Night census and infrared technology monitoring of a black rhinoceros' population and species competition monitoring to inform management action in Tsavo, Kenya

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Abstract

We present the results of the 2019 night census of the black rhino (*Diceros bicornis*) population in Tsavo West National Park, Kenya. A dedicated rhino sanctuary was established in 1986 as part of efforts by the Kenyan government to safeguard the remaining populations of the critically endangered black rhino, and now contains more than 13% of the national population. In response to the challenges involved in observing black rhinos in their natural habitat, population numbers in the sanctuary are monitored using night censuses based on observation of rhino visits to artificial water holes. The 2019 night census recorded 96.2% of the known rhinos in the sanctuary, confirming that this is reliable method for monitoring rhino populations, with potential for use in other areas. It also provides information on health and population structure that are not obtainable by other methods. The results indicate that numbers of black rhino in the sanctuary continue to increase, albeit at a slower rate than in previous years. This slowdown likely reflects intraspecific competition for food resources as population density now stands at more than double the recommended ecological carrying capacity (EEC). The survey also found evidence of interspecific competition with other browsers, as well as a threat from predation of young animals by hyenas. We recommend further study of all these aspects, as well as continued translocation of surplus rhinos from the sanctuary to repopulate surrounding areas.

Résumé

Nous présentons les résultats du recensement nocturne de la population de rhinocéros noirs (*Diceros bicornis*) de 2019 dans le Sanctuaire de rhinocéros dans le parc national de Tsavo West, au Kenya. Le SRN a été créé en 1986 dans le cadre des efforts déployés par le gouvernement kényan pour protéger les populations survivantes de rhinocéros noirs en danger critique d'extinction, et contient maintenant plus de 13% de la population nationale. En réponse aux défis liés à l'observation des rhinocéros noirs dans leur habitat naturel, les populations du sanctuaire sont surveillées à l'aide de recensements nocturnes basés sur l'observation des visites de rhinocéros aux points d'eau artificiels. Le recensement nocturne de 2019 a enregistré 96,2% des rhinocéros répertoriés dans le sanctuaire, confirmant qu'il s'agit d'une méthode fiable pour surveiller les populations de rhinocéros, avec un potentiel d'utilisation dans d'autres zones. Il fournit également des informations sur la santé et la structure de la population qui ne peuvent être obtenues par d'autres méthodes. Les résultats indiquent que le nombre de rhinocéros noirs dans le sanctuaire continue d'augmenter, bien qu'à un rythme plus lent que les années précédentes. Ce ralentissement reflète probablement une concurrence intraspécifique pour les ressources alimentaires, la densité de la population représentant maintenant plus du double de la capacité de charge écologique (CCE) recommandée. L'enquête a également révélé des évidences de compétition interspécifique avec d'autres brouteurs d'arbustes, ainsi qu'une menace de prédation des jeunes animaux par les hyènes. Nous recommandons une étude plus approfondie de tous ces aspects, ainsi que la poursuite du transfert des rhinocéros excédentaires pour repeupler les zones environnantes.

Introduction

The black rhinoceros (*Diceros bicornis*) is categorised as critically endangered in the IUCN Red List of Threatened Species. This conservation status reflects the significant decline of population numbers and of its range mainly due to the impact of poaching for its horns and habitat loss. Globally, various initiatives have been put in place at different scales to reverse the trend. The IUCN's Species Survival Commission (SSC) established the African Rhino Specialist Group (AfRSG), which brings together various experts to provide range states with technical support aimed at enhancing recovery of the species. The focus is on support for law enforcement and *in situ* monitoring to provide accurate and timely information for the protection and management of rhino populations.

The conservation of black rhino in Kenya is guided by a number of strategies. These strategies are based on the 1989 Wildlife Policy Framework, formulated to deal with the poaching crisis experienced in 1970s and 80s. This policy led to the strengthening of the sanctuary approach on both state and private land (Brett 1990). By 1989, the national black rhino population had dropped from an estimated 20 thousand rhinos in 1970 to only 381 rhinos (KWS 2007). In efforts to enhance recovery of the black rhino from this massive decline, the Government of Kenya established a network of ring-fenced rhino sanctuaries and gathered together all the remaining rhinos into these areas in order to enhance their protection and management. The Ngulia Rhino Sanctuary (NRS) in Tsavo West National Park, established in 1986, has made an important contribution to the recovery of black rhino numbers in Kenya, and now contains more than 13% of the national population.

Managers of the NRS are required as set out in the Kenya Black Rhino Action Plan (2017–2021) (KWS 2017) to monitor progress in the recovery of the rhino population. Monitoring approaches that involve direct observation of rhinos (patrols on foot and/or by vehicle, aerial surveys and non-invasive camera trapping) are preferable to indirect methods such as checking tracks and other signs of rhino presence since they provide valuable information on population health. However, estimating populations of black rhinos has always proved difficult due to their elusive behaviour and the dense bush cover of their preferred habitats, such as the dominant Bauhinia-Premna bush-land vegetation in the case of the NRS (Goddard 1970). To improve on rhino observations, the Kenya Wildlife Service (KWS) has adopted annual night censuses at artificial waterholes as a reliable method of monitoring and confirming the presence and status of rhinos.

The seasonal use of artificial watering points by wild mammal species is well documented (Epaphras et al. 2008; Sutherland et al. 2018). Since black rhino are highly dependent on water and there are no permanent natural water sources in the Tsavo West sanctuary, the night census has proved to be an effective monitoring tool. The night census has been implemented over a period of more than 15 years, with continuous improvements, especially to observer training and monitoring equipment. The census is carried out every year in the dry season between July and October. This is in line with the requirements of the Kenya Black Rhino Action Plan (2017–2021) (KWS 2017) that necessitate the application of appropriate rhino survey methods for monitoring rhinos in difficult terrain to ensure that at least 99% of the national rhino population is estimated on an annual/bi-annual basis.

In this article we aimed at establishing the current rhino population status in the sanctuary, and at the same time evaluated the efficiency of the night census approach to monitoring rhinos in difficult retain. We present the results of the 2019 census in Ngulia Rhino Sanctuary and discuss their significance.

Methodology

Study area

The NRS covers an area of 92 km^2 and is located in Tsavo NP. It has been one of the more successful areas for protection and breeding of black rhinos in Africa over the last 20 years (Okita-Ouma et al. 2008). In 2002–2007 the protected area was expanded for the third time, doubling its size to accommodate an expanding rhino population and reduce species competition. The sanctuary was set up in 1986 with an area of 4 km^2. It was expanded in 1987 to 17 km^2 under the management of Bill Woodley); then again in 1990 to 62 km^2 under the management of Rob Brett);

and finally, in 2002–2007 to 92 km^2 under the management of KWS and the Eden Wildlife Trust (Brett and Adcock 2002; Rob Brett pers. comm).

The sanctuary has succeeded in re-establishing a productive breeding nucleus of rhinos within a larger protected area, i.e. Tsavo West National Park, and there is very considerable potential for further expansion to form a large, genetically viable population. Fourteen rhinos were translocated from the sanctuary in 2008 to establish a free-ranging population in the Tsavo West Intensive Protection Zone (IPZ) surrounding the sanctuary. There has been continued growth of the population in the sanctuary and there are plans to translocate more individuals to supplement the growing numbers in the IPZ. The sanctuary thus has a key role in conserving the black rhino in Kenya.

Rhino observation

The NRS has several permanent artificial water points which are fed by water pumped from boreholes and nearby springs. As for all historical rhino censuses, the dry months of July, August and September were selected for this exercise since there are few if any natural water sources in the sanctuary at this time of the year. In 2019, the census was conducted on three consecutive days in each month. Due to rains in the month of October from the previous year, the decision had been made to start the series of censuses a month earlier i.e. in July. The night exercise was carried out at all the artificial waterholes in the sanctuary between the hours of 18:00 to 06:00.

Teams were selected based on their previous experience in rhino monitoring, and each was assigned a waterhole. Each team comprised of at least five members i.e. two experienced observers, one photographer, one data recorder and a driver, with all necessary equipment. Each team was equipped with a pair of binoculars, two pairs of night vision goggles, a night-enabled camcorder and a set of infrared lamps. The teams made observations from bunkers built near the waterholes. Cameras and infra-red flood lamps were set about 30 metres from the waterholes. When rhinos approached the waterhole, binoculars and night vision goggles, were used to identify them in light from the infrared lamps. Rhinos were identified by their ear notches and other distinguishing features and details were recorded on data sheets (Emslie et al. 2009). Monitoring teams used the ID master templates for each known rhino in the sanctuary. Other details like age, sex, and body condition (Reuter and Adcock 1998) were recorded based on the IUCN-SSC AfRSG Rhino monitoring training manual. The presence or absence of calves was also noted and the age and sex of calves, when present, was recorded. For clean rhinos, (i.e. rhinos without any identifiable features), teams recorded as much detail as possible, including age, sex, horn shape and size, and any distinguishing features. Ageing, sexing and horn size and shape identification was done based on the AfRSG Black Rhino monitoring protocols (Adcock and Emslie 2007). Moreover, any identity features of individual rhinos that had changed over time, for example due to injury, were recorded in the black rhino sighting booklets to update the population's master ID files.

Other species

The presence of other wildlife species, especially elephant, hyena and leopard, was also recorded to provide information on possible browse competition and rhino calf predation. Photographs and videos were taken for identification purposes for further analysis and reporting. Due to the sparse distribution of the water holes, it was assumed that animals of each species of interest only utilized a single watering point for each of the census nights.

Statistical analysis

Simple descriptive analysis was conducted in Microsoft Office Excel while the annual rhino population growth rate (r) was computed using the following formula (Lewis 2019):

$$r = \left(\left(\frac{pf}{ps} \right)^{\frac{1}{t}} - 1 \right)$$

where pf = final population, ps = initial population and t = elapsed time in years. To establish the efficiency of the night census, we established the sighting frequencies, calculated as a proportion of the nine census nights on which each of the identifiable rhinos was encountered. We used simple linear regression to establish the relationship between rhino and selected species within the sanctuary.

Results

Rhino population status

The night census was able to account for 96.2% of the total known individuals in the sanctuary. The number counted varied considerably within the three counting days of each month. More rhinos were counted on Day 2 of the census at all the water holes in each month. It appears that the rhinos generally avoided the watering points on Day 1 since they sensed human presence. However, due to their high level of water dependency, they were compelled to visit the water holes on Days 2 and 3, although they still sensed human presence.

In total we recorded 631 rhino sightings of 100 individuals. Out of the total counted [35] (35%) of the rhinos were 'clean', i.e. without any identifiable notches, while [65] (65 %) were already notched. Four rhinos, namely Kadogo's calf 3 2019, Tiva's calf 2019, Tamara's clean calf 2019 and Rita's clean calf 2019, were not sighted in the night census but their continued presence in the sanctuary was confirmed using other monitoring approaches. However, four other known individuals that were not recorded in the census and had been not sighted for a period of over one year were excluded from the analysis.

These results indicate that there has been a steady growth in rhino numbers in the sanctuary, with a 5.2% annual population growth between 2012 and 2019. However, it is important to note that the rate of annual population growth has gradually declined over the years, from a high of 8.0% annual growth between 2014 and 2015, to 7.2% between 2016 and 2017, 4.5% between 2017 and 2018 and 3.1% between 2018 and 2019.

Overall, the sanctuary rhino population has a mean body condition score of 4.2 with individual scores ranging from 4.0 to 4.5, where 4 indicates a 'good' condition and 5 a 'very good' condition in accordance with AfRSG Black Rhino monitoring protocols. There are slightly more male rhinos in the population; i.e. 53% of the animals recorded in the census were males and 47% were females. This represents a ratio of 1.13 males to 1 female. In terms of age distribution, 58 (58%) of the rhinos were adults [i.e. above 7 years], 28 (28%) sub-adults [i.e. between 2–7 years] and 14 (14%) calves [i.e. less than 2 years] (fig. 1).

The mean sighting frequency of individual rhinos over the nine (9) census nights of the three-month survey was 0.66. Of the total population, 11.5%, had a sighting frequency of 9/9, denoting they were sighted on all the nine census days, while 16.3% had a sighting frequency of 8/9. The largest number of individuals, 22.1% had a sighting frequency of 7/9, denoting they were sighted in seven out of the possible nine census days (fig. 2). Moreover, over the three months of the

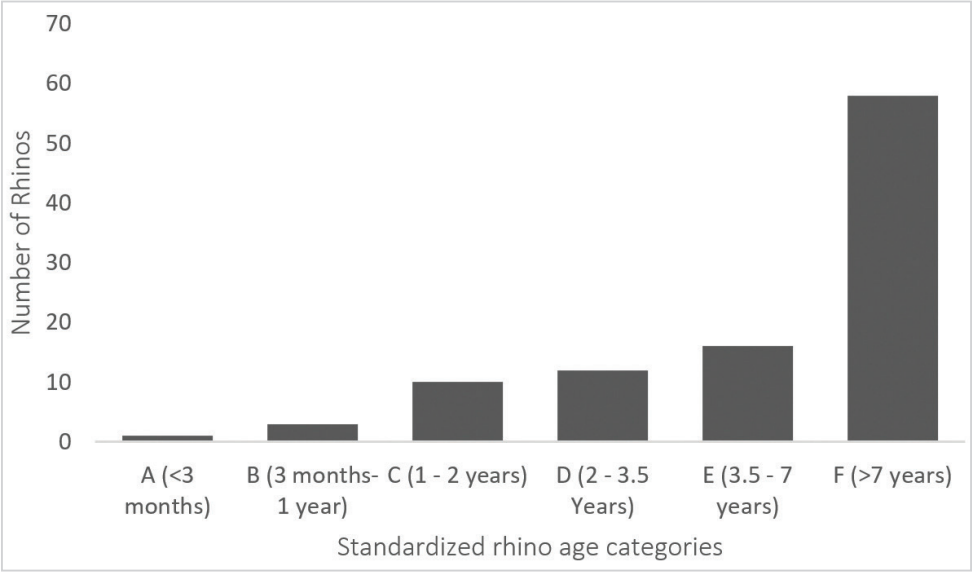

Figure 1. Number of rhinos per age class for NRS recorded during the 2019 night census.

census, there was a higher sighting frequency for rhinos aged over 7 years, i.e. in age class F (392 sightings; 62.1% of all sightings). Ages class E, D and C had sighting frequencies of 17% (107 sightings), 9.3% and 8.6% respectively. The calf in age class A, known as Martha's calf 2, was only sighted once.

Other species of mammal, population status

A total of 15 large to medium-sized mammal species were recorded during the survey. Hyena was the most frequently sighted species (107 encounters; 22.9% of total encounters), followed by giraffe, zebra and elephant. Wild dog and impala were the least encountered with three and two encounters respectively (fig. 3).

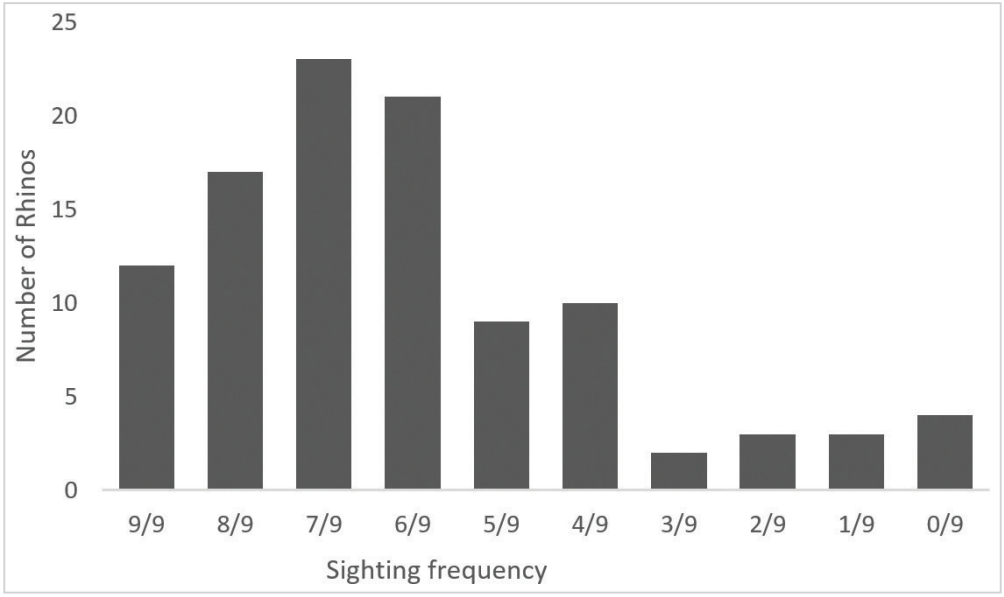

Figure 2. Sighting frequency of the sanctuary rhino population based on the three months census for 2019.

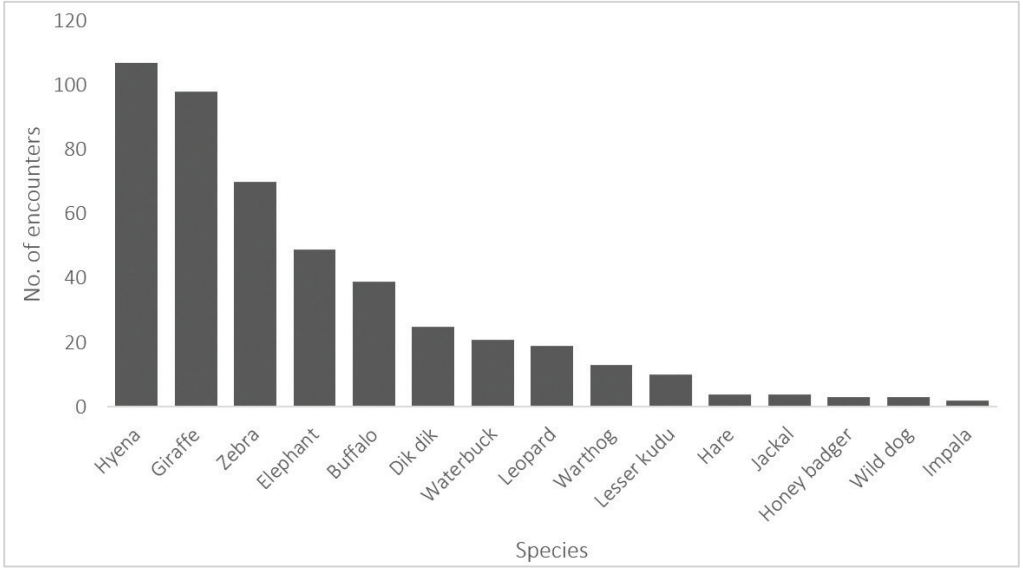

Figure 3. Frequency of encounters of other mammalian species in the sanctuary during the 2019 night census.

In terms of numbers of animals, zebra, buffalo and elephant recorded the highest daily counts, with a mean of 66.8 individuals (n = 9 encounter nights, SD = 21.64) for zebra and means of 29.2 (n = 9, SD = 13.76) and 28 (n = 9, SD = 7.42) for buffalo and elephant respectively. Among carnivores, hyena recorded a mean of 16.9 individuals (n = 9, SD = 7.01), while wild dog and leopard had mean counts of 5.0 (n = 3, SD = 3.46) and 2.5 (n = 8, SD = 1.41) respectively (fig. 4, Table 1).

It is worth noting that the highest number of buffalo and elephants counted in any particular census day was 46 buffalos and 38 elephants, while for carnivores, the highest number of hyena and wild dog counted in a particular census day was 27 hyena and nine wild dogs (Table 1).

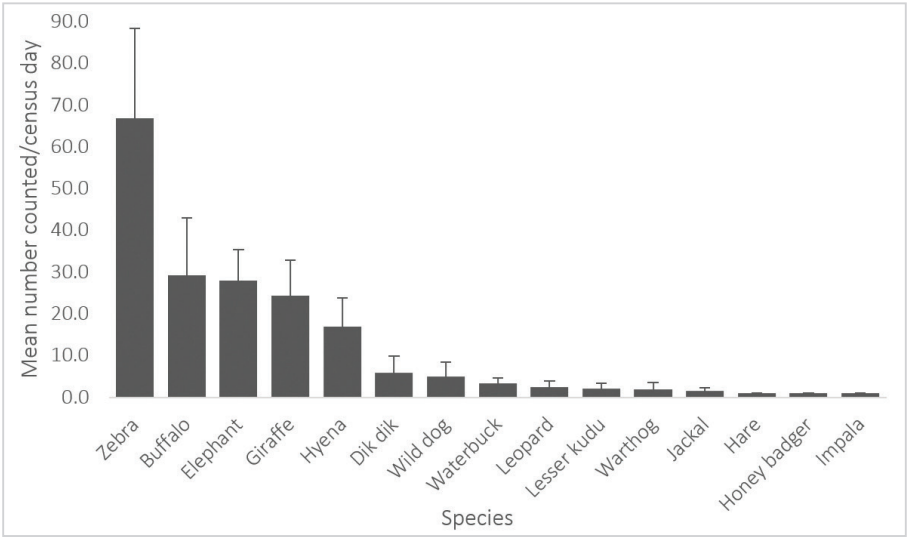

Figure 4. Mean of number counted per census day for other mammalian species in NRS during the 2019 night census.

Table 1. Descriptive analysis of other mammalian species counted in the 2019 night census. Note that standard deviations are calculated for encounter nights and exclude zero counts.

Species	Mean	Range	Encounter nights	Standard deviation
Buffalo	29.2	10–46	9	13.76
Dik dik	6.0	1–11	8	3.96
Elephant	28.0	15–38	9	7.42
Giraffe	24.3	15–42	9	8.56
Hare	1.0	1	4	0
Honey badger	1.0	1	3	0
Hyena	16.9	9–27	9	7.01
Impala	1.0	1	2	0
Jackal	1.7	1–2	3	0.58
Leopard	2.5	1–5	8	1.41
Lesser kudu	2.1	1–4	7	1.21
Warthog	2.0	1–5	7	1.53
Waterbuck	3.4	2–5	7	1.27
Wild dog	5.0	3–9	3	3.46
Zebra	66.8	31–92	9	21.63

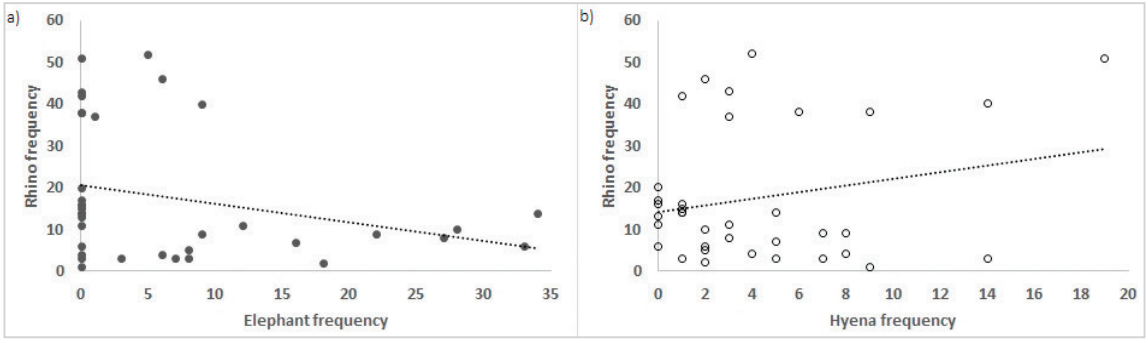

Figure 5. Relationship in the sighting frequency between rhino and elephant (a) and rhino and hyena (b) based on the 2019 NRS census data.

Rhino and distribution of other key species

Waterhole 2 had the highest sighting frequency for rhino, and this waterhole was also most frequented by other species. Combining data from all water holes, there was a significant positive relationship between the sighting frequencies for rhino and hyena (t = 12.39, n = 36, p = 0.01), while a significant negative relationship was observed between elephant and rhino (t = 6.375, n = 36, p = 0.01) (fig. 5).

Discussion

The reliability of rhino sightings in the night rhino census has improved over time. This improvement has been achieved through rigorous training of the observers, continuous ear notching of clean rhinos and the adoption of technological advances in rhino monitoring. The sighting success rate of 96.2% and the mean detection probability score of 0.66 indicate that the night census is a reliable rhino monitoring tool that can potentially be used for other rhino populations where direct observation of rhino by routine patrols is a challenge. Moreover, using this method, we were able to obtain information on the population health and population structure that are unobtainable by other methods.

While the rhino population has increased since 2012 at an average annual population growth rate of 5.2%, this growth rate is lower than the set threshold for established *Key 1*[1] populations as described in the Kenya Black Rhino action plan (2017–2021) (Emslie and Brooks 1999; KWS 2017). Moreover, the annual rate of population growth has continually declined since 2015. A number of possible reasons for this decline are considered in the following discussion.

Browse competition

For many years, numbers of elephants, buffalos, giraffe and hyenas have been increasing in the sanctuary, leading to the management decision to reduce the elephant, buffalo and zebra numbers in 2008 (Okita-Ouma et al. 2008). Habitat assessments conducted in NRS suggested an ecological carrying capacity (ECC) of 0.55 rhinos/km^2 (Brett and Adcock 2002; Okita-Ouma 2004), beyond which a slower population growth rate is expected. Currently, the rhino density of 1.13 rhinos/km^2 in the sanctuary is more than double the recommended density, likely leading to an increase in intraspecific browse competition. Moreover, the negative relation between rhino and elephant sightings (t = 6.375, n = 36, p = 0.01), could be an avoidance mechanism by rhino in response to interspecific competition.

Sex ratio and age structure

The rhino population sex ratio is skewed to males with a sex ratio of 1.13 males to 1 female, and an age structure skewed to adults, which represent more than 55% of the total population. These two features of population structure are recognized to be responses by a species to a population increase beyond the ecological carrying capacity. Calf sex allocation has been documented to be influenced by population size, with the probability of male calf success increasing

[1] *Key 1* population is a rating given by the IUCN's African Rhino Specialist Group to identify significant populations that are stable, increasing and have achieved continental importance.

with population density (Weladji and Laflamme-Mayer 2011). Given the high rhino density in the sanctuary, these phenomena could be responses by the population to limit growth.

Predation threat

The previous years' rhino censuses and monitoring suggested a high predation risk for rhinos in NRS. In the 2018 census, for instance, physical scars and injuries were observed on some of the rhinos, including missing ears (Mrs Maktau-5012), missing tail (Boit-5056) and scratches (Josh-5094; Bill-5014). Most probably, these injuries were the result of failed predation attempts. This census reports a significant positive correlation between the sighting frequencies of rhino and hyena. Based on observational data, hyenas were especially seen in the vicinity of rhinos with young calves. Black rhinos are known to conceal their calves in areas where they are at risk from predation or other threats. In the case of 2019 NRS census, there was only one sighting of a single calf in age class A (fig. 1), although the birth of four other calves in 2019 has been confirmed using other rhino monitoring approaches. This behaviour may be a predator avoidance adaptation, and thus an indicator of the increased presence of predators and hence an increased threat to young calves. Although only lions have been documented to pose a predation threat to rhino (Patton 2009), there is need to further investigate the possible role of hyenas as a predator on rhinos in NRS, especially since there are no lions in the sanctuary. The carcass of one calf aged approximately five months (Mindi's calf 2019) was observed in September 2019 and was suspected to have been predated upon by hyenas.

Conclusion and recommendations

Night census and infrared technology is seldom used by wildlife conservationists for the *in situ* monitoring of wildlife. In addition to the need to estimate numbers and distribution, it is imperative to consider possible impacts on individual and/or population health when designing a monitoring program for critically endangered species such as the black rhino. Impacts may be reduced if monitoring is carried out by direct observation, for example by foot and/or vehicle patrols, and the use of camera traps. However, direct observation is challenging in thick canopy habitats and difficult terrain such as the *Bauhinia-Premna* bush-land dominant vegetation in the NRS, where in the past direct observation by foot and vehicle patrols was only able to account for less than a quarter of the population. The night censuses have proved an effective complement to these direct monitoring approaches, as evidenced by ability of the 2019 census to record 96.2% of the known rhinos in the sanctuary.

The Tsavo West Ngulia Rhino Sanctuary population remains a key population for the conservation of black rhino in Kenya. Due to the increasing rhino numbers, it is recognized that natural density-dependent population regulatory mechanisms may be setting in. To maintain the sanctuary as a healthy (and even donor) population, rhino numbers have to be maintained below the recommended ECC levels. To achieve this, the following measures are recommended:

1. A habitat assessment to confirm the current ECC, and a study of the impacts of exceeding the ECC on the NRS rhino population should be conducted to inform management intervention.
2. With density of rhinos at double the ECC, there is an urgent need for de-stocking and translocation of the surplus rhinos (about half the population), and this is also an opportunity to bolster the population of rhinos in the surrounding IPZ. This should be followed up by the establishment of a regular percentage off-take of the population based on the population numbers to stimulate the birth rate of rhinos in the sanctuary.
3. A study on the effect of predation on population performance should be conducted.
4. Rhino ear notching should be conducted to reduce the number of clean rhinos in the population.
5. Water availability is seasonal, with water well distributed in ephemeral waterholes during and after rainy seasons and restricted to the artificial water holds during the period July–October. Further study should be carried out to assess the seasonal waterholes, by mapping their occurrence and distribution throughout the year, (to better understand use of waterholes and restriction to the permanent sources).

Finally, the results of the NRS 2019 survey give

grounds for optimism, showing a continued increased in the population of black rhino in the sanctuary, as result of measures to improve protection and to counter the persistent threat of poaching.

Acknowledgements

We thank KWS Tsavo NP management for facilitating the night census. Many thanks also to the personnel who participated from the Tsavo NP, wildlife protection and research departments and the KWS HQ Rhino Program. We appreciate the assistance of Rob Brett for proof reading and editing an earlier draft of this paper. Lastly, we would like to thank the Zoological Society of London (ZSL) for the collaboration and financial support for conducting the census.

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