Establishing a monitoring system for black rhinos in the Solio Game Reserve, central Kenya

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Abstract

Solio Game Reserve in central Kenya was the first black rhino (*Diceros bicornis*) sanctuary in the country. In 1970 five remnant individuals were moved into it for safekeeping against poachers. Eighteen further introductions and subsequent births in good habitat with no human interference led to rapid population increase, and the reserve has since become the source of 67 rhinos to assist in stocking new sanctuaries. In 2000, when the reserve had the highest density of rhinos in Kenya, poachers attacked Solio and nine black rhinos were killed in a five-year period. A security and monitoring system needed to be established. All previous records had been destroyed in a fire and there were no accurate population estimates of the number of rhinos. Patrol camps, patrol staff and associated equipment were acquired and training was undertaken. The reserve was GPS mapped and divided into seven security sectors, each with four or five monitoring areas. Photo identification was used to determine the number, identity and demography of the rhinos. A simple computerized record-keeping system was designed and installed and is outlined. In December 2005 field monitoring began. At the end of the first year, using identification photographs and with nearly 6000 sightings, 87 rhinos were identified but with the likelihood that there were some duplication errors and some rhinos not yet found and photographed. From this, a sex and age profile was produced and breeding performance estimated and benchmarked. With a population greatly in excess of estimated carrying capacity, reduction in numbers by translocation to other areas is essential but with an imbalance in the sex and age profile, choosing suitable candidates will be a problem.

Additional key words: photo identification, demography, carrying capacity, benchmark, performance indicators, GPS

Résumé

La Réserve de Faune de Solio, au centre du Kenya, fut le premier sanctuaire du pays qui a accueilli des rhinos noirs (*Diceros bicornis*). En 1970, cinq des individus restants furent déplacés là pour être protégés contre les braconniers. Dix-huit introductions supplémentaires et des naissances dans un habitat favorable qui ne connaissait aucune interférence humaine ont conduit à une augmentation rapide de la population, et la réserve est devenue la source de 67 rhinos qui ont aidé à peupler de nouveaux sanctuaires. En 2000, alors que la Réserve connaissait la plus forte densité de rhinos au Kenya, des braconniers ont attaqué Solio, et neuf rhinos noirs ont été tués en cinq ans. Il fallait installer un système de sécurité et de suivi. Tous les rapports antérieurs avaient été perdus dans un incendie, et il n'existait aucune estimation correcte du nombre de rhinos dans cette population. On fit l'acquisition de campements pour les patrouilles, de personnel et de tout l'équipement nécessaire, et les formations commencèrent. La réserve fut cartographiée au GPS et divisée en sept secteurs de sécurité, avec chacun quatre ou cinq domaines de suivi. L'identification par photo servit à déterminer le nombre, l'identité et la démographie des rhinos. Un système informatique simple pour conserver les rapports fut conçu et installé et il est décrit ici. En décembre 2005, le suivi sur le terrain a commencé. A la fin de la première année, grâce aux photos d'identification et à près de 6000 observations, 87 rhinos avaient été identifiés mais il est possible qu'il y ait eu quelques doublons ou que quelques rhinos n'aient encore été ni vus, ni photographiés. A partir de là, on a produit un profil par âge et sexe de la population et on a estimé ses performances en matière de reproduction, qui serviront de références de base. Avec une population qui dépasse largement la capacité de charge estimée, il est essentiel de réduire le nombre de rhinos par des translocations vers d'autres endroits, mais avec le profil d'âge et de sexe déséquilibré qui a été observé, le choix des meilleurs candidats sera un problème.

Mots clés supplémentaires : identification par photos, démographie, capacité de charge, référence, indicateurs de performances, GPS

Introduction

Over the period 1970 to 2003, the world population of the African black rhinoceros (*Diceros bicornis* L.) declined from ca. 65,000 to ca. 3725 (Emslie 2006). Kenya, with 18,000, held approximately 28% of the population in 1970 but this reduced to 1500 in 1980 and only 400 in 1990—some 12% of the remaining world population (Brett 1993). The reason for the decline was that throughout the 1970s and early 1980s, Kenya's black rhinos were poached in all areas, both inside and outside of national parks and reserves, with few controls and little law enforcement.

One outcome of the intensive killing was to leave small remnant populations, sometimes just a single individual, scattered across the country with no hope of long-term survival and often endangering nearby human settlements while still under threat from poaching.

For this reason, Kenya's Wildlife and Conservation Management Department approached Mr Courtland Parfet, owner of the Solio cattle ranch located on the Laikipia plateau in central Kenya, for assistance. With a commitment to conservation, a 55-km^2 area of the ranch had been fenced off to protect indigenous wildlife and allow them to live their natural life without interference or threat from humans. The Solio Game Reserve was home to many buffalos, zebras, gazelles and leopards but there were no rhinos.

The Wildlife and Conservation Management Department, the forerunner of today's Kenya Wildlife Service, requested Solio to take in some remnant black rhinos while a permanent home was found for them. The first five individuals were moved in from Kiboko in the south-east of Kenya in 1970 and the country's first sanctuary for rhinos was established. With no other secure areas available, over the next 10 years the department continued to move in more rhinos. By 1980, 23 founders from nine different areas had been introduced into Solio Game Reserve.

With excellent habitat and securely hidden from view, this new group of rhinos bred and prospered, and the reserve had to be extended to 68 km^2 in 1991. In the meantime other areas in Kenya in national parks and private ranches were made sufficiently secure to take in rhinos, and Solio became the prime founder source for many populations.

By 1992 there were 66 black rhinos (Brett 1993) in the reserve, and this after some 30 individuals had been moved out to help form nucleus populations in other new reserves including Nakuru National Park, Sweetwaters Game Reserve, Lewa Downs Conservancy and Ol Jogi. The rhinos continued to thrive, and by the end of 2005 there had been 67 translocations to other areas. However, at the start of 2000 the reserve became a major target for professional poachers and in a five-year period nine black rhinos were either shot or caught in snares.

During this period, in March 2003, the Kenya Wildlife Service adopted a new management plan for black rhino conservation in Kenya (KWS 2003). Surplus rhinos from both private land and national parks and reserves were to continue being used to complete the stocking of new sanctuaries in both sectors. Kenya Wildlife Service reported that there was an urgent need to maintain a sustainable and high annual growth rate in population to develop and conserve a genetically viable population of black rhinos of the East African race or subspecies (*Diceros bicornis michaeli*) in their natural habitats in Kenya. This was to be accomplished through increased attention to biological management and law enforcement, which is particularly important in small enclosed reserves where intensive protection to support rhino conservation also benefits the other species present, leading to rapid increases in their population density (KWS 2003).

The specific goal of the KWS strategy was to increase the black rhino numbers by at least 5% per annum and reach a confirmed total of 500 rhinos by 2005, 650 rhinos by 2010 and 1000 by 2020. The strategy also stated that without reliable monitoring data, informed biological management decisions could not be made and progress towards meeting the overall goal could not be assessed (KWS 2003). Basic information on population performance such as birth rate, mortality, sex ratio and calving index would be provided by regular monitoring (Walpole 2002) and, importantly, the monitoring of populations should be undertaken using recognized techniques for identifying individuals.

Individual rhinos can be identified from a number of features including the size and shape of the anterior and posterior horns, peculiarities of the ears, the pattern of wrinkles on the snout, prominent scars and sores on the body, the state of the tail, body size including the size of a calf in relation to the mother, and skin folds (Goddard 1966, 1967; Hamilton and King 1969; Hitchins 1969; Schenkel and Schenkel-Hulliger 1969; Hitchins and Keep 1970; Klingel and Klingel 1996). In Javan rhinos (*Rhinoceros sondaicus* L.) eye wrinkle patterns have been used to separate individuals (Polet et al. 1999).

For Solio, a key problem was that in the 1990s a fire had destroyed all the records and there was not an accurate census of the rhino population; management was estimating the herd size to be around 55. To combat poaching and support biological management of the rhino herd, a security and monitoring system had to be established. To monitor the rhinos it was important to know how many there were and how to recognize each individual. To manage the rhinos for maximum breeding performance and ensure their health, ideally the age, sex and condition of every rhino would be known.

Management area

Solio Game Reserve covers 68.3 km^2. The seven sectors vary in size between 4.5 and 13.2 km^2 (average 9.8 km^2) with the 31 areas varying between 0.8 and 4.3 km^2 (average 2.2 km^2). The size difference reflects the amount of open bush habitat and plain, where monitoring is easier and patrols can cover a greater area than in the dense thicket found especially in the west of the reserve. The area of plains in Solio Game Reserve is 7.82 km^2, representing 11.4% of the total area and varying among sectors by 0.9% to 29.0%.

Materials and methods

The 68-km^2 reserve was mapped using a Garmin 12 hand-held GPS set with freely available TrackMaker software enabling the transfer of data to computer. Features included the reserve fence, all main roads and usable side roads, bridges, rivers, dry riverbeds, water points such as dams and water troughs, and all entrance gates. The map was partitioned into smaller sections and areas (fig. 1) based on established roadways or natural features such as riverbeds. For security purposes, there were seven sectors with the objective of staffing each with a resident basic three-man patrol. For monitoring purposes, each sector was divided into four or five areas, and further by habitat type into bush or plain. All the data were loaded into ArcView GIS and used to draw sector maps and determine their size, the size of each area, and the proportion of bush and plain in each sector and area.

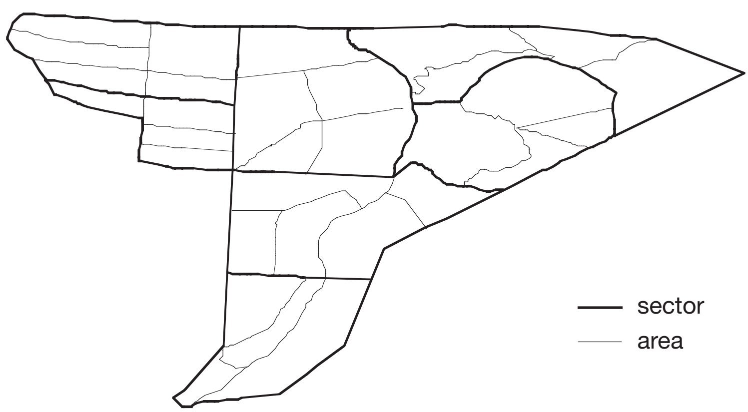

Figure 1. Solio Game Reserve showing partitioning into sectors and areas.

Photographs of the rhinos were taken over 21 days in September–October 2005, 14 days in February–March 2006 and 22 days in August–October 2006.

Identification photographs were taken where possible of the left and right body profile, rear view, left and right head profile, front view of the head, left and right ear, nose wrinkles, and left and right eye wrinkles, using a Minolta Dynax 7D single-lens reflex digital camera with a Tokina 80 mm to 400 mm zoom lens. The single lens with variable zoom allowed for greater flexibility and versatility in open ground conditions. Creating noise by changing lenses in the presence of a dangerous animal is not recommended and such disturbance could lead to an abrupt end to the photographic opportunity (F. Patton, pers. obs.). Manual focus was selected, with ISO settings of 400, 800 or 1600 depending on light levels. The highest-quality 'fine' setting was chosen to enable later editing. Photographs were edited in PaintShop Pro 9.01 software and were saved as jpeg files in greyscale to eliminate colour change effects as this gave the most observable contrast. Features were cropped out and resized to a height standard of 2.25 inches (572 mm). Where the file size was large, more than 500 kb, this was done by reducing the dpi but where it was small, less than 500 kb, this was done by adjusting the print size to the required height. Scans were adjusted for brightness and contrast using PaintShop Pro software as and where necessary.

Individuals were identified by the visual assessment of only those photographs of sufficiently good quality to show clear identification features. The assessment was carried out by the main author and the head of security working together, and each newly identified rhino was given an identity number. Over the three periods of photography, duplications were expected and the photo database was regularly reviewed to sift out as many as possible. At the time the photograph was taken, a record was made of the sector, sex of the animal, age class (calf, subadult, adult), size of the group it was with, and identity number of any of the individuals that had previously been found that were in the group.

A rhino photographic master ID file was created for the reserve. Three of the identification photographs—face view, right profile and left profile—were copied into an identification folder, printed on inkjet paper, the identity number written alongside the photographs, the paper laminated and plastic-comb bound into a pocket-sized (A5) booklet, which allowed two rhinos per page (fig. 2).

Monitoring began in mid-November 2005 after training newly recruited patrol rangers in the identification features of each rhino and equipping each

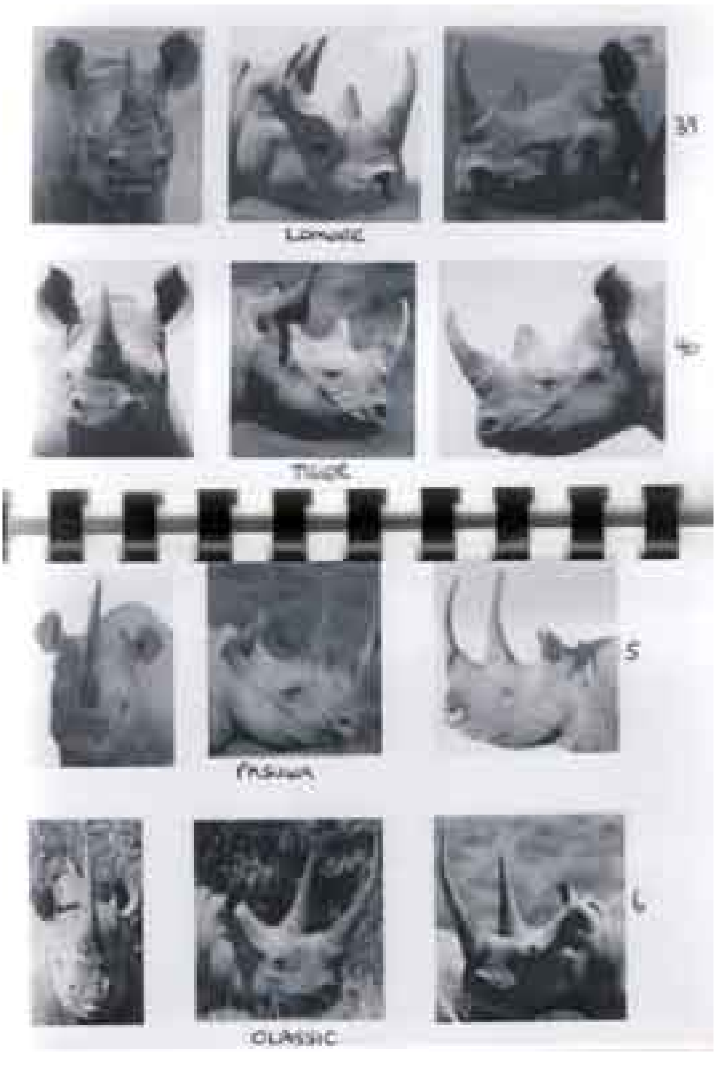

Figure 2. Typical pages from the rhino ID booklet.

patrol team with an identification booklet, binoculars and hand-held radio. To record rhino sightings made by each patrol, a simple-to-use computer-based database was created using linked Excel spreadsheets. At a sighting, the patrol radioed in to the rhino monitoring control centre the identity number, sector, area, bush or plain habitat, identity of other rhinos present, activity of the rhino (walking, sitting or sleeping, browsing, mating, fighting), name of the reporting ranger, and whether morning or afternoon. The data were loaded directly into the daily control report sheet using drop-down menus to minimize mistakes. At the end of each day a series of other Excel spreadsheets was automatically updated: 1) sighting data for individuals, separately recording sightings of each rhino, 2) monthly sighting sheet, showing which rhinos were seen on each day of a month, 3) quarterly report and annual summary, recording the number of sightings per month, quarter and year, 4) quarterly records of the number of sightings per sector for each rhino, and 5) monthly records of the number of sightings per sector per area for each rhino.

The computerized daily sighting data entries were regularly checked against a daily rhino patrol report sheet, a handwritten record patrols made of their sighting information. Any discrepancies were discussed with the patrol and then amended. Field checks of patrol sightings were made at random by the head of security and the main author.

Results

For security, data are summarized and not presented in detail.

In most cases it was possible to obtain high-quality identification photographs with features as intricate as nose and eye wrinkles. The mostly open habitat and the rhinos' lack of fear of humans, rarely found in other reserves, enabled photographs to be taken at close proximity, sometimes as close as 5 m. Where individuals were found on plain areas, all three identification views could often be captured; when in bush habitats it was usual to obtain only either a left or a right profile, but not both, along with a face view.

Visual assessment of the photographs to determine new individuals was generally straightforward, using clear differences in horn shape and size and by comparing the length of the rear horn with that of the front. In addition, some rhinos had distinct ear markings, from tears, artificial notches or hair tuft configuration. Most confusion as to whether particular rhinos were different individuals or the same one could be confirmed by reviewing photographs taken at different times and comparing them visually. In some cases, analysis of sighting data or the suspicions of the patrols led to identifying duplications, especially as more data were recorded and therefore more experience was obtained.

By the end of the first year of monitoring, 5947 sightings had been made with an average probability of sighting each individual rhino per day of 16% (range 2–46%) or a mean of 4.8 sightings per individual per 30 days. The critical sighting period—the maximum number of days acceptable in between sightings of any individual rhino—was set at 10 days for Solio, which required a sighting probability average of 10% per day. During the first year only13 rhinos were seen at a frequency of less than once every 10 days.

With only two rhinos not resighted or rephotographed, and with six births and three natural deaths (that is, not caused by poaching), the free-ranging population was estimated for December 2006 from photographic and sighting records at a definite minimum of 82 but possibly up to 10 more and most likely 87 in total. Using the lower estimate of 82 gave a density of 1.2 per km^2. Also, assuming a population of 82 with a net increase of 3 individuals, the growth rate over the year was 3.8%; only 6 of the 29 females (21%) calved that year—the growth rate and calving rate of females are both indicators of suboptimal breeding performance.

Separating the population by sex gave 46 males, 38 females and 3 unsexed calves. The three age classes were insufficient to fully describe the age profile of the population so three experienced evaluators—the main author, the Solio head of security and the rhino warden at Nairobi National Park—reviewed the photo database and further separated the age classes into seven: calves, 3.5–7 years, 7–10 years, 10–15 years, < 20 years, > 20 years, > 30 years. The evaluators' individual results were then averaged for the profile, which gave the number per class: 17 calves; 1 of 3.5–7 years; 6 of 7–10 years; 10 of 10–15 years; 16 < 20 years; 23 > 20 years; and 9 > 30 years.

The 17 calves were further subdivided into age classes according to Hitchins (1970) by comparing their size with that of their mother. From this an estimate was made for when their mothers should calve again; when the current calf would be 3 years old, a new calf would hopefully have been born. While not a precise analysis, this enabled an estimate to be made of a further breeding performance indicator—inter-calving interval. Eight females were considered to have the potential to calve within 2006 but only two did so with the calving interval for both estimated at 34 months. The other six females did not calve within 36 months.

Sighting data showed that 59% of the rhinos were found normally in one sector (over 90% of sightings), 22% were found normally in one of two adjacent sectors and only 19% were found in three or more sectors.

Discussion

While with experience patrols became confident in being able to discriminate between individuals, they placed much reliance on horn size and shape. Although no signs of horn rubbing were found, some photographs showed rhinos with broken horns and several individuals had long, slender horns that potentially could break. It will thus be important for the photographic database to be regularly updated and for patrols to report any change in horn size and shape or other identification features.

The photo identification booklet ensured there were only a few 'confusions' between individuals reported by patrols. This, coupled with field verification of rhino identification, resulted in a high level of accuracy in reporting sightings. There was therefore no general need for artificially marking the rhinos with ear notches.

This paper reports on the first year of rhino monitoring at Solio Game Reserve, before which there was no formal system in place. Full staffing was not achieved until August 2006. It can be expected that sighting numbers will increase in the second year as patrols become experienced in where to find rhinos in their sector. The critical sighting period requirement of 10 days and a sighting frequency minimum of 10% will therefore most likely be achieved for all rhinos, although a few of particularly nervous disposition may remain more difficult to locate. The density of rhinos in Solio Game Reserve at 1.2 per km^2 is high compared with other similar enclosed Kenyan reserves, which is typically around 0.5 rhinos per km^2. A habitat evaluation study showed that there had been severe degradation of important rhino browse species and suggested that the population was well in excess of the reserve's carrying capacity (Adcock 2006). Evidence of this was found in the analysis of breeding performance. The 3.8% growth rate is below the Kenya Wildlife Service target of 5% per annum although single-year rates in small populations must be treated with caution.

Benchmarks of breeding performance for black rhinos (du Toit 2001) class the annual (December 2005–November 2006) Solio growth rate of 3.8% as poor to moderate, the calving interval of 36+ months as poor to moderate, and percentage of cows with calves of that year of 21% as very poor to poor although again single-year rates in small populations must be treated with caution. This poor performance may be due to foetal deaths caused by poor nutritional conditions as a result of habitat degradation, or just that poorer nutrition means it may take longer for females to build up sufficient condition to be able to successfully conceive and raise calves. However, with six females estimated to calve in 2007 and six that did not calve as estimated in 2006, there could be 12 new calves by the end of 2007. If there are no deaths, this increase would give a population size of 99 at a growth rate of 14.6% and percentage of cows with calves of that year of 41%—both performance indicators rated as good to excellent. This would also mean that 12 current calves would move to independent status either as calves (≤ 3.5 years old) or as subadults (3.5–7 years), giving 29 individuals younger than 7 years (30% of the increased population compared with the current 21%), improving the age balance between young and old.

Of the nine rhinos judged to be over 30 years old and with the knowledge that there had been little ear notching undertaken except for the founder individuals, it was considered probable that some of the nine were from the original stock, which meant that they were likely to be over 40 years old and therefore some of the oldest wild black rhinos in the world. These included the magnificently horned female Pasuka (fig. 3), and the 'three-horned' male, Karanja (fig. 4).

While the sex ratio of the population is considered acceptable at 1.2 males per 1 female, the ratio of rhinos less than 10 years old is imbalanced at 2 males per 1 female. This may be the result of a number of factors. For example, it is known that females in poor body condition because of inadequate feed may produce sons as they will disperse and not compete locally for resources (S. Reece 2005 pers. comm.). However, it may also be simply chance that has led to a run of male births, which could be countered over time by a run of female births.

Sex ratios have been shown to have a significant effect on population increase, and to promote population growth it would be beneficial to distort adult sex ratios in favour of females (Knight 2001). If the current situation of too many males does not change with new births being predominantly female, the effect on future population growth rates could be detrimental.

Figure 3. Pasuka, probably one of the oldest female rhinos in the world.

With data collection, many rhino sightings in Kenyan reserves are recorded by specific GPS location points. This information is later analysed to estimate each rhino's home range. The Garmin 12 units usually used for this are not cheap at about USD 200 per set, and the financial resources available to Solio, as with any other reserve, were limited. This was especially true in the setup year, when establishment costs were high for building and equipping patrol camps, purchasing ranger uniforms, paying salaries and buying mobile communication equipment. There was a need to assess the value of collecting data on GPS locations in Solio.

Figure 4. Karanja, probably one of the oldest male rhinos in the world.

Rhino patrols are normally carried out at specific times, and sightings were most frequent either very early when rhinos were browsing or moving to a day bedsite or mid-morning where a rhino was on a day bedsite. Where a rhino was moving, the GPS reading taken depended on the precise time of the observation. Had it been 15 minutes earlier or later, the location could have been different by 1 km or more. Also to find a rhino, a patrol may have followed its footprints for several kilometres. For monitoring purposes, once a rhino has been found, it need not be seen again that day and there may be other duties for patrols such as detecting snares or other signs of poaching. This resulted in afternoon sightings being much less frequent than morning ones. It was found that rhinos often moved, especially around midday, from their initial morning location to a new location, which could be several kilometres away. There were instances where a rhino was sighted at night or in the early morning several kilometres from its normal daytime location. All these factors suggest that single precise GPS location fixes are heavily biased to time-related sightings and do not represent the full range the rhino uses. According to Tatman et al. (2000), the range should be estimated using additional data from middens, scrapes, browse, footprints and so on where an individual can be correctly identified. In the Solio situation, it was considered sufficient for management purposes to obtain representative use of space and ranging areas from the sector or area blocks either by using the whole block or by using a point at the centre of the block to demonstrate which rhinos were using the same areas and any changes in area use.

Another use of GPS location data could be to find a 'missing' rhino by reviewing the sightings to determine where the rhino was most often seen. The simplified Solio record-keeping system made it possible to present the sighting data for an individual rhino in an automatically produced table that showed where it would most often be found—although the rangers knew this anyway without using technology. In any case, it would be unlikely that the rhino would be in precisely the same location but rather in a rough area that could be determined by the block system.

GPS data may be collected on the patrol routes undertaken so that in any time period it can be seen which areas of a reserve have been covered and which areas need to be covered. Block data with an average size of 2.2 km^2 could be used as effectively to record areas covered on patrol.

There are practical considerations. GPS units fail: they fail eventually due to hardware degradation; they fail in the field due to lack of battery power; they fail when they are dropped; they fail when the wrong buttons are pressed; they fail when they are forgotten; they fail when the data are incorrectly entered into the computer. Gaps in GPS data collection and errors in entering data into the computer are known to occur (Okita 2004). GPS data are significantly more difficult and time consuming to enter into the computer than block data where simple drop-down menus can be used to minimize entry errors.

The general conclusion was that GPS location information was unnecessary in a small reserve such as Solio and its use for scientific analysis was potentially flawed. The data required for management purposes could be produced from the block system employed with the additional benefit that as records were entered into the computer at the time of the sighting, the database could be updated immediately thereafter. It was considered more important to acquire a digital camera with minimum x10 optical zoom to maintain an up-to-date photo identification database and to be able to update the field identification booklets. However, Solio is a small sanctuary, intensively patrolled. GPS data can be useful in bigger, less intensively monitored parks of say 350–1000 km^2 in size where the data can be used, for example, to confirm that guards actually patrolled where they said they did and to allow for plotting search effort.

The carrying capacity for Solio was provisionally modelled at 42 individuals (Adcock 2006) giving a maximum sustainable yield (75% of carrying capacity) of 32, although it was thought it could be somewhat higher due to the permanent wetland area providing a nutrition 'bank' and low densities of other potentially competing browsers compared with other black rhino areas. This suggested a need to reduce population by between 45 and 55 individuals. Data obtained from the first year of monitoring was used to inform management on the selection of candidates for translocation of 30 individuals from Solio to two other rhino reserves in Kenya in early 2007. After this a further 15 to 25 individuals would have to be moved to meet the targets. However, with currently 20 calves and 19 breeding females, both of which belong to classes less favoured for translocation (Brett 1998), there are insufficient candidates to enable such a movement to be completed in the near future.

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