deux mois précédents et une variable factice pour le mois d'août. Les deux dernières variables représentent les effets négatifs de la croissance de longues herbes et de la migration annuelle des gnous sur l'observation des rhinos et leurs résultats sur les faiblesses saisonnières des contrôles. Pendant les patrouilles motorisées, 51% des observations se sont faites en mouvement et 41% à l'arrêt, en observant aux jumelles, mais le taux de captures visuelles était un ordre de grandeur supérieur à l'arrêt. De même, le taux de captures visuelles obtenu à partir d'une mongolfière était le double de celui obtenu lors des patrouilles motorisées, mais la précision des identifications était plus faible. L'introduction de patrouilles à pied augmenterait la rentabilité des patrouilles et permettrait de combler les lacunes saisonnières et d'assurer une meilleure continuité de la surveillance.

Introduction

Over the past two decades, conservation of Africa's elephants and rhinos *in situ* has relied, in no small part, on intensive human surveillance efforts in the areas where

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these species survive. Such effort has served as a deterrent to poachers and as a means of apprehending them, and has also provided information on illegal activity and animal population growth and decline (Leader-Williams, 1996).

The principal focus of surveillance has been security, to halt the decline in elephant and rhino populations as a result of poaching. Assessments of the performance of surveillance efforts for elephants have revealed that appropriate resource allocation, in terms of increased effort and incentives for rangers, increases the efficacy of surveillance both as a deterrent to poachers and for addressing population decline (Leader-Williams, Albon & Berry, 1990; Jachmann & Billiouw, 1997).

The critically endangered black rhinoceros (*Diceros bicornis* L.) is now exhibiting a gradual recovery in the wild after decades of poaching (Martin & Martin, 1982; Western, 1982; Leader-Williams, 1988, 1992), and numbers approximately 2600 individuals across Africa (Emslie & Brooks, 1999). This success has been achieved through intensive protection and management of small populations, combined with metapopulation management using translocation as a tool to maintain sustained reproductive output and genetic viability (Dublin & Wilson, 1998; Emslie & Brooks, 1999). Whilst security surveillance remains paramount, there is also a need for biological monitoring of black rhino populations.

Population monitoring is a key facet of current black rhino conservation and management strategies (Emslie & Brooks, 1999). Most back rhinos are confined to relatively small populations, therefore the onus of management is on maximising population growth. Monitoring rhino populations is important to ensure that performance targets are reached. Regular monitoring provides the basic information on population performance, such as birth rate, mortality, sex ratios and calving intervals necessary for biological management.

Whilst security surveillance is predicated on maximising the detection and apprehension of poachers, population monitoring aims to maximise the number of rhino sightings and resightings. Regular resightings confirm that individuals are still present, permit assessment of their health and reproductive status, and allows confirmation of new births at an early stage. By maximising resightings at regular intervals managers can react more quickly to potential problems, such as a sick calf, injured rhino or missing rhino.

Rhino monitoring is usually conducted on the ground, using vehicles or foot patrols, because aerial methods are more expensive and less reliable (Goddard, 1967). In the Masai Mara National Reserve (MMNR) in Kenya, rhino surveillance has been conducted since the mid-1980s by a team of rangers in a single motor vehicle. MMNR is a relatively large area with good visibility, and a low-density black rhino population (Morgan-Davies, 1996; Walpole *et al.*, 2001). Hence vehicle patrols, which allow a greater area of ground to be covered in a shorter space of time, are considered to be more appropriate than foot patrols.

The effectiveness of population monitoring methods, in terms of maximising rhino sightings to provide adequate and timely data for assessing population performance, will depend upon the performance of the methods themselves and the factors that affect them. Whilst the efficacy of security surveillance has been examined in detail (Leader-Williams *et al.*, 1990; Jachmann & Billiouw, 1997), the same is not true of population monitoring.

This study examined the performance of the vehicle-based method for monitoring rhinos in MMNR, and identified factors affecting performance over a 6-year period. It also compared different methods of monitoring rhinos (stationary versus mobile, ground-based versus hot air balloons) that were implemented in 1999, and estimated the potential contribution of proposed foot patrols to an integrated ground-based monitoring programme in MMNR.

Materials and methods

Study area

The Masai Mara National Reserve (MMNR) is a 1510 km^2 unfenced protected area in the south-west of Kenya on the border with Tanzania, lying between 34°45′ and 35°25′ E and 1°13′–1°45′ S (Fig. 1). It is an area of undulating grassland savanna intersected by numerous drainage lines and rivers (Dublin, 1984, 1991).

MMNR is the northernmost extension of the world-famous Serengeti-Mara ecosystem which supports an extremely high diversity and biomass of large mammals, including a range of ungulate and large carnivore species (Sinclair & Norton-Griffiths, 1979; Dublin, 1984; Broten & Said, 1995; Sinclair, 1995). It is also a key refuge for the black rhinoceros. In the 1960s, MMNR contained a

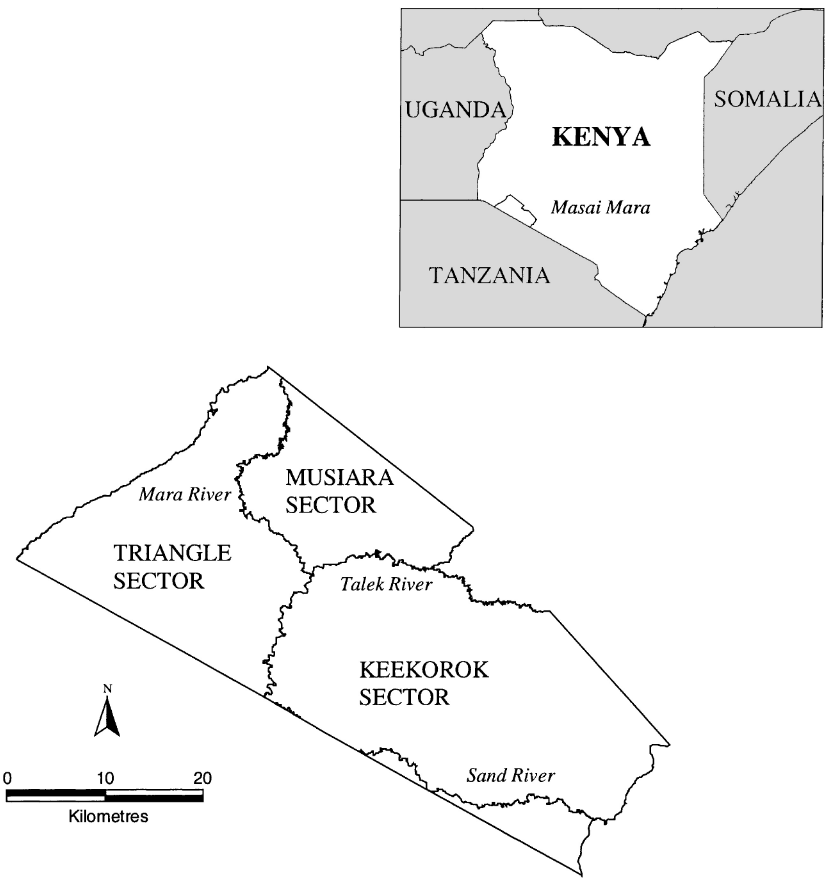

Fig 1 Masai Mara National Reserve, Kenya

population of around 150 black rhinos (Brett, 1993). A study in the early 1970s identified 108 individuals (Mukinya, 1973). However, throughout the 1970s and early 1980s, the population was greatly reduced by poaching to supply the illegal trade in rhino horn, and declined to less than fifteen individuals (Morgan-Davies, 1996). Since the mid-1980s security has increased and the population has begun to recover; now reaching numbers of approximately 23 (Walpole *et al.*, 2001).

Factors affecting monthly rhino sightings

The MMNR Rhino Surveillance Unit patrolled twice daily within the Keekorok sector of the Reserve, where all but one of the MMNR black rhinos reside. Occasional patrols were also made to other areas, but were excluded from this analysis. Each patrol consisted of a team of three to six rangers and a driver in one vehicle, who drove a predetermined route (which varied for each patrol to allow adequate cover of the area) through part of the Reserve. Throughout the patrol the rangers remained alert to the presence of rhinos, and intermittently the vehicle stopped to allow the rangers to make binocular scans of the surrounding area. The open terrain and frequent high vantagepoints within MMNR permit large areas to be patrolled and scanned using this method.

After each patrol, the date, start and end time, areas traversed and personnel involved were recorded, along with a record of any rhinos encountered and the general area of sighting. Patrol records were available from November 1993 until December 1999.

Independent rhino sightings (where a single animal, a mother/calf pair, or other group of rhinos seen together each constitutes one independent sighting) were compiled into monthly totals. This was used as a measure of monitoring success in a stepwise multiple regression (Tabachnik & Fidell, 1989). Independent variables included in the analysis were the number of patrols each month, total amount of time spent on patrol, rainfall, rainfall the previous month, rainfall the previous 2 months, dummy variables for each month, and the estimated annual rhino population size (from Walpole *et al.*, 2001).

Comparing ground-based and aerial monitoring methods

During 1999, records were kept of whether each sighting was made by the naked eye whilst the patrol vehicle was in motion, or whilst stationary and scanning with binoculars. In addition, on a sample of patrols, the duration of each period of binocular scanning was recorded. This facilitated a comparison of sightings capture rates whilst driving and whilst scanning. The proportion of sightings made by each method was determined, as was the mean capture rate (sightings per hour).

In addition, during 1999, the assistance of three commercial hot air balloon companies operating within the Keekorok sector of MMNR was sought to record sightings of rhinos during morning flights. This provided an aerial sighting capture rate for comparison with the official ground-based monitoring (assuming an average flight lasted for duration of 1 h).

Estimating the value of foot patrols

Data for the recurrent costs of implementing rhino monitoring (salaries, bonuses and vehicle running costs) were collected from January to December 1999. These were used to calculate monthly costs per sighting in US dollars for this period (using an exchange tare of 70 Kenyan Shillings to US$1). Estimates of the cost of implementing foot patrols, and the capture rate of rhino sightings, were used to simulate the effect of foot patrols on: (1) overall cost per sighting, and (2) monthly sightings capture rate.

The costs of implementing foot patrols were estimated using the following assumptions. First, that it would be possible to incorporate one or two foot patrols per day within the current vehicle-based monitoring programme by dropping rangers off during morning patrols and collecting them during afternoon patrols. Second, that incorporating foot patrols would not add more than 10 km per foot patrol to daily vehicle use. Third, that a pair of armed rangers would conduct patrols, earning the same salary and bonuses as the existing vehicle-based team. Fourth, that each patrol would cover 10 km (a conservative estimate). Finally, that sightings capture rate during foot patrols would remain constant throughout the year. The capture rate of rhino sightings per kilometre walked on foot patrols, for a given rhino density, was taken from a study using foot patrols to monitor rhinos in South Luangwa National Park, Zambia (Leader-Williams, 1985). For the 1999 population density within MMNR, this translates into one sighting per 37.3 km walked.

Two scenarios were investigated, one with an even spread of foot patrol effort throughout the year and the other with focused deployment of effort at certain times of year. The first employed a single foot patrol for each day that morning and afternoon vehicle-based patrols were undertaken, throughout the year. The second, using an equivalent amount of effort, employed two foot patrols per day in the 6 months with the lowest capture rate (sightings/vehicle-based patrol), and no foot patrols during the other 6 months of the year.

Results

A total of 11,334 h were spent undertaking 3047 patrols between November 1993 and December 1999, during which time 1825 independent rhino sightings were recorded. The mean capture rate of sightings during this time was 0.60 sightings/patrol and 0.16 sightings/h of patrol (Table 1). However, on an annual basis capture rates have been declining since 1993 in line with declining rhino population size estimates within MMNR (Walpole *et al.*, 2001). In 1999, the mean capture rates were 0.45 sightings/patrol and 0.11 sightings/h of patrol.

Factors affecting monthly rhino sightings

Out of a total of 74 months of data, two had missing variables and one was found to be an outlier. These were excluded from the multiple regression analysis. The best

Table 1 Annual sightings capture rates during rhino patrols in MMNR, 1993–1999

Year	Rhino sightings per patrol	Rhino sightings per hour of patrol
1993	0.69	0.21
1994	0.81	0.23
1995	0.81	0.22
1996	0.62	0.17
1997	0.62	0.17
1998	0.29	0.08
1999	0.45	0.11

model of monthly sightings, with a good level of prediction (adjusted $R^2 = 0.66$, $n = 71$), included four variables. These were, in order of entry, number of patrols undertaken, population size, rainfall over the preceding 2 months and a dummy variable for the month of August (Table 2). The model revealed that the number of sightings each month increased with increasing patrol effort and increasing population size, and decreased with increasing rainfall over the 2 preceding months. Sightings were also significantly fewer during August.

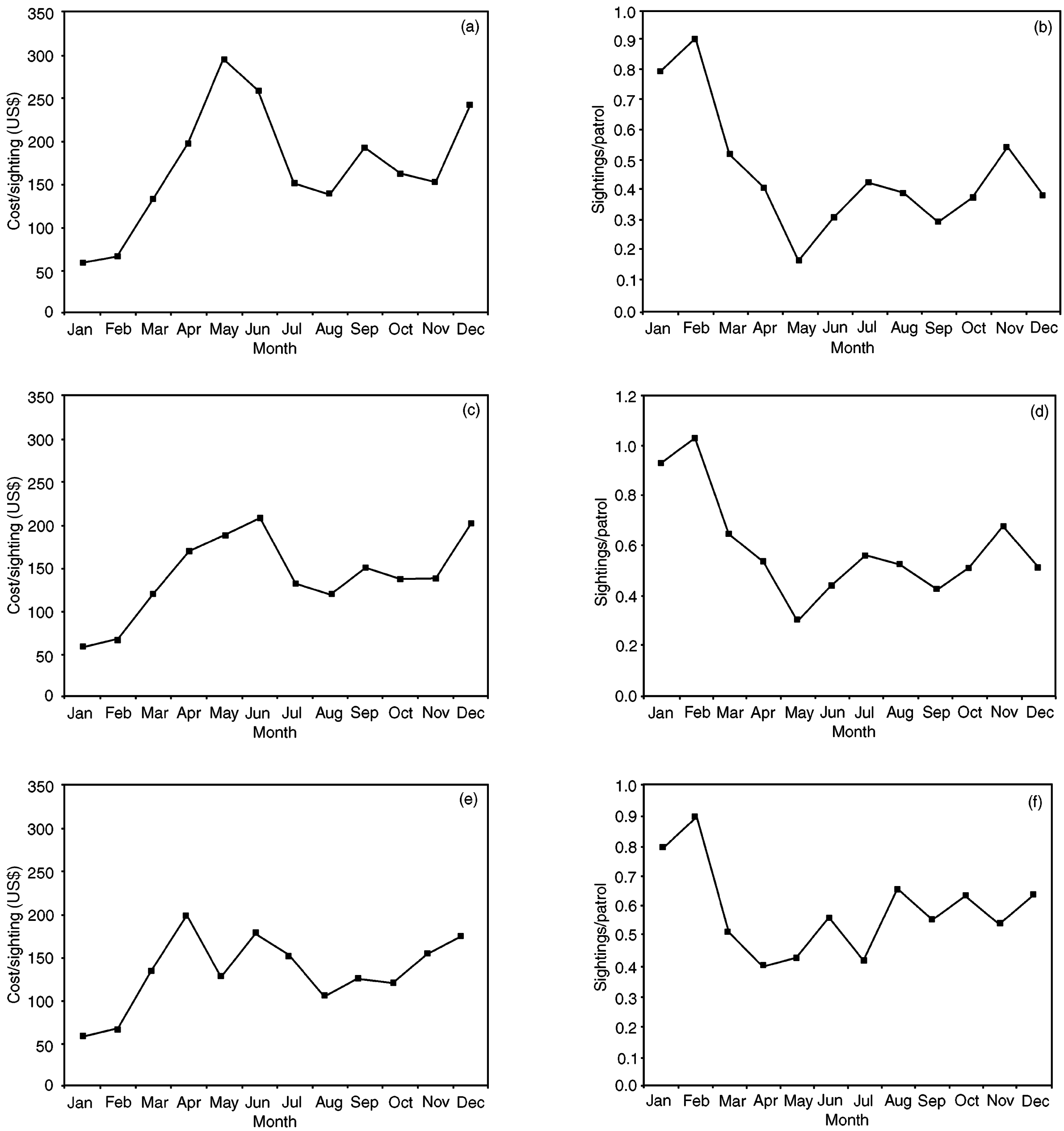

Fig 2 The effect of implementing foot patrols on cost effectiveness [cost/sighting (a), (c), (e)] and sightings capture rate [sightings/patrol (b), (d), (f)]. (a) and (b) represent vehicle patrols only (c) and (d) represent vehicle patrols with foot patrols throughout the year, and (e) and (f) represent vehicle patrols with foot patrols focused in low efficiency months

Table 2 Results of the multiple regression model of monthly rhino sightings

Variable	Cumulative adjusted R^2	Coefficient (B)	Standard error of B
Number of patrols	0.26	0.478	0.066
Population size	0.51	1.470	0.219
Rainfall over past 2 months	0.64	−0.052	0.010
August dummy variable	0.66	−6.523	3.087
Constant	–	−24.79	6.825

When the analysis was repeated using sightings/patrol and sightings/h as dependent variables, to take account of patrol effort, the three other variables were still entered in the same order (adjusted $R^2 = 0.56$ and 0.58, respectively).

Comparing ground-based and aerial monitoring methods

On an average patrol, six scanning stops were made, with an average of 3.74 min of scanning per stop, giving an average of 22.43 scanning minutes per patrol ($n = 27$). Mean patrol duration during 1999 was 3 h 54.5 min ($n = 452$).

Approximately half of all sightings where records were kept were made whilst stationary and scanning with binoculars (48.9%), and half were made whilst driving (51.1%, $n = 92$). However, capture rate whilst scanning was an order of magnitude greater than whilst driving (0.59 and 0.06 sightings/h, respectively).

The mean sightings capture rate by pilots in hot air balloons during 1999 was similar to that for ground-based patrols (0.13 sightings/h, $n = 248$). However, if records from one company that flies predominantly over an area devoid of rhinos are excluded, the capture rate rises to almost double that of ground-based patrols (0.21 sightings/h, $n = 156$). This result is tempered by a lack of positive identification of rhinos by balloon pilots in most cases where close-up photographs were not taken.

Estimating the value of foot patrols

During 1999, the overall mean cost per rhino sighting using vehicle-based patrols was US$169.12 (monthly SD = US$70.87), with some monthly seasonality (Fig. 2a). There were 0.45 sightings/patrol, but there was a marked seasonality to the capture rate (Fig. 2b). By incorporating single daily foot patrols throughout the year, the cost per sighting decreased to US$137.21 with a more even pattern of cost-effectiveness witnessed throughout the year (Fig. 2c). Equally, sightings capture rate increased to 0.58 sightings/patrol, however the seasonality in capture rate remained (Fig. 2d).

By focusing foot patrols in the months of May, June, August–September and December, when the lowest sightings/patrol were recorded, a similar decrease in cost per sighting (to US$130.77) and smoothing of the monthly cost curve was observed (Fig. 2e). However, in this simulation the monthly pattern of sightings/patrol also became more balanced, with the seasonal trough in capture rate disappearing (Fig. 2f).

Discussion

The results revealed that rhino sightings by vehicle were affected by four factors. Two of these are intuitive; monthly sightings increase with increasing patrol effort and increasing population size (and therefore density). The other two relate to seasonal ecological processes.

The first of these, rainfall in the preceding 2 months, is likely to be a combined measure of grass growth and accessibility. Grass in MMNR reaches its maximum height of 1.5–2 m several weeks after the onset of the long rains. Rhinos become less visible at distance across the plains when the grass is tall and areas of long grass become more difficult to traverse. Equally, after sustained periods of rainfall areas at a distance from major roads become inaccessible due to the wet ground, particularly on black cotton soil and close to rivers and streams.

The second seasonal variable to affect rhino sightings was the month of August, during which sightings were significantly lower than expected after taking into account patrol effort, population size and rainfall. August is the peak month for the wildebeest migration, which begins to arrive from the Serengeti National Park in June or July, and which lasts until October (Sinclair & Norton-Griffiths, 1979). When wildebeest numbers are high it becomes very difficult to differentiate rhinos amongst them. Furthermore, it is thought that the presence of the wildebeest in such large numbers disturbs the rhinos and causes them to seek refuge in thickets and drainage line vegetation (P. Bett, personal communication).

These factors result in gaps in the efficiency of rhino monitoring in MMNR. If the motive for monitoring is simply to generate annual population estimates, one would recommend maximising patrol effort during dry periods of low grass height outside of the wildebeest migration, in this case during January and February. This is precisely the strategy employed for the combined ground and aerial census of rhinos that was conducted in 1999. However, it should be noted that this rapid, intensive survey did not reveal all of the rhinos known to be residing in the area from the regular monitoring records (Walpole & Bett, 1999a). It takes up to 2 years of regular monitoring to re-sight every rhino within MMNR (Walpole *et al.*, 2001), and it is unlikely that a complete census can be achieved in an intensive survey, even with aerial support.

If the motive of monitoring is to provide accurate and up-to-date information upon which to base management decisions, then the monitoring programme must maintain a more or less constant level of efficiency year-round. Three recommendations are made to ensure that monitoring in MMNR meets this requirement.

First, more stops could be made during vehicle patrols. Whilst this may decrease the total distance travelled during patrols, it should increase the capture rate per patrol, because it will permit more detailed scanning of remote areas and the edges of thicker vegetation where rhinos are often missed.

Second, balloon pilots should be encouraged to adopt standard reporting of rhino sightings. Pilots see rhinos more frequently than ground patrols, because of their slow speed and aerial vantage point, which increases visibility into thickets. Whilst pilots may not be able to identify individuals to the same level of accuracy as trained rangers, they can provide detailed information on group composition and location using GPS, and in some cases have been able to provide photographs to enable identification. Recently, pilots have alerted the rhino surveillance unit to the presence of a calf within a few days of birth, enabling the unit to focus patrols in that area to verify the birth more rapidly than would otherwise have been the case (Walpole & Bett, 1999b). Similarly, it would be valuable to encourage the many tour drivers operating within MMNR to report rhino sightings whenever they occur.

Third, and most importantly, it is recommended that foot patrols are implemented in MMNR. Not only would foot patrols increase both the rate of sightings and the cost effectiveness of the monitoring programme, they would permit much more detailed information to be gathered. This includes evidence of rhinos (footprints, browse points, middens and scrapes, skulls and carcasses) and of poachers (Leader-Williams *et al.*, 1990; Leader-Williams, 1985; 1988). Vehicle patrols rarely find rhino carcasses, and so disappearances are difficult to attribute to death or dispersal (Walpole *et al.*, 2001). However, foot patrols, which can enter thicker vegetation where rhinos hide, are much more likely to find such evidence (Leader-Williams, 1988). Equally, foot patrols are more likely to come across poachers or evidence of their presence, and hence would provide a more efficient security system as well as a population monitoring system (Leader-Williams *et al.*, 1990; Jachmann & Billiouw, 1997).

The simulation results presented here suggest that the most efficient use of foot patrols for balancing seasonal rhino sightings would be to focus them in certain periods of the year. However, to ensure an even security presence foot patrols should be implemented throughout the year, but should be focused in those areas where rhinos are present. Given adequate resources appropriately deployed, an improved system of surveillance and monitoring can be developed.

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