Short communications

Re-introduction success of black rhinoceros in Marakele National Park

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INTRODUCTION

Re-introduction is a key conservation management response and forms the backbone of several species recovery programmes (Armstrong & Seddon, 2008). The south-central black rhinoceros (*Diceros bicornis minor*) (black rhino hereafter) epitomizes this conservation response with several genetically connected strongholds in Zimbabwe and South Africa (Kotze *et al.,* 2014). The Kruger National Park and Hluhluwe-iMfolozi Game Reserve are home to key populations. The population in the Kruger National Park was created through re-introduction of 81 black rhinos between 1971 and 1990 (Ferreira, Greaver & Knight, 2011). Within South Africa, the Black Rhino Range Expansion Project (Sherriffs, 2003) seeks to create several populations in addition to 10 already established populations, as part of implementing the National South African Black Rhino Management Plan (Knight, Balfour & Emslie, 2013).

Evaluating the success of black rhino re-introductions focuses on the reproductive and survival outputs of the actual re-introduction operation (*e.g.* survival during the first year after introduction, Linklater *et al.,* 2011) as well as the eventual persistence of an established population (Seddon, 1999). Black rhino re-introductions typically comprise few individuals, although usually recommended to be a least 20. This imposes small sample size effects on population performances such as population growth and demographic indices (Akçakaya, 2002). Evaluation of reduced local extinction risks, indicated by population parameters, do better when several indicators are combined (O'Grady *et al.,* 2004).

South Africa initiated the development of the Kransberg National Park in 1986 and Gazetted the same area as Marakele National Park in 1994. As part of the process, authorities embarked on a species re-introduction programme (SANParks, 2014). Black rhinos formed part of this re-introduction programme. We evaluate the success of the black rhino re-introductions into Marakele National Park by estimating population size, growth and extracting demographic variables from age and sex distributions.

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METHODS

Marakele National Park (639 km^2) is located in the Savanna Biome of the North West Province of South Africa and includes the Marakele Park (Pty) Ltd. managed as a contractual park (SANParks 2014). Mountains and bottomlands dominate the landscape. We collated all initial re-introduction records as well as subsequent introductions and removals. In addition, conservation authorities regularly ear-notched individuals using unique ear markings (*e.g.* Ngene *et al.,* 2011), which allowed individual monitoring.

We conducted an aerial survey during November 2015 to record sightings of individual rhinos, including taking high-definition digital images using a Nikon 10D camera and a 70–200 mm zoom lens. Comparison of these images against historical records allowed us to use collated historical notch records to identify individual rhinos and identify un-marked rhinos. Our survey used a helicopter-based (Bell Jet Ranger 500) observation platform flying 150 feet above the ground at 50 knots to systematically search the Park, flying transects that were 200 m apart that resulted in 100% coverage of the area. Note that we expected that some individuals would be missed by the observers.

The observation of notched and un-notched rhinos allowed us to use the Peterson Estimator (Caughley, 1977) to obtain population estimates of cows and bulls. We made use of the proportion of all cows seen with associated calves to estimate the total associated calves in the population. A total estimate combined estimates of cows, associated calves and bulls.

Using an exponential model defined as

$$N_{t+1} = (N_t - N_{c,t\rightarrow t+1} + N_{i,t\rightarrow t+1})^r \quad (1)$$

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where N_t is population size at time t, $N_{c,t \to t+1}$ is the number of rhinos removed between time t and t+1, $N_{i,t \to t+1}$ is the number of rhinos introduced between time t and t+1, and r is the exponential growth rate, we used the introduction and removal histories for every year since 1993 with the confidence intervals of population size during November 2015 and estimated population growth using a maximum likelihood approach (Edwards 1972). We also estimated growth rate for bulls and cows separately using the same approach.

Combining the estimated, sex-specific population growth rate with sex-specific smoothed age distributions allowed us to estimate sex-specific survival rates. We assigned sex and age to individual rhinos observed using standard age classes (A: <0.25 years, B: 0.25 to 1 year, C: 1 to 2 years, D: 2 to 3.5 years, E: 3.5 to 6.9 years, and F: 7 years and older; Emslie, Adcock & Hansen, 1995). Age class assignments used sizes of calves relative to adult cows. From the observed age and sex distribution, we smoothed age distributions following the smoothing function of Ferreira & van Aarde (2008) defined by

$$\sum_{x}^{w} n_x = n_0 \alpha^x \left[\frac{(1-\alpha^{(w-x+1)})}{(1-\alpha)} \right] \quad (2)$$

as the sum of frequencies of individuals that were x to w years old where n_x is the number of individuals x years old and n_0 is the number of newborn individuals. The frequencies decay at a rate α as age increases ($\alpha = s/\lambda$, s = survival, λ = finite growth rate = 1 + r; Eberhardt, 1988). Black rhinos can live up to 45 years of age in captivity (Jones, 1993), while those in the wild may live shorter (Adcock 2009). In small populations longevity may approximate that noted in captivity. We thus set w at 45. We used maximum likelihood approaches (Edwards, 1972) to estimate sex-specific values of α from which we derived sex-specific survival rates.

The definition of sex-specific survival rates in age class x ($s_{x,♂}$ and $s_{x,♀}$) allowed estimation of birth rates and calving intervals (c). We estimated recruitment rate as the fraction of rhinos less than one year old. Such a recruitment rate (r') is the consequence of calves born and their subsequent sex-specific survival during the first year ($s_{1,♂}$ and $s_{1,♀}$). If sex-ratio at birth is at unity (but see Berkeley & Linklater, 2010) then birth rate (β) can be estimated from $r' = 0.5\beta_{s1,♂} + 0.5\beta_{s1,♀}$. Black rhinos have their first calf at 7 years of age (Smith & Read, 1992). We thus converted the birth rate to number of rhinos and expressed these as a fraction of the number of F-class adult females (*i.e.* females 7 years old or older). The inverse of this ratio provided an estimate of calving interval.

RESULTS AND DISCUSSION

Although authorities introduced the first black rhinos to Marakele National Park during 1993, the bulk of the initial introduction took place during 1996 when 12 black rhinos were released (Table 1). A total of 28 black rhinos have been introduced while five were removed between 1993 and 2015. The Marakele case is similar to most black rhino introductions – these typically involve few individuals and often take place over extended

Table 1. Summary of the re-introduction and removal history of south-central black rhinos in Marakele National Park.

	Introduced						Removed					
	Male			Female			Male			Female		
Year	D-class	E-Class	F-Class	D-Class	E-Class	F-Class	D-class	E-Class	F-Class	D-class	E-Class	F-Class
1993			1			2						
1994			1			1						
1996	1	1	5		1	6						
2000											1	
2002			2		1	1						
2003								1	1		1	
2004			2									
2005						1						
2007			1									
2008									1			
Unknown[1]						1						

[1]Introduction most likely took place during 2007.

periods (Adcock, Hansen & Lindemann, 1998; Linklater & Swaisgood, 2008; Linklater *et al.,* 2011; Greaver, Ferreira & Slotow, 2014).

Recovering species, using small initial release sizes, imposes stochastic risks (Akçakaya, 2002) that increase local ecological and genetic related extinction risks (Polishchuck *et al.,* 2015). Although multiple introductions, avoiding calves and all-male cohorts can overcome such risks (Linklater *et al.,* 2011), success in other species associated with the source populations being wild, a large number of animals initially introduced, and the removal of the cause of original decline (Fischer & Lindenmayer, 2000). The re-introduction of south-central black rhino fulfils at least two of these criteria which, together with multiple introductions, predict sustained recovery of the black rhino population in Marakele National Park. Our study together with other studies (*e.g.* Linklater & Swaisgood 2008), suggest that the consequences of density-associated social interactions may vary in small reserves. Multiple re-introductions may thus impose different social and density-related constraints on population performance. We advocate that implementing multiple re-introductions requires a case-by-case assessment for populations.

During November 2015, 20 adult cows and 15 adult bulls were present in the park with ear-notches. During the aerial survey we encountered a total of 47 individuals, 22 of which had ear-notches (Table 2). Note that 14 notched cows and three un-notched cows had calves associating with them. None of these calves were notched. This resulted in an estimate of 25 (95% CI: 23–28) and 23 (17–29) adult cows and bulls respectively. The overall proportion of cows with calves (0.894, variance = 0.094) allowed us to estimate that 23 (20–26) calves associated with adult cows. Combined, these results suggest that a total of 71 (63–78) black rhinos lived in Marakele National Park during November 2015.

When we combined the 2015 estimate with the introduction and removal history we estimated annual exponential population growth at 0.061 (0.055–0.066). This falls above the 0.05 target of the South African National Black Rhino Management Plan (Knight *et al.,* 2013) and compares favourably with population growth rates in other recovering black rhino populations (Hrabar & du Toit, 2005; Greaver *et al.,* 2014; Law, Fike & Lent, 2015). It also supports the prediction that multiple introductions result in sustained recovery, but most likely in concert with other factors such as available food and spatial resources in Marakele National Park.

Table 2. Summary of individuals noted for surveys of black rhino in Marakele National Park during November 2015.

		Female	Male	Unknown
Notched	Individuals	15	7	
	Associated calves	2	9	3
Not notched	Individuals	4	4	
	Associated calves	1	1	1

Survival rates of females were 0.994 (0.989–0.998), while that of males were 0.889 (0.883–0.894). Note that rangers recorded four females and three males dying between 1994 and 1997. An additional two females died during 2001 and 2002. Two young males were found dead between 2011 and 2012. During 2013, an introduced female was killed by the resident bull. No black rhinos have been poached. Inflated estimates of mortality are expected when using small samples of direct observations (Akçakaya, 2002) as noted in our case study and in at least one other recovering black rhino population (Law *et al.,* 2015). Complementing observed deaths with derived estimates may overcome misinterpretation of the performance of black rhino re-introductions induced by small sample effects.

We recorded recruitment as a 0.106 fraction of the population comprising A- and B-class calves. When corrected for sex-specific survival rate from birth to one year of age, we estimated birth rate at 0.113 (0.112–0.114). Such a birth rate predicts that reproductively active cows will have calves every 2.64 (2.62–2.65) years. These calving intervals compare well with those noted in other recovering black rhino populations (Adcock, 2009; Ferreira *et al.,* 2011).

CONCLUSION

The re-introduction and supplementary introductions of black rhinos in Marakele National Park led to a population growth rate exceeding the national South African targets. Using a combination of population modelling and direct observations, we could illustrate that vital rates are high. This reflects positively on a successful outcome of establishing a population of south-central black rhinos. Extinction risk, however, is not only associated with trends in population sizes, but also the absolute size of the population (Polishchuk *et al.,* 2015). The small size of the black rhino population at Marakele National Park is thus a key potential driver of local extinction, primarily because stochastic events can have devastating effects on the demographics of small population resilience to disturbance and social factors (Linklater *et al.,* 2011). Expanding the available area which will allow the evolution of a larger black rhino population should thus be of highest priority informed by monitoring to identify and evaluate key performance indicators.

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