Diceros bicornis – Black Rhinoceros

Regional Red List status (2016)	Endangered C2a(i)*†
D. b. bicornis	**Endangered D*†**
D. b. minor	**Endangered C2a(i)*†**
D. b. michaeli	**Critically Endangered D*†**
National Red List status (2004)	
D. b. bicornis	Critically Endangered D
D. b. minor	Vulnerable D1
D. b. michaeli	Not Evaluated
Reasons for change	
D. b. bicornis	Genuine change: Increased population
D. b. minor	Genuine change: Projected decline
D. b. michaeli	Genuine change: New listing

*Watch-list Threat †Conservation Dependent

While Black Rhinoceros subpopulations are generally faring well within the assessment region, they are threatened by the poaching pandemic, especially in Kruger National Park. Combatting the poaching crisis requires a multifaceted strategy including anti-poaching programmes, demand reduction campaigns, disrupting criminal networks and providing options for alternative economies in areas abutting protected areas (Ferreira et al. 2015).

Global Red List status (2012)‡		
D. bicornis		Critically Endangered A2abcd
D. b. bicornis		Vulnerable D1
D. b. minor		Critically Endangered A2abcd
D. b. michaeli		Critically Endangered A2abcd
TOPS listing (NEMBA) (2007)		
D. b. bicornis	*D. bicornis*	Endangered
D. b. minor		
D. b. michaeli		
CITES listing (2005)		Appendix I
Endemic		No
Percentage of global wild population conserved in South Africa and Swaziland at end of 2015:		
D. bicornis		36.4%
D. b. bicornis		11.6%
D. b. minor		73.0%
D. b. michaeli		8.9%

‡Currently under revision

Taxonomy

Diceros bicornis (Linnaeus 1758)

ANIMALIA - CHORDATA - MAMMALIA - PERISSODACTYLA - RHINOCEROTIDAE - *Diceros* - *bicornis*

Synonym: *Rhinoceros bicornis* (Linnaeus 1758)

Common names: *Diceros bicornis*: Black Rhinoceros, Hook-lipped Rhinoceros (English), Swartrenoster (Afrikaans), !Nabas (Damara, Nama), Umkhombo, Ubhejane Onzime (Ndebele), Makgale (Sepedi), Tshukudu (Sesotho), Bodilê, Kenenyane (Setswana), Chipenbere, Hema (Shona), Sibhejane (Swati), Thema (Tshivenda), Mhelembe (Tsonga), Umkhombe (Xhosa), Ubhejane, Isibhejane (Zulu). *Diceros bicornis bicornis*: Southwestern Black Rhinoceros (English). *Diceros bicornis minor*: Southern-central Black Rhinoceros (English). *Diceros bicornis michaeli*: Eastern Black Rhinoceros (English).

Taxonomic status: Species and subspecies.

Taxonomic notes: There is significant population genetic differentiation between all three extant subspecies of Black Rhinoceros (hereafter Black Rhino) recognised by the IUCN SSC African Rhinoceros Specialist Group (AfRSG) (Harley et al. 2005), and the differences are consistent with them being considered subspecies although it is unlikely that outbreeding depression would occur in any mix of these populations (E. Harley pers. comm. 2016). Rhino DNA Indexing System (RhODIS) analysis of DNA samples also supports the separation of the three recognised subspecies/ecotypes, with

Recommended citation: Emslie RH, Adcock K. 2016. A conservation assessment of *Diceros bicornis*. In Child MF, Roxburgh L, Do Linh San E, Raimondo D, Davies-Mostert HT, editors. The Red List of Mammals of South Africa, Swaziland and Lesotho. South African National Biodiversity Institute and Endangered Wildlife Trust, South Africa.

differences greatest between *D. b. michaeli* and the other two subspecies. Putative subspecies boundaries in part reflect climatic and habitat differences as well as taking into account potential barriers to movement such as the "Transkei gap". Recent molecular work indicates that the KwaZulu-Natal (KZN) population of *D. b. minor* exhibits lower genetic diversity than the Zimbabwean population, but that these populations were historically connected (Kotzé et al. 2014). However, KZN animals have still bred very well when translocated to new populations elsewhere such as the Eastern Cape and the Zimbabwe Lowveld. Additionally, the region's largest population Kruger National Park (KNP) and Swaziland's only Black Rhino population were both founded with a mix of Zimbabwe and KZN *D. b. minor* animals, with some KNP animals having been translocated to other areas since. Thus, the regional metapopulation does contain Zimbabwean genes.

Assessment Rationale

Continentally, Black Rhino numbers declined by an estimated 97% since 1960. This was mainly due to poaching with continental numbers bottoming out at 2,410 in 1995. Since then, numbers have steadily increased with total Black Rhino numbers in Africa doubling to 4,880 by the end of 2010 and reaching 5,250 by the end of 2015 (with 90% bootstrapped confidence levels from 5,040–5,458). There were an estimated 65,000 Black Rhino in Africa in 1970 and so, at the continental level, current Black Rhino numbers are still 90% lower than three generations ago, making the species Critically Endangered at a global level.

While Black Rhino populations in some range states have at times declined over the last three generations, numbers within the South Africa and Swaziland have been increasing for many years. In 1930, there were only an estimated 110 *D. b. minor* in South Africa in just two populations in KZN. With protection, active biological management and translocations to expand range and numbers, by the end of 2015 there were 54 breeding populations of *D. b. minor* in the region conserving an estimated 1,580 animals. This subspecies was reintroduced into Swaziland in 1987. In 1985 the more arid-adapted *D. b. bicornis* was reintroduced into South Africa from Namibia, and by the end of 2015, there were nine breeding subpopulations of this subspecies conserving an estimated 254 animals. A single out of range *D. b. michaeli* population was also established in South Africa in 1962. This population was later relocated to a private reserve in the country, and, by May 2016, numbers had grown to 93. From only 110 rhino in 1930, by the end of 2015 there were an estimated 1,913 Black Rhino overall in the South Africa and Swaziland region. Thus, both *D. b. michaeli* and *D. b. bicornis* numbers show an increase with long-term average population growth rates of around 7% and, for periods, well in excess of 9%. Neither of these subspecies had suffered any poaching up to end 2014. In contrast, the more numerous *D. b. minor* metapopulation, while still growing substantially, has performed less well. The long-term average underlying growth of this subspecies in South Africa has been 4.2% (weighted geometric mean for assessments over a number of periods). This subspecies has borne the brunt of the poaching, with KNP's *D. b. minor* population being especially impacted. Additionally, some long established subpopulations have not performed as well as others due in part to negative habitat changes and increased competition from other browsers. However, with increased biological management (translocations to reduce densities) it appears that underlying performance is improving. Based on empirically based model projections (explained in **Population** section below), the following listings are supported:

Diceros bicornis: At the species level, the predicted status at a regional level under criteria D would become Near Threatened due to their having been more than 1,000 mature individuals for over 5 years. Projected declines over 5 years when modelling based on unadjusted reported poaching levels were not statistically significant and would not qualify under C1. However, the best prediction (assuming an 80% poaching detection rate in KNP – due to its size and lower field ranger densities), estimated that numbers would decline over the next 5 years and that this decline would be statistically significant ($p < 0.0001$). With the decline in numbers in KNP, no subpopulation in the region currently has more than 448 individuals (equivalent to 250 mature individuals). The species therefore now qualifies to be Endangered C2a(i).

D. b. bicornis: There has been an increase in regional population size from both breeding and introductions of additional founder rhino from Namibia. Even under a scenario with future poaching, numbers of this subspecies are predicted to increase over the next 5 years. As there are fewer than 250 mature individuals in the region, this subspecies now qualifies as Endangered D.

D. b. minor: Numbers of individuals have now exceeded 1,792 for more than 5 years and so no longer qualifies as Vulnerable under D1. However, no subpopulations have more than 250 mature individuals, and numbers are projected to decline ($p < 0.0001$) over the next 5 years (due primarily to a predicted KNP decline), so the subspecies now qualifies as Endangered C2a(i).

D. b. michaeli: Numbers of this out of range subspecies have been increasing and are projected to continue to increase over the next 5 years, even under a modelled scenario with future poaching. While the single population of this subspecies in the region has very recently exceeded 90 animals (~ 50 mature individuals) this has not been the case for at least 5 years. While numbers are projected to increase over the next 5 years, future translocations out of the region are likely to reduce numbers of mature individuals back to below 50 mature individuals. The subspecies therefore regionally continues to qualify as Critically Endangered D.

Black Rhino population estimates are revised by the AfRSG every 2–3 years and in South Africa there is regular confidential annual status reporting to the Southern African Development Community Rhino Management Group (SADC RMG). These assessments will thus be revised regularly to monitor the poaching threat.

Regional population effects: All three Black Rhino subspecies occur in other range states outside of South Africa and Swaziland, and translocation techniques are well developed. If the South African and Swaziland indigenous subspecies were to face extinction due to poaching, rhino could potentially be brought back to this region. This would be conditional on the generosity of other range states and the continued survival of these subspecies in these countries. However, given the likelihood that such heightened poaching pressure would also be felt in other range states, they may well then not be in a position to provide founder animals to rescue the

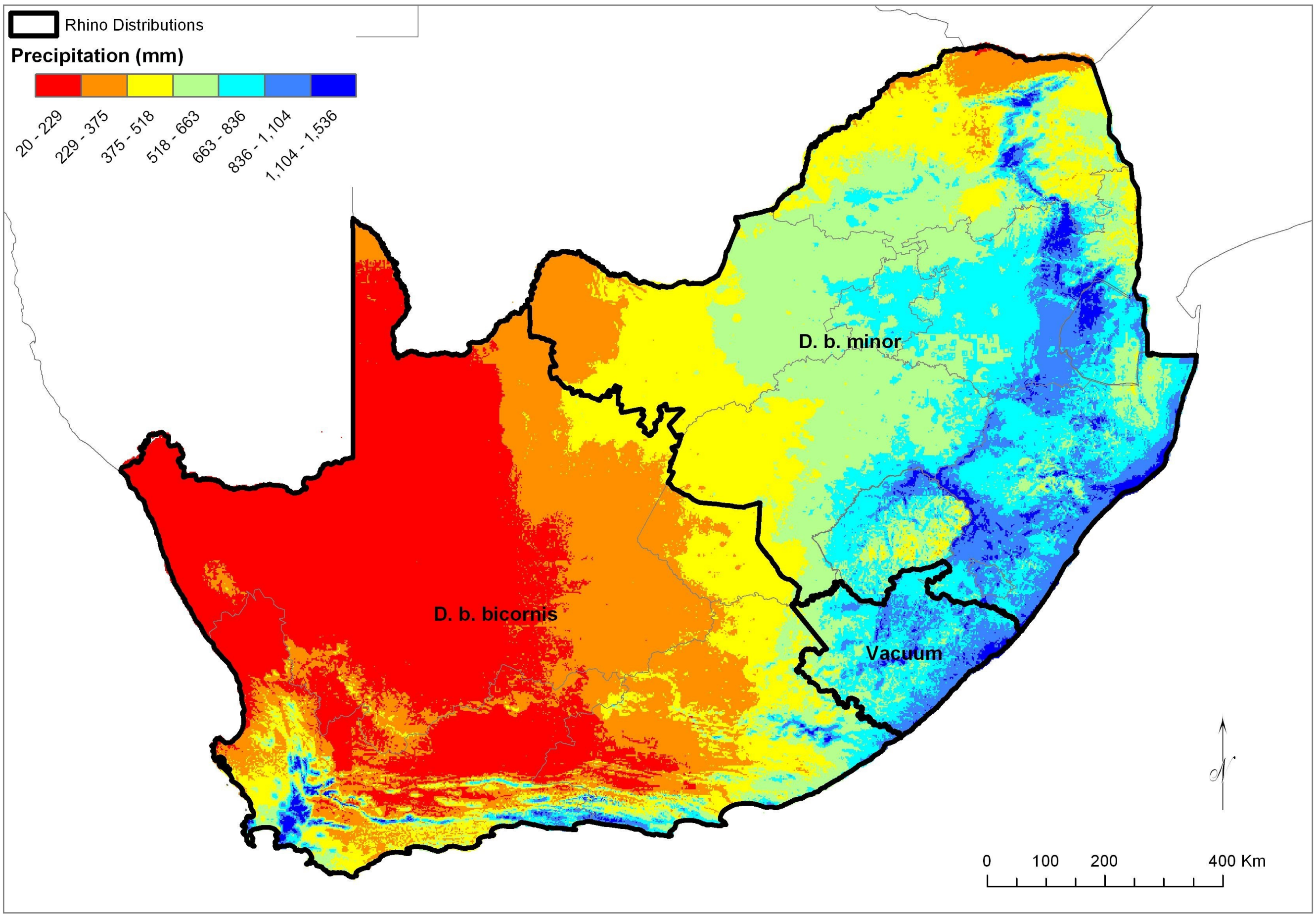

Figure 1. Revised subspecies ranges and annual rainfall with *D. b. bicornis* being the more arid adapted of the Black Rhino subspecies. It is important to realise that the above revised subspecies boundaries in the South African Black Rhino Biodiversity Management Plan represent a practical construct for management purposes and may not exactly match historical subspecies distributions. In any event these are imperfectly known and probably always will be. Since 2007, the deemed *D. b. bicornis* range in the Eastern Cape has expanded westwards up to the "Transkei Gap" which is now classified as extra-limital (and not range for either indigenous subspecies) and a barrier to movement of *D. b. minor* southwards. It is important to realise that some areas marked as subspecies range contain unsuitable/more marginal habitat, with rhinos probably either being absent or likely to have only occurred at very low densities in these areas (for example, parts of Free State). On pragmatic grounds, North West and Free State provinces have decided to classify themselves as single subspecies *D. b. minor* provinces (however, there is a *D. b. bicornis* subpopulation in eastern North West Province), although a case could have been made for these provinces to be subdivided based on rainfall. Rainfall base map from Schulze (1997).

subspecies in this region. Therefore, it has been assumed for the purpose of these assessments that rescue from outside the region is unlikely to occur.

Distribution

There are now three remaining recognised ecotypes/ subspecies of Black Rhino occupying East and southern African countries. The fourth recognised subspecies *D. b. longipes* once ranged through the savannah zones of central West Africa but has gone extinct in its last known habitats in northern Cameroon. Within the assessment region, Black Rhino have never occurred in Lesotho. There is also an area south of Lesotho and the southern boundary of KZN into Eastern Cape where it is believed rhinos never occurred, and this is not considered Black Rhino range.

There were no Southwestern Black Rhino (*D. b. bicornis*) in South Africa in 1973 with the subspecies first being reintroduced in 1985. The subspecies is not native to Swaziland. The AfRSG data shows that its area of occupancy in South Africa is estimated at 3,819 km^2 in western and southeastern South Africa.

Southern-central Black Rhino (*D. b. minor*) are believed to have occurred from southern Tanzania through Zambia, Zimbabwe, and Mozambique to the northern, north-western and north-eastern parts of South Africa (north of the Mtamvuna River). It also probably occurred in southern Democratic Republic of the Congo, eastern Botswana, Malawi, and Swaziland. Today, its stronghold is South Africa and, to a lesser extent Zimbabwe, with smaller numbers remaining in southern Tanzania. The Southern-central Black Rhino is now thought to be extinct in Angola. It also is believed to have gone extinct in Mozambique, although in 2015 it was reported that two animals had migrated into the country from South Africa. The subspecies has also been reintroduced to Botswana, Malawi, Swaziland and Zambia. Although previously widely distributed within the assessment region, the subspecies now only exists in a few isolated pockets within its former range. The majority of these are on formal conservation areas although some are on private lands. Specifically, it occurs within the eastern Lowveld in Limpopo and Mpumalanga and KZN Lowveld habitats. In the Limpopo Province, its range extends westwards to the North West Province. Its putative distribution is partially predicted by rainfall isohyets but also the potential barrier to movement south of KZN posed by the "Transkei gap". There are 54 breeding locations within the region and the estimated area of occupancy is 25,029 km^2.

Table 1. Countries of occurrence within southern Africa (distribution maps and names of subpopulations kept confidential for security reasons)

Country	Presence	Origin
Botswana	*D. b. bicornis* ~ Absent *D. b. minor* ~ Extant *D. b. michaeli* ~ Absent	- Reintroduced -
Malawi	*D. b. minor* ~ Extant	Reintroduced
Lesotho	Absent	-
Mozambique	*D. b. bicornis* ~ Absent *D. b. minor* ~ Small variable population from cross-border migration of animals from South Africa. *D. b. michaeli* ~ Absent	- Native -
Namibia	*D. b. bicornis* ~ Extant *D. b. minor* ~ Absent *D. b. michaeli* ~ Absent	Native - -
South Africa	*D. b. bicornis* ~ Extant *D. b. minor* ~ Extant *D. b. michaeli* ~ Extant	Reintroduced Native Introduced
Swaziland	*D. b. bicornis* ~ Absent *D. b. minor* ~ Extant *D. b. michaeli* ~ Absent	- Reintroduced -
Zimbabwe	*D. b. bicornis* ~ Absent *D. b. minor* ~ Extant *D. b. michaeli* ~ Absent	- Native -

The Eastern Black Rhino (*D. b. michaeli*) was introduced to South Africa in 1962 and now exists on private land. The long-term goal is to repatriate animals from this population back to its former range in East Africa. For the time being, we include the subspecies in the national assessment as the one out-of-range population is of continental significance for the subspecies, and is well-protected and breeding successfully. AfRSG data show that its area of occupancy in South Africa was estimated at 350 km^2. This population in the region has to date been increasing rapidly and there have not been extreme fluctuations in numbers. The Eastern Black Rhino regionally therefore does not qualify under any of the threatened categories using Criterion B.

For security reasons detailed maps of the distribution of Black Rhino in the region are not provided by AfRSG or SADC RMG and the current subspecies ranges defined for South Africa in the national Black Rhino Biodiversity Management Plan (Knight et al. 2011) are shown in Figure 1 taken from the plan that was formally approved and gazetted in 2013. Historically, a small number of subpopulations of *D. b. minor* were established in what was before 2007 considered *D. b. minor* range in the Eastern Cape, but which has now been reclassified as *D. b. bicornis* range. The largest of these subpopulations has become an AfRSG-rated *Key1* population of continental significance and is now a significant donor population. On pragmatic conservation grounds, it has been decided not to try to move the animals from this subpopulation as this would be very expensive, take many years, and would result in some mortalities and short-term negative effects on breeding. As there is no chance of subspecies mixing from this and the other smaller privately owned *D. b. minor* subpopulations in the Eastern Cape, these can remain, but the smaller subpopulations have been encouraged to replace their *D. b. minor* with *D. b. bicornis* should the opportunity arise in future (Knight et al. 2011). Swaziland falls within *D. b. minor* range.

Population

Historically the Black Rhino was once the most numerous of the world's rhinoceros species and could have numbered around 850,000 individuals. Relentless hunting of the species and clearances of land for settlement and agriculture reduced numbers, and by 1960 only an estimated 100,000 remained. Between 1960 and 1995, large-scale poaching caused a dramatic 98% collapse in numbers. Over this period, numbers only increased in South Africa and Namibia, from an estimated 630 and 300 in 1980 (Emslie & Brooks 1999) to 1,893 and 1,946 respectively by the end of 2015 (AfRSG data 2016). Continentally numbers bottomed out at only 2,410 in 1995 (Emslie & Brooks 1999). From 1992–1995 total numbers remained relatively stable with increases in some countries (those with the best-protected and managed populations) being cancelled out by declines in others. However, since the low of 1995, Black Rhino numbers at a continental level have increased every time continental population estimates have been revised by the AfRSG, doubling to 4,880 by December 2010 and reaching 5,250 by the end of 2015 (Emslie 2006; AfRSG data 2008, 2011, 2013, 2016; Emslie *et al.* 2016). Increases in numbers have occurred in countries where investments in conservation programmes (including monitoring, biological management and law enforcement) have been high. As with White Rhinoceros (White Rhino; *Ceratotherium simum simum*), four range states (South Africa, Namibia, Zimbabwe and Kenya) currently conserve the majority (96%) of remaining wild Black Rhino. However, the emerging threat of poaching through trafficking syndicates may ultimately undermine such successes.

Within the assessment region, numbers remain low but stable or increasing over three generations. Generation length is empirically derived to be 14.5 years (SADC RMG unpubl. data). This gives a three generation window of 43.5 years. The number of mature individuals has been estimated at 55.8% of total numbers based on the average of Black Rhinos that are adults (based on SADC RMG confidential status reporting and data). There were an estimated 254 Southwestern Black Rhino (*D. b. bicornis*) in South Africa at the end of 2012. There were no Southwestern Black Rhino in South Africa in 1973 with the subspecies first being reintroduced in 1985. By the end of 2015 the Southern-central Black Rhino (*D. b. minor*) was estimated at 2,164 individuals throughout Africa with 1,560 in South Africa, and 20 in Swaziland. Details of the population data and models for the species overall and for each subspecies are described below.

On average in the region, proportionately fewer of the Black Rhinos have been poached each year than the White Rhinos, particularly in South African subpopulations outside of KNP and KZN[1]. However, the average underlying performance of *D. b. minor* has also been lower than that achieved by the region's White Rhinos, and the other two Black Rhino subspecies in South Africa. Following the recent period of rapid increase in poaching of both rhino species in the region (which started in 2008), over the last year poaching in the region has slowed and started to decline (Figure 2). However, if poaching were to continue to escalate once again, this could threaten the

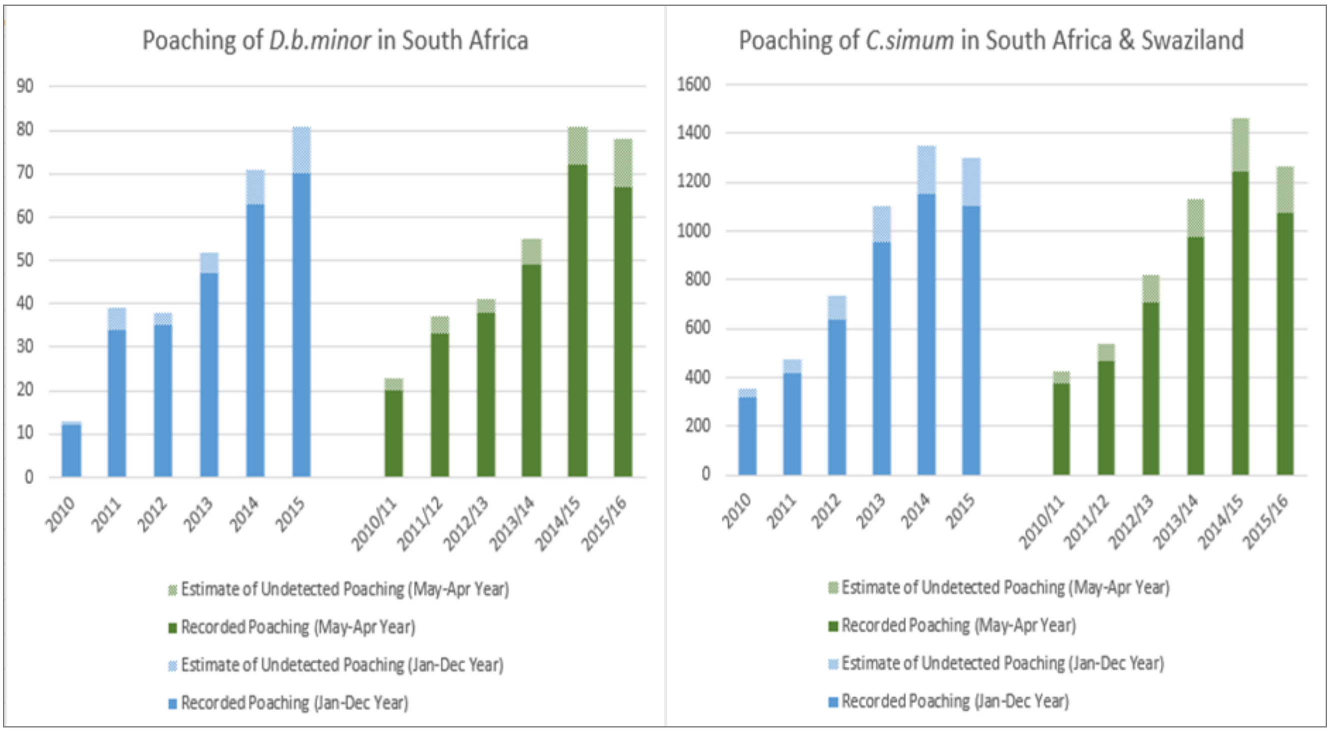

Figure 2. Reported poaching of undetected poaching of Black (left) and White Rhino (right) in the South Africa/Swaziland Region summarised over calendar years (blue), as well as years from May to April (green). Since 2010, only three White Rhino[2] and no Black Rhino have been poached in Swaziland. All Black Rhino poached in the region up to the end of 2014 were *D. b. minor*[3], and it was assumed that this also applied to the Black Rhino poaching in the rest of South Africa over the 16 months Jan 2015–Apr 2016. At the time of assessment, a breakdown of the total reported rhino poached by species and subspecies for the same period was only available for some major but not all South African rhino populations. Where a species breakdown was not available, poaching was allocated to species on a pro rata basis based on past data going back to January 2010 for these areas[4]. Additional estimates for undetected poaching (lighter shaded areas at top of bars in graph) were based on an estimate that the rhino poaching detection rate in Kruger National Park was 80%[5].

progress achieved in the South Africa and Swaziland region (and rest of Africa) over the last two decades.

There is uncertainty in predicting the future for Black Rhino, and Red List Guidelines (IUCN Standards and Petitions Subcommittee 2014) recognise that "*the way this is handled can have a major influence on the results of an evaluation*". For example, outcomes can vary depending upon underlying rhino population growth rates (before poaching) which may improve or decline (compared to a metapopulation's longer term average), and depending on whether future poaching follows recent, intermediate or longer term poaching trends. Measurement error around population sizes and poaching estimates also needs to be factored into the assessment process. According to Red Listing Guidelines "*uncertainty may be represented by specifying a best estimate and a range of plausible values for a particular quantity*". We have adopted this approach here. The Red Listing Guidelines also state that "*the method used* (to represent uncertainty) *should be stated and justified in the assessment documentation*", and that "*projected trends require a discussion of the methods and assumptions behind models used*". In the interests of transparency, the approaches taken when modelling have been outlined in some detail. We have tried to follow the Red List Guidelines' advice and adopted "*a moderate attitude, taking care to identify the most likely plausible range of values, excluding extreme or unlikely values*". With a high-profile species like Black Rhino, the assessors felt it was especially important to be transparent and provide full details of the methods, approaches and assumptions used. Phillip Tetlock, has for over two decades examined the success of predictions, and the factors associated with superforecasters that are consistently much better than others (who often do little better than "dart-throwing chimpanzees" would). He concluded that better forecasters tended to be more granular in their thinking and invariably considered a range of alternative possibilities (Tetlock & Gardner 2015). Where possible we have tried to follow this more detailed approach in an effort to try to ensure that the predictions and hence the Red List Assessments are as good as they can be.

Thanks to a process of confidential annual Black Rhino Status Reporting to the SADC RMG that has continued uninterrupted since 1989, and regular reporting to AfRSG; detailed data exist on Black Rhino numbers, poaching and population performances for most subpopulations over time. The size of many Black Rhino subpopulations, which are monitored using individual identification methods, is also known exactly or to within a few rhino. A minority (20%) of Black Rhino in the region occur in its largest subpopulation in KNP (where ID based monitoring over the whole area is not feasible). Here, numbers are monitored using intensive helicopter block counts which have wider confidence levels. However, overall numbers of Black Rhino are probably known much more precisely than for most other mammal species, with bootstrapped 90% confidence levels for *D. b. minor* in the region ranging from 1,503–1,658. Numbers of the other two Black Rhino subspecies are much more precisely known.

Where possible, modelling of future numbers for these Red List assessments used parameters that had been empirically derived from this reported data:

- Past confidential SADC RMG annual status reporting data for South Africa (Adcock 1995 and similar for 1996, 1998, 2000, 2002, 2006, 2007, 2013, 2016).
- Past confidential SADC RMG status report summary analyses (and especially estimates of past subspecies metapopulation underlying growth rates) (Adcock et al. 2010).
- Specific queries of the SADC RMG data by the compiler of these reports.
- Confidential data provided by Swaziland Big Game Parks to the AfRSG.
- Confidential South African estimates provided to the February 2016 AfRSG meeting by Dave Balfour.
- Official rhino poaching statistics provided by both South Africa and Swaziland over the years.
- Past population estimates were derived as best as possible from the population estimates in the literature (Emslie & Brooks 1999; AfRSG data and SADC RMG data with interpolation for years without estimates).

For security reasons only subspecies totals are given in this assessment, and, apart from KNP, no subpopulations are individually named.

For many species, measurement error *"is often the largest source of uncertainty"* (IUCN Standards and Petitions Subcommittee 2014). Fortunately, for the reasons outlined above, this is much less of a problem for Black Rhino in South Africa and Swaziland region which must be one of the best monitored of large mammal species. Apart from the use of individual identification techniques in many subpopulations (allowing reasonably or very precise monitoring of many population sizes and trends), many subpopulations also have high field ranger densities and carcass recovery rates that are generally very high. The major source of uncertainty with regards rhino numbers and poaching statistics primarily relates to the largest subpopulation in KNP[6]. However, in general, uncertainty across the region is not primarily a problem of data uncertainty, but rather due to the range of possible future trends in breeding performance and poaching.

Given the generally increasing poaching threat since 2008, and its potential future impact should the recent slowing in poaching only prove to be temporary lull (Figure 2), it appears sensible to project possible changes in rhino numbers into the future under a range of poaching scenarios. However, in order to undertake the modelling of rhino numbers into the future under a reasonable range of scenarios, and to make assessments under Criteria A4 and C1, there were 11 questions that needed to be addressed:

1. How long is a generation for Black Rhino?
2. How far back should one look in the case of *D. b. bicornis* (that hadn't yet been reintroduced into the region three generations ago)?
3. How many years should the three generation (43.5 year) assessment window be moved into the future under criterion A4? (It seems reasonable that this decision should depend on how far into the future one can predict with a reasonable degree of confidence).
4. What kind of annual rates of increase or decrease in poaching should be modelled (exponential and/or arithmetic), and if modelling exponential increases, is it better to model increases in absolute numbers or increases in the percentage of the population that is poached each year?
5. How far back in time should one look at past poaching trends when determining how to model future poaching?
6. What is the poaching detection rate? In other words, how much of an underestimate of true poached numbers are official poaching statistics (that are based on recorded poaching deaths and subsequent rhino deaths associated with poaching)?
7. How much should poaching change by each year, when modelling into the future?
8. Up to the end of 2014, no *D. b. bicornis* or *D. b. michaeli* had been poached in the region since the upsurge of poaching started in 2008. However, given the rhino poaching pressure in the region, under a precautionary approach what might be a reasonable estimate of future poaching to model for these subspecies?
9. What range of underlying population growth (net annual population growth in the absence of poaching and after allowing for regional translocations) should be modelled?
10. How should one deal with uncertainty around population estimates? Especially, how can we decide whether or not there would be a significant decline (necessary under criteria A4, C1, and especially C2, where there just has to have been an unspecified "decline" in numbers)?
11. The criteria specify minimum numbers of mature individuals, but data primarily reflects total number of individuals of all age classes. What rule of thumb should be used to convert threshold numbers of mature individuals to equivalent threshold total numbers of rhino?

1. How long is a Black Rhino generation? For this assessment SADC RMG data was examined to determine the average age of breeding females to get an empirically derived generation time of 14.5 years (K. Adcock unpubl. data). This gives a three generation window of 43.5 years within which to assess changes in regional Black Rhino numbers. To use the most updated information available at the time of assessment modelling, it was decided to model poaching based on trailing 12-month (TTM May–April) data rather than calendar years.

2. How far back to assess changes in *D. b. bicornis* numbers? *D. b. bicornis* was only reintroduced into South Africa in 1985. The subspecies therefore wasn't present in the region three generations ago. It was decided to compare modelled 2020 numbers with numbers present in 1989 (13) as this was the date that the first calf was born in the re-established *D. b. bicornis* metapopulation that had a) been conceived in the region, and b) that went on to breed successfully. Thus, the 1989 baseline is the first date that the ability of the reintroduced *D. b. bicornis* metapopulation to reproduce and self-sustain itself was confirmed.

3. How many years should we predict into the future? The Red List assessment team in discussion with some other AfRSG members[7] and IUCN Red Listing experts (Michael Hoffman, Resit Akcakaya, Craig Hilton-Taylor and Carlo Rondinini) have concluded that it is reasonable for this Red List assessment to predict population sizes 5 years into the future (from the latest population estimate).

The rationale behind this decision was:

- Black Rhino population estimates are revised by AfRSG every 2–3 years and in South Africa there is regular confidential annual status reporting to the SADC RMG. It thus will be possible to keep a watching brief on the situation and to re-assess the Red List status of African rhino at frequent intervals in future. Analysis spreadsheets have been developed to help automate and facilitate this process in future.
- History has shown that there can be marked changes in poaching and rhino numbers over short periods (for example, following heavy poaching in some countries in the 1960s and 1970s, the rapid extermination of the Northern White Rhino population in Garamba National Park, past successful demand reduction in Japan, Taiwan and South Korea, and following the collapse of horn sales in Yemen). The recent period of rapidly escalating poaching has over the last year slowed regionally and continentally (there have been declines in overall rhino poaching numbers in Kenya and South Africa, Figure 2), despite some recently increased poaching in Namibia and Zimbabwe.
- As can be seen later, the variable trends in poaching levels over time create a wide range of possible outcomes: The further into the future one projects, the wider the possible range of outcomes and the less confidence one can have in the projections.
- A 5-year period is also suggested for other predictive fields too where little confidence can often be placed in predictions as far as 10 years out[8].
- Transnational organised crime is behind the poaching, and these syndicates are effectively illegal businesses. Just as businesses cannot be expected to exponentially increase earnings by 30–50% / year for long periods, it is also probably not reasonable to model any significant very high exponential increase in poaching for more than about 5 years.
- Continual negative messages that rhinos are getting rarer may increase black market prices and demand for illegally sourced horn. Consumers and any speculative buyers may then want to get in now and buy horn before it gets rarer and goes up in price, potentially boosting poaching levels and making the situation worse. For the good of the rhinos, a balance therefore needs to be struck between being overly evidentiary or over precautionary, and to try to honestly assess a species' future prospects without being overly negative. It is therefore probably better to estimate a range of possible outcomes with greater confidence over a shorter time frame rather than to speculate over a longer term when a huge range of possible outcomes may result.

Despite the decision to use predicted numbers 5 years into the future to obtain the "best estimates" for use in these Black Rhino Assessments, it was still decided for illustrative purposes to model a range of both exponential and arithmetic changes in rhino poaching up to 10 years into the future. Readers can then see a full range of possible outcomes that might occur under different scenarios and the possible range within which the Red Listing might perhaps fall in future. After 10 years, it would be necessary to redo Red List assessments, and one can have very little confidence predicting any further into the future than this.

South African regional population estimates are available for the end of 2015, so projecting numbers forward 5 years take us to the end of 2020 for these Black Rhino regional Red List assessments; with mid-1976 providing the starting point of the 43.5-year window (except for *D. b. bicornis* as discussed above). The only Black Rhinos in the region in mid-1976 (three generations back from 2020) were an estimated 481 *D. b. minor* and 11 *D. b. michaeli*. Swaziland only reintroduced Black Rhinos back into the country in 1987.

Estimates of baseline rhino numbers were derived for each year from mid-1971 (for comparison to current end 2015 numbers) all the way up to mid-1981 (when moving the three generation window to project 10 years into the future). Similarly, baseline estimates were derived for each year from mid-2000 to mid-2010 and from 1986–1996 to be able to look back one and two generations if needed under criterion C1. Fortunately, annual Black Rhino estimates are available for South Africa since SADC RMG Annual Status Reporting started in 1989. However, prior to this, estimates were only available for some and not all years. Estimates for "missing" years between estimates were interpolated by applying appropriate average annual exponential rates of population increase/decrease for each period for which estimates were not available, which, when compounded annually, would produce the next estimated subpopulation size available[9].

4. What kind of annual rates of increase or decrease in poaching should be modelled (exponential and/or arithmetic)? While modelling a very high rate of annual exponential increase in absolute numbers poached many years into the future is not likely to be justified, this could be very appropriate for shorter periods. In the longer term it probably would be more realistic to model an average annual arithmetic increase in poaching. This is illustrated by the KNP example below. Figure 3 shows numbers of rhinos (both species) reported poached in KNP and the table gives the differences between years in both number of rhino poached and as a percentage (%) change in absolute numbers poached from year to year. The 2016 data only covers the first 4 months of the year and the additional 470 represents a simple extrapolation (assuming the same rate of poaching for the rest of the year)[10].

Figure 3 shows that as absolute rhino poaching numbers in KNP increased rapidly up to 2014, the percentage (relative) rate of increase in numbers poached dropped considerably. Modelling a constant exponential percentage increase in numbers poached would not have been accurate in this case. When modelling exponential increases in absolute numbers poached under extreme rapid poaching increase scenarios, the numbers poached can (due to compounding) after a number of years increase markedly in a very short space of time. When modelling rapid exponential increases in absolute numbers poached, Red List assessments under criterion A4 tend to change the rating somewhat unrealistically from Near Threatened to Critically Endangered and/or close to extinction (assuming the last few will be well protected and harder to find) in only a single year, or possibly 2 years[11]. If we instead model an exponential increase in the *proportion* of the population poached each year rather than absolute numbers, the results appear more realistic, with it taking a bit longer to progress from Near Threatened to Critically Endangered and close to extinction[12]. For this reason, when modelling exponential increases in poaching scenarios, we opted to

Period	% change	Number change
2009–10	190%	96
2010–11	73%	106
2011–12	69%	173
2012–13	42%	181
2013–14	36%	221
2014–15	0%	-3
2015–16	-15%	-122

Figure 3. Poaching of African rhinos (both species) in Kruger National Park since the upsurge in poaching began in 2008, with text box showing the % change in numbers recorded poached compared to previous years, and differences in absolute numbers poached. 2016 estimated poaching consists of 232 recorded poached in the first four months of the year, with the balance being a simple pro rata projection for possible poaching over the rest of the year assuming the same poaching rate / day as the first 4 months of the year.

exponentially increase the percentage of the population poached each year (rather than the absolute numbers poached). However, for the reasons discussed above, caution still needs to be exercised with regards to long-term 10-year projections of continued high exponential growth rates in poaching

5. How far back in time should one look at past poaching trends when determining how to model future poaching? Past poaching trends can be used to empirically guide modelling of future poaching trends (assuming that observed recent to medium term trends in regional Black Rhino poaching will continue up to 10 years into the future). When assessing changes in past poaching, it was decided not to look back more than 5 years. This avoids earlier years with much lower poaching and when expenditure and effort on security was much lower than it is now. However, a 5-year period still includes the main period of poaching increase and heavier poaching years, and the last (TTM) year where the Black Rhino poaching level in the region declined slightly. Continentally, the rate of increase in overall rhino poaching (both species) has also slowed considerably over the last 2 years. There also have been no rhinos poached in Swaziland over the last 2 TTM years. It was therefore decided to model three poaching scenarios based on most recent (1 year), intermediate (3 year) and longer medium term (5 year) Black Rhino poaching trends in the region. The results of all three poaching scenarios were then averaged to provide a best predicted estimate or Black Rhino number 5 years into the future.

6. What adjustment to reported Black Rhino poaching numbers should be made to account for possible undetected poaching in Kruger National Park? Given KNP's vast size it is not possible to have as high a field ranger density as in other smaller parks. It is also not feasible to monitor this subpopulation using individual identification methods (that can help alert you to possible missing rhino). Despite 90% of rhino carcasses in the KNP currently being found within two weeks of death (S. Ferreira pers. comm. 2016), it is probable that some poached carcasses will have gone undetected. As Red Listing requires assessors to adopt "*a precautionary but realistic attitude*", it was decided to include an estimate for undetected poaching in KNP (which has suffered the brunt of the poaching), based on a guesstimate that 20% of the Black Rhino poaching in KNP has gone undetected[13]. Due to much more intensive monitoring in all other Black Rhino sites, we assumed all Black Rhino poaching throughout the rest of the region was found and reported. In due course, as better information on poaching detection rates becomes available, these can be incorporated into future Red Listing assessments. Figure 2 shows the estimated proportion of poached rhinos missed over time in the region based on this assumption (lighter shaded areas at top of bars).

7. How much should modelled poaching change from year to year? The next step was to decide what to extract and use from past poaching data. Estimated absolute numbers poached / year data for the last 6 TTM years (which included estimates for some undetected poaching in KNP) provided average arithmetic increases in poaching over the three periods (looking back 1, 3 and 5 years). These were also expressed as a percentage of the population poached over the last 5 TTM years[14]. Estimates of the exponential growth in percentage of the population poached / year for 3- and 5-year periods were obtained by graphing the percentage of the population poached / year data for the last 6 TTM years 2010/11 to 2015/16 and for the last 4 TTM years 2012/13 to 2015/16 respectively, and then fitting exponential trend lines with the exponent in displayed equations on the charts giving the estimated exponential growth rates in proportion of population poached over 5- and 3-year periods respectively.

The estimated numbers of White and Black Rhino poached in the region over the last 5 TTM's derived from the above process are given in Table 2. White Rhino poaching statistics are also given for comparison and show an approximately similar trend (also see Figure 2).

8. What poaching levels should be modelled for *D. b. bicornis* and *D. b. michaeli*? Up to the end of 2014 no *D. b. bicornis* or *D. b. michaeli* had been poached in the region, and both subspecies had healthy long term underlying population growth rates of around 7% / annum. If numbers are modelled based on a continuation of zero past poaching levels then estimated numbers of both subspecies increase, and would therefore qualify both as Near Threatened under both A4, C1 and C2. The only exception to this would occur if substantial numbers of the out of range *D. b. michaeli* are transferred to populations out of this region (for example, to former range in East Africa or to other countries such as Chad) in future.

However, being precautionary, and given the rhino poaching pressure in the region, what might be a reasonable estimate of future poaching to model for these subspecies? The proportion of Black Rhinos of total rhinos

Table 2. Estimated White (WR) and *D. b. minor* Black Rhino (BR) poaching in South Africa and Swaziland over the last six trailing twelve months (TTMs) together with derived arithmetic and exponential annual changes to apply based on poaching trends over the three periods looking back 1 (recent), 3 (intermediate) and 5 (longer) years. The tables (right hand side) include estimates for additional rhino poached if one assumes the rhino poaching detection rate in Kruger National Park (KNP) was 80%. Starting levels of poaching for Year 0 were set as the past level of poaching for the TTM May 2015–April 2016. For example, if modelling poaching of *D. b. minor* over three years, and assuming 80% poaching detection rate in KNP, one would model an arithmetic increase in *D. b. minor* (and Black Rhino) poaching of +12.7 / year and an exponential 22.6% / year increase in the percentage of the population poached / year with a starting 78 poached / year or 4.7% of the *D. b. minor* population (3.9% of Black Rhino). The 1, 3 and 5 years refer to TTMs, not calendar years.

Period	Period	Region WR	Region BR	Region WR	Region BR	Region WR	Region BR
Start	End	Numbers reported poached		Estimate for undetected poaching assuming 80%		Total estimate (reported + estimate for undetected	
May	April		(all *D. b. minor*)		(all *D. b. minor*)		(all *D. b. minor*)
2010	2011	375	20	46	3	421	23
2011	2012	470	33	69	4	539	37
2012	2013	705	37	113	3	818	40
2013	2014	977	49	155	6	1,132	55
2014	2015	1245	71	217	9	1,462	80
2015	2016	1076	67	186	11	1,262	78
Recent	1 year	-169.0	-4.0			-200.0	-2.0
Intermediate	3 years	123.7	10.0			148.0	12.7
Longer	5 years	140.2	9.4			168.2	11.0
Starting at Year 0						1,262.0	78.0

Period	Period	Region WR	Region BR	Region *D. b. min*	Region WR	Region BR	Region *D. b. min*
Start	End	% of estimated population reported poached / year (assuming all poaching detected)			% of estimated population poached / year (adjusted to include estimate for undetected poaching)		
May	April						
2010	2011	1.99	1.02	1.15	2.18	1.18	1.32
2011	2012	2.45	1.71	1.97	2.73	1.92	2.21
2012	2013	3.67	1.97	2.31	4.09	2.13	2.49
2013	2014	5.15	2.55	3.01	5.63	2.86	3.37
2014	2015	6.65	3.60	4.28	7.24	4.04	4.80
2015	2016	5.82	3.38	4.07	6.39	3.92	4.70
Recent	1 year	-12.49	-6.02	4.95	-11.79	-2.99	-1.91
Intermediate	3 years	16.36	19.68	20.51	15.92	21.81	22.61
Longer	5 years	24.89	24.17	25.44	24.63	24.42	25.66
Starting at Year 0					6.39	3.92	4.70

being poached is lower outside of KNP. It was decided to model future *D. b. bicornis* and *D. b. michaeli* poaching assuming that poaching of Black Rhino outside of KNP would from now on be equally spread between subspecies on a pro rata basis according to their relative numbers[15]. Past numbers and the percentage of Black Rhino poached outside KNP were used to produce estimates for modelling poaching rates of all Black Rhino outside KNP based on past trends over 1, 3 and 5 years. Pro rata shares of these numbers were then calculated to estimate arithmetic changes in numbers of *D. b. bicornis* and *D. b. michaeli* (Table 3).

Using these past data in Table 2 and Table 3, six different poaching scenarios were modelled for Black Rhino at a species and subspecies level within the region as summarised in Table 4.

9. What rate of underlying population growth should be modelled? While young growing rhino populations with a slightly skewed age structure can and have grown (in the absence of poaching) for periods at rates in excess of 9% (Adcock 1995 and similar for 1996, 1998, 2000, 2002, 2006, 2007, 2013, 2016); this underlying growth rate is around the long term maximum expected for rhino subpopulations with a stable age distribution (Owen-Smith 2001). As part of regular confidential SADC RMG Status Reporting, metapopulation breeding performances have been calculated for seven consecutive periods (ranging from 2–5 years) over a 25-year period from 1989–2014, for each of the three Black Rhino subspecies in South Africa (Adcock et al. 2010). These calculations made allowances for translocations of Black Rhino in and out of the country, and did not make allowances for the very low baseline levels of past poaching (which until recently would have minimally impacted on overall growth). However, given the

Table 3. Estimates of modelled poaching rates to apply to Black Rhino (BR; *D. b. bicornis* and *D. b. michaeli*) in the region based on assuming a pro rata allocation of estimated poaching of Black Rhino in areas outside Kruger National Park (KNP) across all subspecies based on end 2015 rhino numbers outside of KNP. The 1, 3 and 5 years refer to TTMs, not calendar years.

Period Start May	Period End April	Estimated % of region's BR outside KNP = *D. b. bic*	Estimated % of region's BR outside KNP = *D. b. mic*	% BR outside KNP poached / yr	Number BR outside KNP poached	Estimated pro rata number *D. b. bic* poached	Estimated pro rata number *D. b. mic* poached
2010	2011	14.0	4.7	0.93	12	-	-
2011	2012	14.7	5.0	1.19	16	-	-
2012	2013	15.3	4.9	1.67	24	-	-
2013	2014	15.8	5.4	1.80	26	-	-
2014	2015	16.6	5.4	2.41	35	-	-
2015	2016	16.6	5.2	1.83	28	-	-
Recent	1 year			-23.92	-7.0	-1.2	-0.4
Intermediate	3 years			5.71	1.3	0.2	0.1
Longer	5 years			15.03	3.2	0.5	0.2
Starting at Yr0				1.83	28.0	4.7	1.4

Table 4. Summary of six poaching scenarios modelled for Black Rhino and all three subspecies in in the South Africa and Swaziland Region.

Type of growth in poaching modelled	Method used to determine magnitude of annual change in poaching from poaching data	Based on looking back at regional Black Rhino and *D. b. minor* rhino poaching data and assuming poaching of *D. b. bicornis* and *D. b. michaeli* similar to average Black Rhino poaching outside Kruger NP	Changes modelled per calendar year
Exponentially increasing poaching based on last **5 years** of poaching trends	Determined by graphically fitting an exponential trend line to the % of population poached/year data over time in Excel and displaying equation on chart.	% of population poached/year for each of last 6 trailing 12 month (TTM) periods (May 2010–Apr 2011 to May 2015–Apr 2016), giving 5 periods to assess annual changes in % of population poached / yr.	% change in % of rhinos poached / yr *D. bicornis* **+24.42%** *D. b. minor* **+25.66%** *D. b. bicornis* **+15.03%** *D. b. michaeli* **+15.03%**
Exponentially increasing poaching based on last **3 years** of poaching trends	Determined by fitting exponential trend line to % of population poached/year data in Excel and displaying equation on chart.	As above but for last 4 (TTM) years' worth of data from May 2012–Apr 2013 to May 2015–Apr 2016 giving 3 periods to assess annual changes in % of population poached / yr.	% change in % of rhinos poached / yr *D. bicornis* **+21.85%** *D. b. minor* **+22.61%** *D. b. bicornis* **+5.71%** *D. b. michaeli* **+5.71%**
Exponentially increasing poaching based on last **1 year** of poaching trend	% Change in poaching in time over last TTM.	Change in % of population poached/ year for the last two TTM periods (May 2014/Apr 2015 and May 2015/Apr 2016) assessing change in poaching over one year.	% change in % of rhinos poached / yr *D. bicornis* **-2.99%** *D. b. minor* **-1.91%** *D. b. bicornis* **-23.92%** *D. b. michaeli* **-23.92%**
Arithmetic based on last **5 years** of poaching trends	Average yearly change in absolute numbers poached which = (poached number at t5 – t0)/5.	6 (TTM) years of absolute numbers reported poached (May–Apr 2010/5 years (May 2011–Apr 2016) giving 5 periods to assess average annual changes in absolute numbers poached per year.	Change in absolute numbers of rhinos poached / yr *D. bicornis* **+11.0** *D. b. minor* **+11.0** *D. b. bicornis* **+0.5** *D. b. michaeli* **+0.2**
Arithmetic based on last **3 years** of poaching trends	Average yearly change in absolute numbers poached which = (poached number at t3 – t0)/3.	Same but for 4 (TTM) years of data (May 2013-Apr 2016) giving 3 periods to assess average annual changes in absolute numbers poached per year.	Change in absolute numbers of rhinos poached / yr *D. bicornis* **+12.7** *D. b. minor* **+12.7** *D. b. bicornis* **+0.2** *D. b. michaeli* **+0.1**
Arithmetic based on last **1 year** of poaching trend	Change in absolute number poached over last TTM.	Same but for 2 TTM years of data and 1 year of change (May 2014–Apr 2015 to May 2015–April 2016).	Change in absolute numbers of rhinos poached / yr *D. bicornis* **-2.0** *D. b. minor* **-2.0** *D. b. bicornis* **-1.2** *D. b. michaeli* **-0.4**

Table 5. South African metapopulation underlying growth rates over 24 years based on SADC RMG Status Report Summary Analyses over seven consecutive periods covering 1990–2014

	Black Rhino	*D. b. min*	*D. b. bic*	*D. b. mic*
Minimum	2.4%	2.0%	2.8%	2.9%
Moving 10-yr window minimum	4.0%	3.6%	6.3%	5.6%
Lower quartile	5.1%	4.7%	8.3%	9.2%
Geomean	4.7%	4.2%	6.9%	7.1%
Median	5.1%	4.7%	8.3%	9.2%
Upper quartile	5.4%	4.9%	10.0%	11.0%
Moving 10-yr window maximum	5.4%	5.2%	9.2%	8.8%
Maximum	6.2%	6.1%	10.6%	12.4%

recent upsurge in Black Rhino poaching, a recalculated estimate of underlying growth was made for the last 3-year reporting period 2011-2014, which made allowances for poaching mortalities in addition to international translocations. A weighted average geometric mean was used to determine an overall average underlying population growth rate over the 25 years covered. As South Africa conserves 98.7% of the assessment region's Black Rhino, the minimum, maximum and weighted geometric mean[16] underlying growths recorded for South Africa over the seven periods were applied to model growth in the region.

The best estimates of modelled future rhino numbers used in these Red List assessments were derived from modelling using the long-term 1989–2014 year geometric mean underlying growth rates. The extreme minimum and maximum values from RMG reporting periods were also applied for heuristic purposes to model a wide range of possible outcomes. However, it should be appreciated that, due to mean reversion, over longer periods (up to 10 years) the extreme minimum and maximum growth levels from single shorter 2–5-year periods are likely to under and overestimate average population growth rates that can be achieved over longer 10-year periods. Minimum and maximum weighted geomeans of the 15 moving 10-year windows across the whole period are likely to provide a better bounds when modelling over 10 years (Table 5).

10. Deciding on whether or not a population decline has occurred. While we have reasonably precise estimates of starting rhino metapopulation sizes, there is still some uncertainty around metapopulation population estimates of especially *D. b. minor (D. b. bicornis* numbers are known to within a few animals, while *D. b. michaeli* numbers are known exactly). Given that the true population size is likely to fall in a confidence interval range around a point estimate where the true population size is higher than the point estimate, the estimated number poached will represent a lower percentage of the true (higher) population size; and modelled poaching will have less of a negative impact on projected numbers. A hypothetical example (Figure 4) illustrates how in some circumstances a change in starting number of rhino can affect model outcome. The graph shows the outcomes when modelling three different starting numbers 1,000, 1,066 and 1,100 and in each case modelling a 5.0% annual underlying growth (2.5% increase every 6 months) with a constant 52 rhinos be assumed poached (mid-year) each year for 5 years. Numbers decline to 992 when starting at 1,000, stay the same when starting with 1,066 and increase to 1,109 when starting with 1,100. Under some circumstances it is possible that a higher starting population can change what otherwise is a predicted decline over 5 years into a predicted increase. This can affect the assessment because, if one concludes projected numbers have not declined, then the criteria A, B and C no longer apply. The question that needs to be assessed is what are the chances that the true population size at the start of modelling is of a magnitude that may change the conclusion (decrease in numbers over time or not?).

In most cases possible margins of error around metapopulation estimates will not pose a problem and the decline will be obvious. The scale of most modelled declines in rhino numbers over 5 years and especially over 43.5 years (three generations) will be of a far greater magnitude than any uncertainty around initial starting population estimates.

In the hypothetical example in Figure 4, any starting number below 1,066 produces a decline (allowing further assessment under Criteria C2) but any starting number from 1,066 upwards does not produce a decline. Supposing our best estimate of the starting population size from our monitoring was 1,040 with a standard deviation around this estimate of 30. This means that 90% of the time we could expect the true number of rhinos to fall within the range of 991-1,089. Running the model with our point population estimate (1,040) as the starting point would predict a slight decline six rhino to 1,034 after 5 years. However, we can see from our confidence levels that in this case there is a reasonable chance that the true number of rhinos could quite potentially be 1,066 or greater, and if so, this would not produce a decline. To apply criterion C2, one has to have concluded there has been, or in this case will be, a decline in numbers in future. For these Red List assessments, we have accepted modelled declines as real declines (and not just an

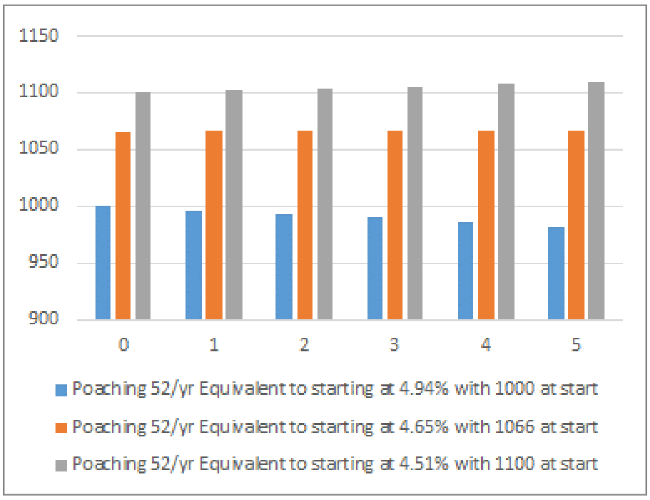

Figure 4. Hypothetical example to illustrate how in some circumstances a change in starting number of rhino can affect model outcome. The graph shows the outcome modelling three different starting numbers 1,000, 1,066 and 1,100 and in each case modelling a 5.0% annual underlying growth (2.5% increase every 6 months) with a constant 52 rhinos being assumed poached (mid-year) each year for 5 years. Numbers decline to 992 when starting at 1,000, stay the same when starting with 1,066 and increase to 1,009 when starting with 1,100.

Table 6. Starting rhino numbers and poaching levels for Year 0 (end 2015) used in the modelling (AfRSG data – Emslie et al. in prep.). 90% confidence levels around starting estimates (derived from bootstrapped estimates of numbers) are also given. *D. b. michaeli* numbers are known exactly. Species and *D. b. minor* poaching assumes an 80% detection rate in Kruger National Park (increasing starting estimated % Black Rhino poached / year from 3.38% (assuming 100% detection) to 3.92% and *D. b. minor* poached from 4.07% to 4.70%).

Starting	Black Rhino *(species)*	*D. b. minor*	*D. b. bicornis*	*D. b. michaeli*
Rhino number	1,913 (Dec 2015)	1,580 (Dec 2015)	254 (Dec 2015)	93 (Apr 2016)[19]
Bootstrapped 90% CI	1,817–1,970	1,483–1,637	249–259	93–93
Number poached	78	78	4.7	1.4
% population poached (for mean estimate)	3.92%	4.70%	1.83%	1.83%

artefact of sampling chance) if they can be deemed significant at the 90% level[17]. A bootstrapping approach was used to do this. In this case the *p* value for the critical threshold value of 1,066 under a normal distribution is 0.8069 (given a mean of 1,040 and std. dev. of 30). There is therefore an estimated 19.3% chance that the true population size in this instance could be equal to or larger than the threshold value of 1,066 needed to not generate a decline in numbers over 5 years. In this case we would deem our small modelled decline of 6 over 5 years to be not statistically significant, and a decline under criterion C2 would not be assessed further.

To test for significance of declines it was first necessary to derive distributions of possible true rhino numbers in the species and subspecies metapopulations. This was done using a bootstrapping approach[18]. From these distributions, maximum estimated metapopulation population sizes could be obtained. The population models used in these Red List assessments could then be re-run with this higher starting number. If rhino numbers are still are projected to decline one can conclude the modelled declines are likely to be significant at $p < 0.0001$ (as bootstrap sample sizes were 10,000). However, if numbers are projected to increase with a higher starting estimate, then one can find the lowest starting number where modelled numbers stop declining. The bootstrapped distribution of metapopulation numbers can then be examined to determine the appropriate percentile for this number (with the p value being 1-this percentile). If the minimum number needed to not get a decline falls at or above the 90% percentile, then the modelled decline using our best starting estimate of numbers would be deemed statistically significant (at $p < 0.1$ level).

This problem only occurred with respect to modelled declines of regional Black Rhino at a species level (over 5 years). When modelling assuming an 80% poaching detection rate in KNP the modelled declines in Black Rhino numbers over 5 years were highly significant (Table 6). However they were not significant ($p = 0.1145$) if one modelled uncorrected poaching estimates (assuming a 100% poaching detection in KNP). Given the closeness of the *p*-value to the threshold significance level being used it is likely that the detection rate in KNP would only have to be a small amount under 100% for any modelled declines of Black Rhino to be significant and hence for the species to be classed at Endangered under criterion C2a(i).

11. How to determine critical threshold levels of total rhino numbers? SADC RMG data indicated that, on average, about 55.8% of Black Rhino populations were adult (K. Adcock unpubl. data). This was used to convert specified mature individual number thresholds into equivalent total number thresholds as estimates of abundance are generally available as total numbers rather than numbers of mature individuals.

Starting data used in Black Rhino Red Listing Assessment population modelling

The starting rhino numbers, numbers poached and proportions of populations poached are shown in Table 6. As discussed above, the species and *D. b. minor* number poached estimates used in modelling assumed an 80% poaching detection rate in the KNP.

Rhino Population Modelling algorithm

- Each year in each scenario modelled, the model starts with adding half a year of population growth. Given an annual underlying growth rate of x%, half a year's growth rate was determined as ((1+x%)^0.5) -1[20]
- Poached animals were then "removed" from the modelled population in mid-year[21].
- Another half year of growth was then added to get modelled year-end rhino numbers.
- This process was repeated 10 times to estimate numbers up to 10 years in future.

If poaching were to escalate dramatically, it was assumed that the last few rhinos would be harder to find and most probably would be extremely well protected and very difficult to poach. It would be unrealistic for any model to reduce numbers to extinction over a short time period without including a poaching tapering function at low numbers to account for this. However, when modelling 5 years out this was not an issue for any of the scenarios modelled for any subspecies.

Total number of models

We used six poaching scenarios (Table 4) (two types of growth in poaching based on three historical poaching periods) and three underlying rhino population growth rates, giving 18 different scenarios for each species and subspecies, each predicting yearly rhino numbers up to 10 years into the future. The mean of the projections was used to calculate a best estimate for population reduction (IUCN Standards and Petitions Subcommittee 2014).

Graphical display of predicted rhino numbers and Red List threatened category threshold levels under Criteria A4 and C1.

- Models for each taxon assessed are shown on three different graphs **based on poaching trends over the last 5, 3 or 1 years**.

- The **red lines** show the scenarios where poaching was modelled with **arithmetic increases in absolute numbers poached / year**.
- The **blue lines** were based on modelling **exponential increases in % of population poached / year**.
- The **thicker solid** red or blue **lines** show **(best estimate) scenarios modelled using the long term geometric mean estimate of underlying growth rate**. These are the estimates used in deriving the best average estimate across all three graphs for use in the assessments.
- The **dotted lines** show **ranges based on minimum and maximum underlying growth rates recorded** in seven periods over a 24-year period. As discussed above, over longer periods they probably under and over-estimate rhino numbers.
- The **round black dots** show **average rhino numbers for all six scenarios** (for the specific time period poaching was modelled for that graph).
- The **thick triple dashed line** shows the **average of all 18 scenarios shown on all three graphs** (results averaged for all three poaching periods).
- The **star symbol** shows the **average of all six scenarios** (solid red and blue lines on the three graphs) **modelling the best long-term metapopulation underlying growth rate** and predicting **5 years into the future** (end 2020). **The star symbol represents the best estimate of numbers 5 years out used in the Red List Assessments** (*Diceros bicornis*: 1,801, *D. b. minor*: 1,350, *D. b. bicornis*: 325 and *D. b. michaeli*: 120).
- The **shaded areas at the bottom of each graph** show the **threshold levels** below which numbers have to drop to fall into any of the three threatened categories under **criterion A4**.
- The **lines with symbols at the bottom of each graph** show the **threshold levels** below which numbers have to drop to qualify under any of the threatened categories under **criterion C1**.
  - Under C1, the assessment for Critically Endangered is over one generation, Endangered over two generations and Vulnerable over three generations.
  - In the case of *D. b. bicornis* the maximum we went back for comparison was 1989 (the first year the reintroduced population had started to sustain itself).
  - In all cases modelled, the number of mature Black Rhino individuals by 2020 would have been less than 10,000 (17,920 individuals given 55.8% of Black Rhino populations on average being adult).
  - When threshold rhino numbers after specified % declines under C1 exceeded the threshold numbers of mature individuals (or their equivalent in rhino numbers) to qualify to be rated under C, the C1 thresholds in the graph were set to zero. For example, when modelling *D. b. minor* numbers 5 years into the future, and assessing if Critically Endangered, looking back over one generation a 25% decline gives 1,014 rhino. This far exceeds the minimum threshold number (448, equivalent to < 250 mature individuals) to be considered under C; and hence the Critically Endangered threshold line in this case would be set at zero.
  - Where there were sufficiently few mature animals predicted for 2020 under C1, and it was appropriate to assess status under C, positive threshold values are shown on the graph with maximum levels set at the threshold minimum number of individuals specified for assessments under C. For example, under Critically Endangered, if appropriate the maximum threshold level would be set at 448 (equivalent to 250 mature individuals) with lower threshold values possible if a 25% reduction in numbers over one generation results in fewer than 448 rhino.

Black Rhino *Diceros bicornis*: <u>Endangered C2a(i)</u>

At the end of 2015, there were an estimated 1,913 Black Rhino in South Africa and Swaziland (estimated 90% bootstrapped confidence levels of 1,817–1,970). Black Rhino numbers in the region have exceeded 1,792 individuals (~ 1,000 adults) over the last 8 years (Figure 5). The predicted number 5 years into the future (end 2020) based on averaging arithmetic and exponential poaching scenarios using the long term average underlying population growth rate was 1,801. Thus the Black Rhino in the region no longer qualifies to be rated as Vulnerable under Criterion D.

Using the best long-term estimate of underlying metapopulation growth, the arithmetic and exponential models based on last 5 year poaching trends estimated end 2020 numbers at 1,789 and 1,591 rhino, respectively (thicker solid lines) (Figure 6). The overall average estimated number at end of 2020 based on the 5 years poaching trend and the average long-term underlying growth rate was 1,690 rhino (black dotted line). After 5 years projected numbers are predicted to have not declined sufficiently to cross any of the thresholds under Criteria A4 and C1, even under the most extreme low growth and high exponential poaching scenario. The average of all six scenarios projecting forward 5 years would give a Red List categorisation under A4 and C1 of NT for all years.

Up to and including 8 years into the future all six scenarios modelled would qualify as NT. After 9 years the range is from NT to EN (under C1) and after 10 years outcomes cover the full spectrum from NT to CE (under C1). However, if one were to model a less severe but probably more reasonable longer term minimum underlying growth rate (based on minimum geomean of 15 moving 10-year moving windows in Table 4) the first 8 years would again qualify as NT, but with a range in outcomes from NT to EN for years 9 and 10.

Using the best long-term estimate of underlying metapopulation growth, the arithmetic and exponential models based on last 5 years poaching trends estimated end 2020 numbers at 1,761 and 1,640 rhino respectively (thicker red and blue solid lines). The overall average estimated number at end of 2020, based on the 5 years poaching trend and the average long-term underlying growth rate was 1,701 rhino (black dotted line). Figure 7 shows that projected numbers would not decline sufficiently over the next 5 years to cross any of the thresholds under Criteria A4 and C1, even under the most extreme low growth/high exponential poaching scenario. The average of all six scenarios would once again give a Red List rating of NT for all years.

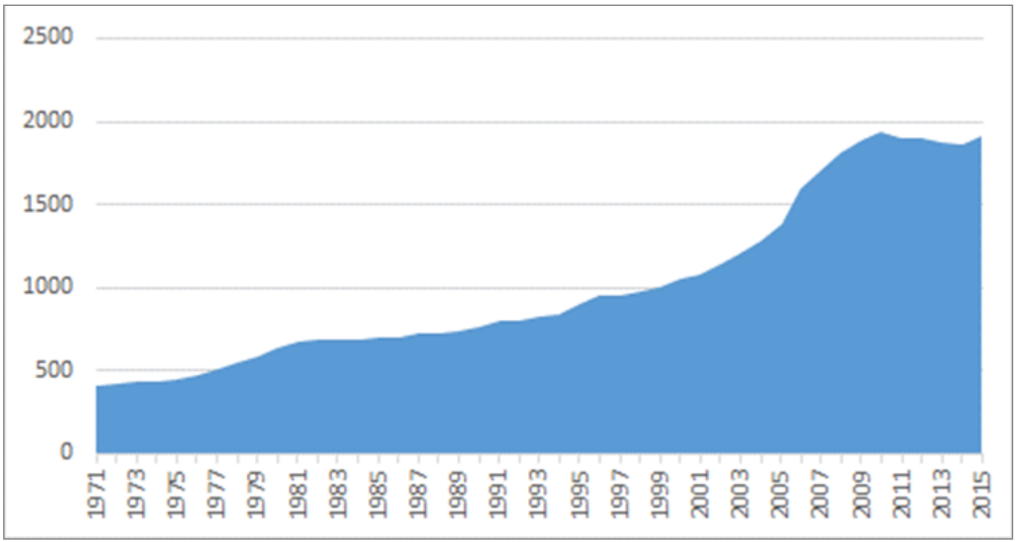

Figure 5. Estimated numbers of *D. bicornis* in South Africa and Swaziland over the last three generations

Up to and including 9 years into the future all six scenarios modelled would qualify as NT. After 10 years the range is from NT to EN (under C1) and the assessment range would be the same if modelling the less severe but probably more reasonable longer term minimum underlying growth rate (based on minimum geomean of 15 moving 10-year moving windows in Table 5).

Figure 8 shows that if the most recent (May 2014 to April 2016) poaching trends continue, then the prognosis is much better than Figures 6 and 7; with rhino numbers now projected to increase on average (black dotted line). Using the best long-term estimate of underlying metapopulation growth, the arithmetic and exponential models with 1-year poaching trends projected numbers in 2020 at 2,001 and 2,025 rhino. With the overall average projection after 5 years of 2,013 rhino, projected numbers would not decline sufficiently after 5 years and up to 10 years in the future to cross any of the thresholds under Criteria A4 and C1, even under the most extreme lowgrowth + high exponential poaching scenario.

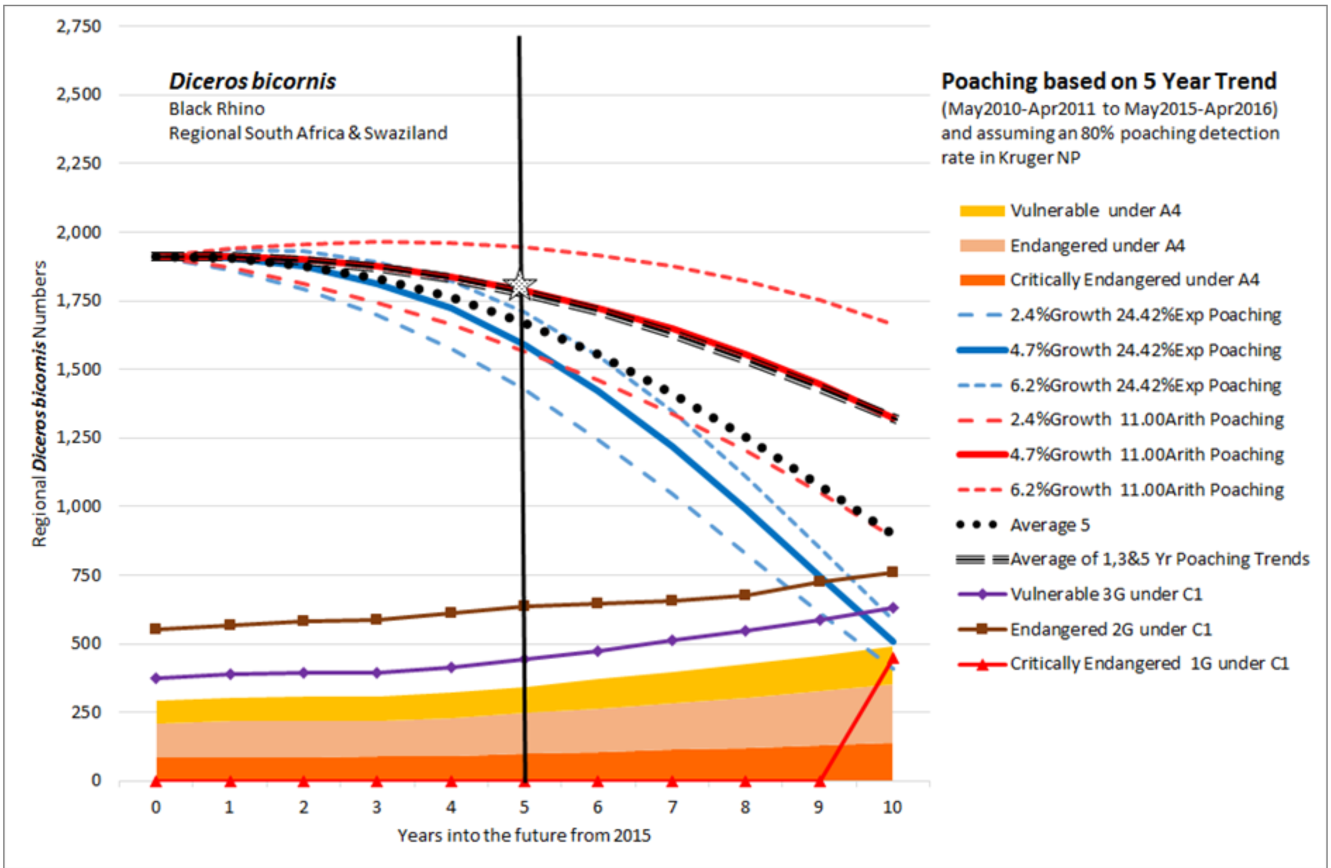

Figure 6. Modelling of total Black Rhino (*Diceros bicornis*) numbers in the region based on last five year poaching trend and assuming an 80% poaching detection rate in Kruger National Park. (See previous text on graphical display of predicted rhino numbers for an explanation of the graph).

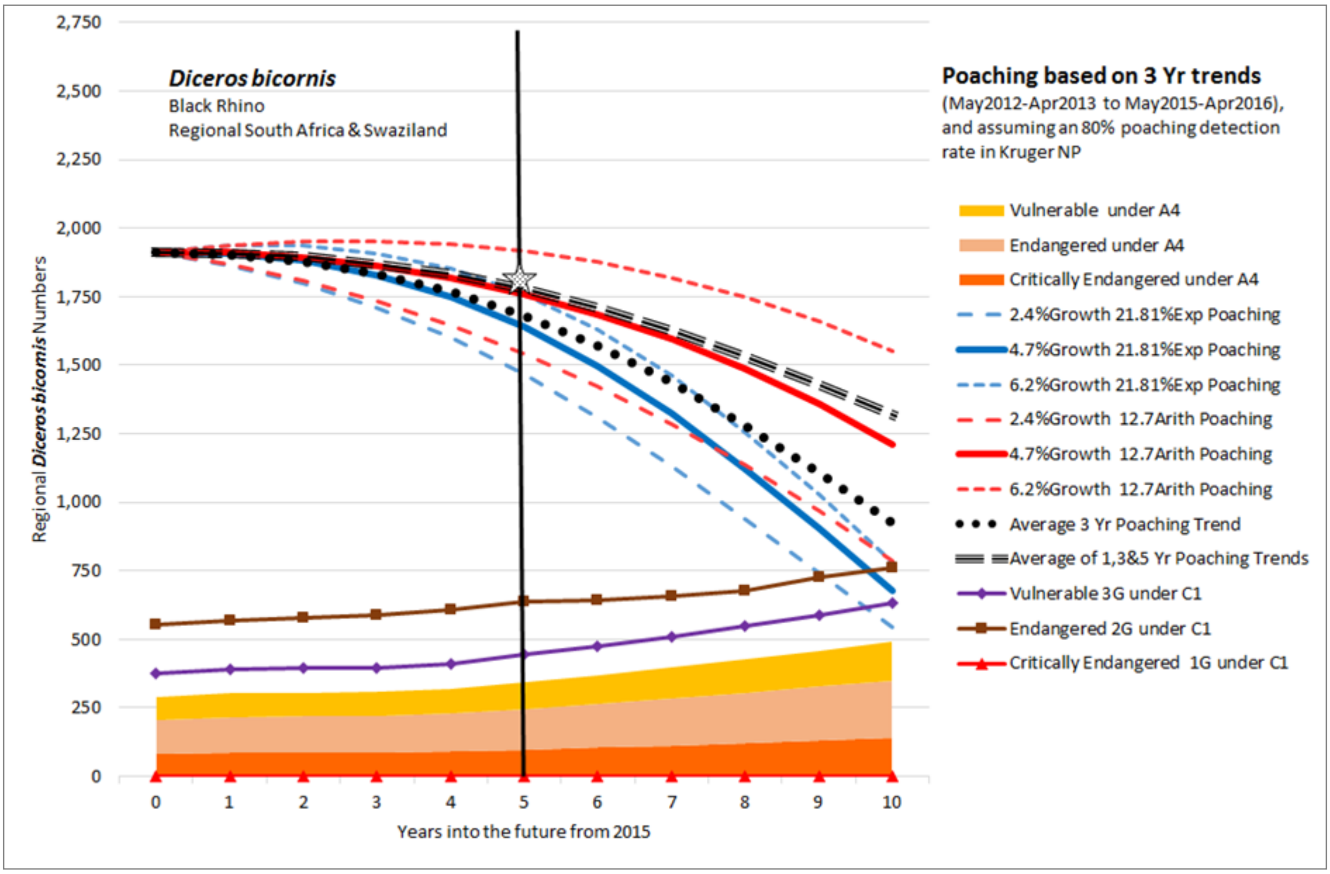

Figure 7. Modelling of total Black Rhino (*Diceros bicornis*) numbers in the region based on last three year poaching trends and assuming an 80% poaching detection rate in Kruger National Park. (See text above for an explanation of the graph).

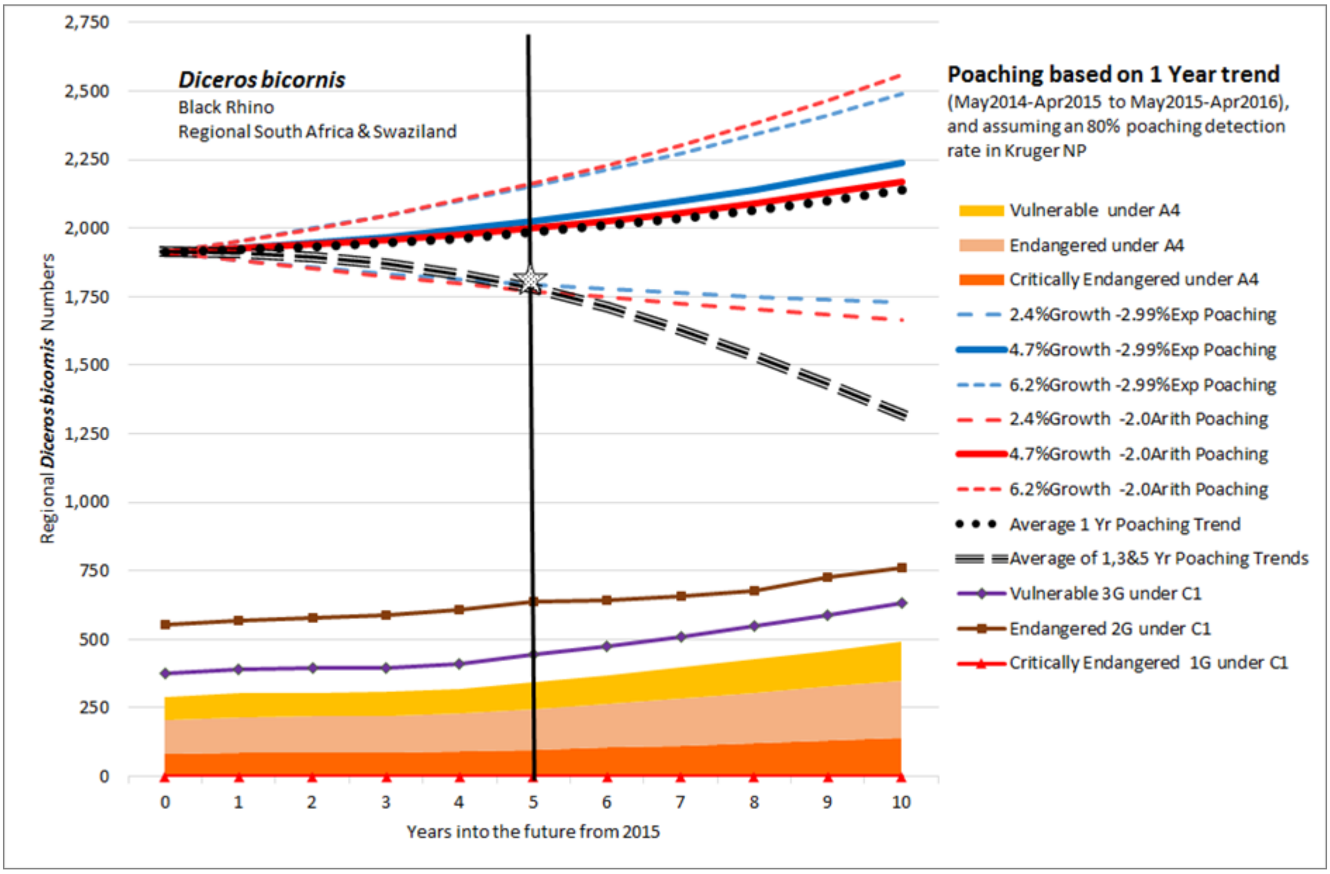

Figure 8. Modelling of total Black Rhino (*Diceros bicornis*) numbers in the region based on last one year poaching trend and assuming an 80% poaching detection rate in Kruger National Park. (See text above for an explanation of the graph).

In conclusion, for the Black Rhino in the region, the average estimated number after 5 years across all poaching scenarios modelled using best average estimate of underlying growth (1,801) predicts a 5.9% decline in numbers from current levels over the next 5 years. This scale of projected decline is not sufficient to take the species near to threshold levels to qualify under any of the threatened categories under A4 or C1. However, all populations of Black Rhino in the region currently have fewer than 448 individuals (≈ 250 mature individuals) and would therefore qualify to be rated as Endangered under C2a(i) given the projected decline in numbers. While a modelled decline based on official poaching statistics over 5 years just failed to be significant at the 90% level (p=0.1145), the modelled decline was highly significant under the precautionary assumption of 80% poaching detection for KNP used in the assessment. Thus, one only would need to miss a few poached rhino carcasses for the species to be rated Endangered under C2a(i); and therefore this seems to be the most appropriate assessment at the species level.

Southern-central Black Rhino – *D. b. minor*: <u>Endangered C2a(i)</u>

Globally, the Southern-Central Black Rhino is listed as Critically Endangered as the subspecies is estimated to have undergone a decline exceeding 80% over the past three generations with the major declines being in Zambia, Zimbabwe, Mozambique, Malawi, Botswana and Tanzania. Continentally numbers of this subspecies have declined by an estimated 58% since 1980 (5,100 to 2,164).

The subspecies (and species) was also only reintroduced to Swaziland in 1987 and within South Africa numbers of this subspecies in the region have increased over the last three generations (Figure 9) up from only 110 in 1930. The geometric mean underlying growth rate of this subspecies in the region over the 24 years up to 2014 was 4.2% ranging, over periods, from 2.0% to 6.1%. Minimum and maximum growth rates estimated from all 15 10-year moving window periods across 24 years of SADC RMG analyses showed a smaller range from 3.6% to 5.2%.

Using the best long-term estimate of underlying metapopulation growth, the arithmetic and exponential models with the last 5 year poaching trends predicted end 2020 numbers at 1,330 and 1,154 rhino, with an overall best average prediction of 1,242 rhino. After 5 years projected numbers would have not declined sufficiently to cross any of the thresholds under Criteria A4 and C1 (Figure 10).

Up to 7 years from 2015, all six scenarios modelled continue to qualify as NT. After 8 years the range is from NT to EN (under C1). After 9 and 10 years outcomes cover the full spectrum from NT to CE (under C1). If modelling using the more appropriate longer-term minimum and maximum underlying growth rates (based on minimum and maximum geomeans of 15 moving 10-year moving windows (Table 4), the results are not as extreme with the average of all six scenarios, remaining at NT for years 0–8 and becoming EN rather than CE (under C1) in years 9 and 10.

Using the best long-term estimate of underlying metapopulation growth, the arithmetic and exponential models with the last 3 year poaching trends predicted end 2020 numbers at 1,302 and 1,207 rhino, with an overall average prediction of 1,255 rhino. <u>After 5 years, projected numbers would have not declined sufficiently to cross any of the thresholds under Criteria A4 and C1 (Figure 11).</u>

Up to 7 years, all six scenarios modelled would qualify as NT. After 8 years the range is from NT to EN (under C1). After nine and 10 years, outcomes cover the full spectrum from NT to CE (under C1). If modelling using minimum and maximum geomeans of 15 moving 10-year moving windows (Table 5) the results are not as extreme when all scenarios modelled up to 8 years would qualify as NT with ranges of NT to EN after 9 years and NT to CE after 10 years. The average of all six scenarios would be NT for years 0–8 and E (under C1) for years 9 and 10.

Using the best long-term estimate of underlying metapopulation growth, the arithmetic and exponential models based on most recent year's poaching trends predict 2020 numbers at 1,540 and 1,565 rhino giving an overall average prediction of 1,553 rhino. <u>After 5 years projected numbers would not have declined sufficiently to cross any of the thresholds under Criteria A4 and C1 (Figure 12).</u>

In contrast to modelling a continuation of 3 to 5 year poaching trends, all six scenarios modelled using poaching trends over the last year would qualify as Red List ratings of NT even 10 years into the future.

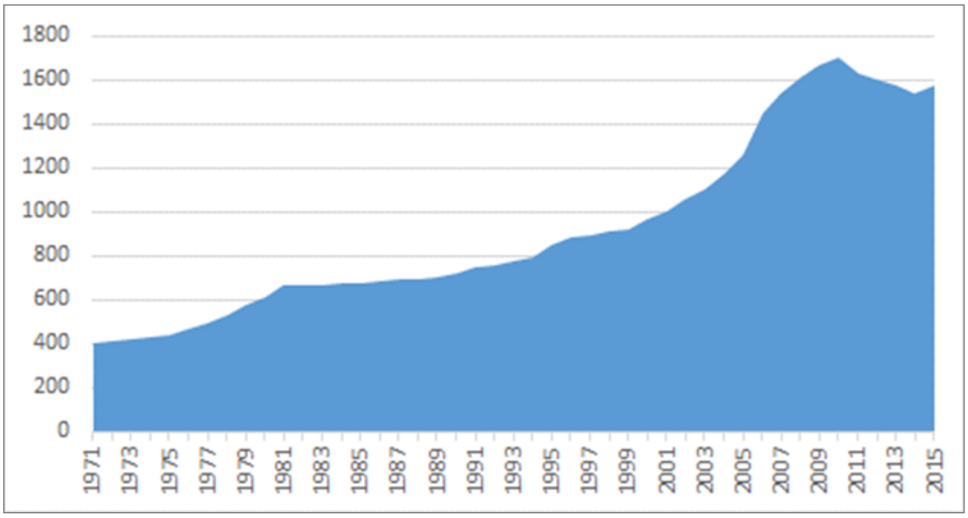

Figure 9. Estimated numbers of *D. b. minor* in South Africa and Swaziland over the last three generations. The apparent peak in 2009 is due in part to a high block count estimate that year in Kruger National Park.

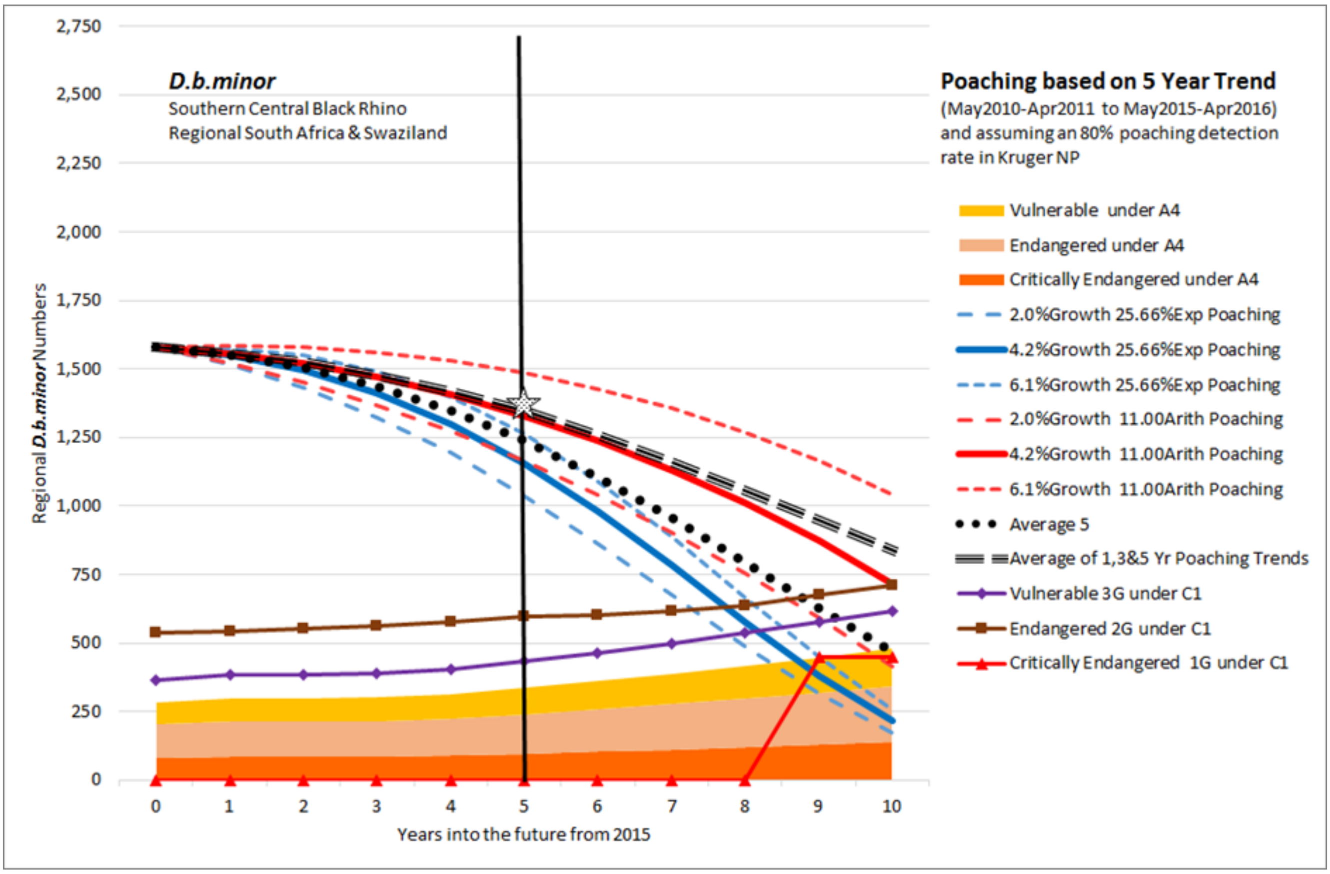

Figure 10. Modelling of *D. b. minor* numbers in the region based on last five year poaching trends and assuming an 80% poaching detection rate in Kruger National Park.

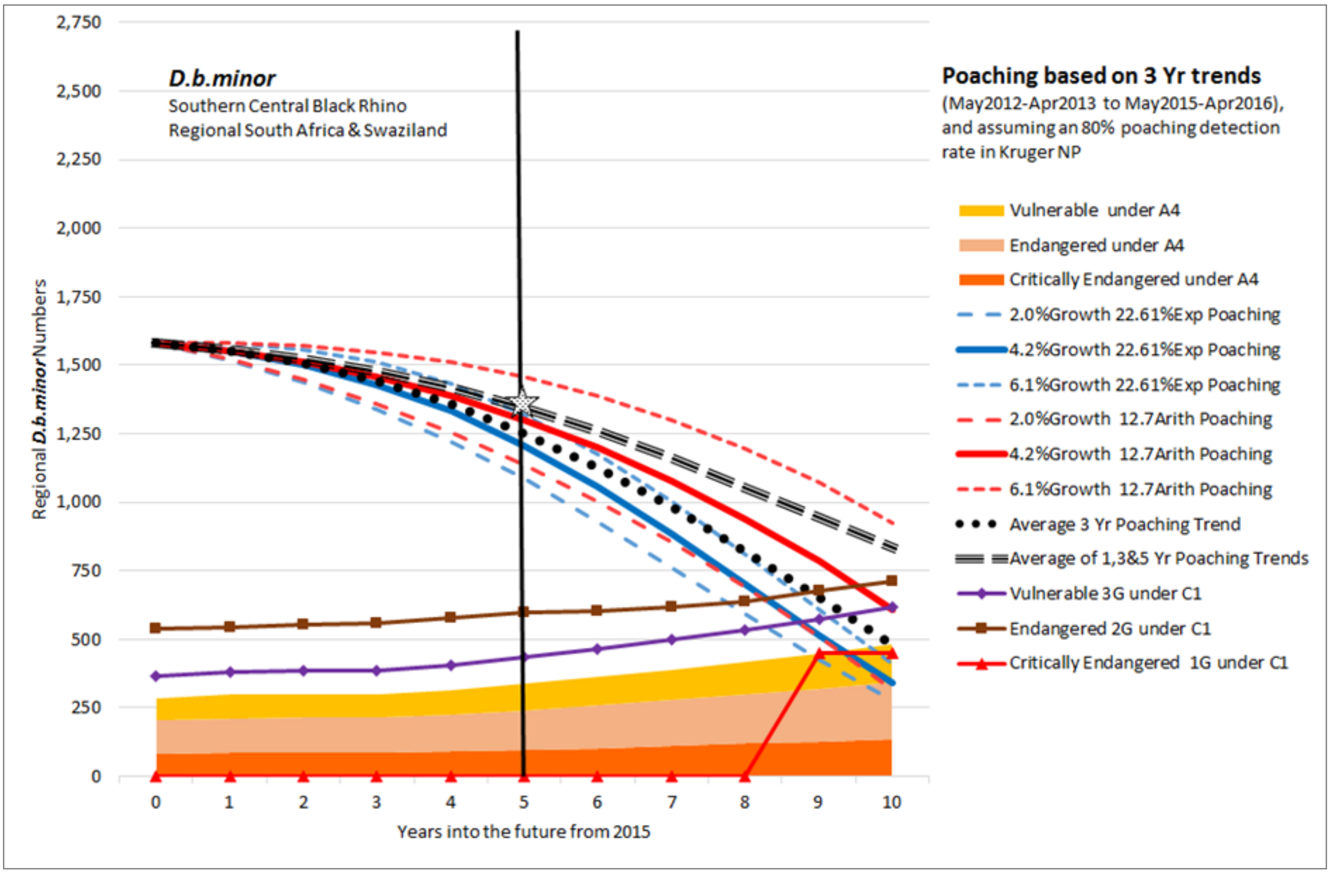

Figure 11. Modelling of *D. b. minor* numbers in the region based on last three year poaching trends and assuming an 80% poaching detection rate in Kruger National Park.

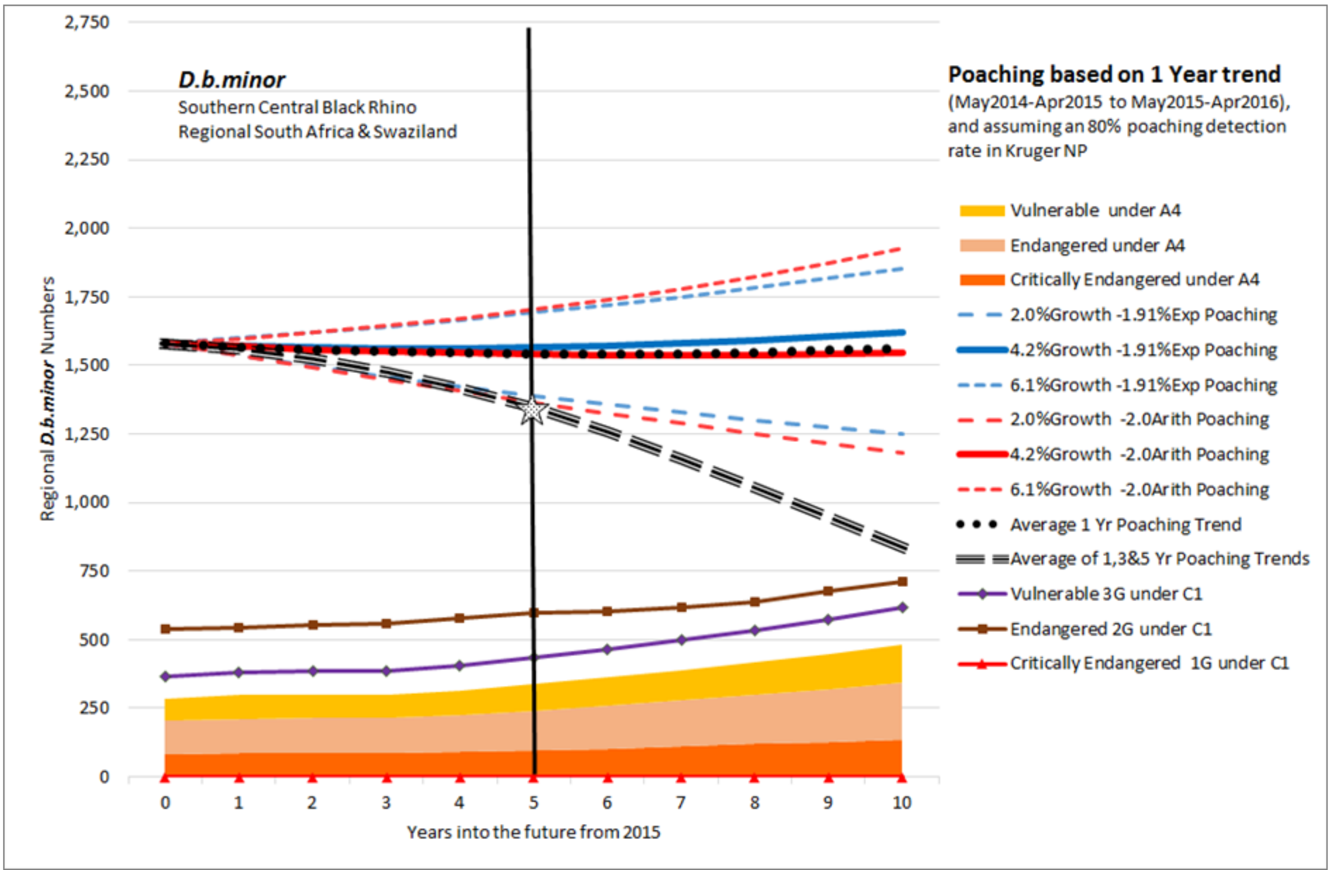

Figure 12. Modelling of *D. b. minor* numbers in the region based on poaching trends over the last one year and assuming an 80% poaching detection rate in Kruger National Park.

At the end of 2015, there were an estimated 1,580 individuals of this subspecies in the South Africa and Swaziland region. This is fewer than the 1,792 individuals required to ensure 1,000 adults. Also, the population size has not exceeded this level for more than 5 years. Therefore the Southern-central Black Rhino could qualify to be listed as Vulnerable D1 in the region. As it occurs in many more than five populations it does not qualify to be listed Vulnerable under D2.

The wide range of possible outcomes (and huge uncertainty) 10 years into the future (range 173–1,929) was 2.6 times greater than the range predicting 5 years into the future (1,037–1,704), and the 10-year possible outcome range exceeded the starting number of rhinos at the end of 2015. This supports the decision to predict only 5 years into the future for this Red List Assessment.

All populations of* D. b. minor *in the region currently have fewer than 448 individuals (≈ 250 mature individuals) and the best estimate of numbers after 5 years projects a decline that would be statistically significant. This subspecies therefore qualifies to be rated as Endangered under C2a(i) given the projected significant decline in numbers over the next 5 years. These statistically significant declines in numbers of this subspecies are projected to occur after 5 years irrespective of whether 80% or 100% of poaching is detected in KNP.

Southwestern Black Rhino – *D. b. bicornis*: <u>Endangered D</u>

Three generations ago there were no Southwestern Black Rhino in South Africa, with the subspecies having been reintroduced in 1985 with founders from Namibia. Additional founders from Namibia have since been imported from time to time subject to limited availability. This subspecies has bred very well in South Africa (Figure 13), and up to end 2014, had not suffered any poaching.

The first *D. b. bicornis* calf born and conceived in the region was in 1987. This unfortunately died (aged six) from man-induced translocation related issues. The first calf conceived and born in the region which went on to successfully have offspring of its own was born in 1989, with more successful calves following in 1991. As it was not possible to project back three generations for this subspecies, it was instead decided to project back to 1989 (the first year the reintroduced metapopulation demonstrated it could be self-sustaining when the metapopulation size was just 13 animals).

Using the best long-term estimate of underlying metapopulation growth, the arithmetic and exponential models using the last 5 years' poaching trends for the region predicted 2020 numbers at 318 and 307 rhino with an overall best average prediction of 313 rhino. After 5 years, projected numbers would not decline sufficiently under any scenario modelled to cross any of the thresholds under Criteria A4 and C1. Up to 10 years, all six scenarios modelled continue to qualify as NT under Criteria A4 and C1 (Figure 14).

Using the best long-term estimate of underlying metapopulation growth (6.9%), the arithmetic and

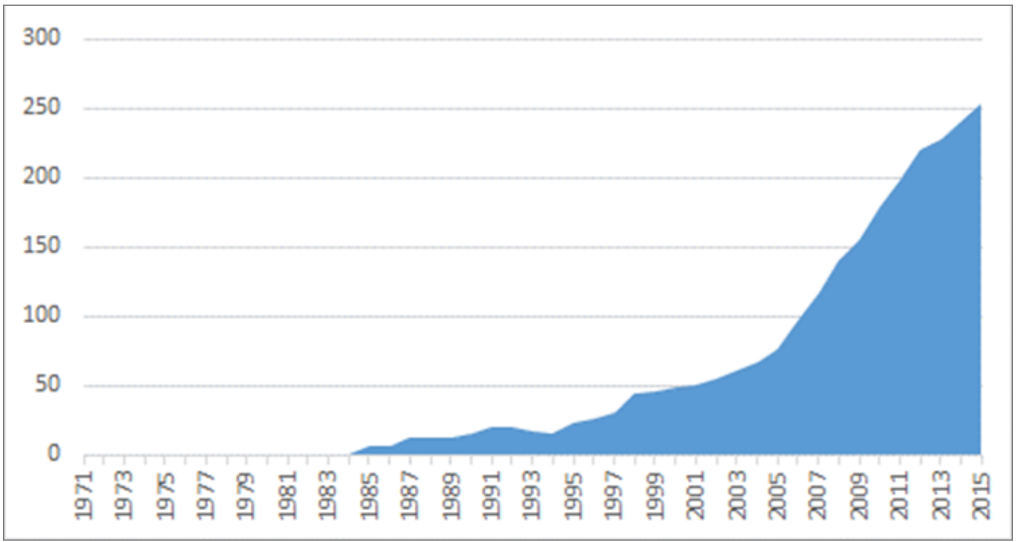

Figure 13. Numbers of *D. b. bicornis* in South Africa since reintroduction in 1985 going back three generations. The subspecies was reintroduced to the region in 1985 and demonstrated it could be self-sustaining in 2009

exponential models based on last 3 year poaching trends predicted end 2020 numbers at 323 and 318 rhino, with overall best average prediction of 321 rhino. After 5 years projected numbers would not decline sufficiently to cross any of the thresholds under Criteria A4 and C1. Up to 10 years, all six scenarios modelled continue to qualify as NT under Criteria A4 and C1 (Figure 15).

Using the best long-term estimate of underlying metapopulation growth, the arithmetic and exponential models using the last 1 year poaching trend predicted end 2020 numbers at 346 and 340 rhino with an overall best average of 343 rhino. After 5 years, projected numbers have not declined sufficiently to cross any of the thresholds under Criteria A4 and C1. Up to 10 years, all six scenarios modelled continue to qualify as NT under criteria A4 and C1 (Figure 16).

Averaging all six modelling scenarios using the best estimate of underlying growth, projected numbers at the end of 2020 were 325 rhino. This represents a 28% increase on estimated end 2015 numbers.

AfRSG data show that the area of occupancy of the Southwestern Black Rhino in South Africa was estimated at 3,819 km^2 and this exceeds the threshold level of 2,000

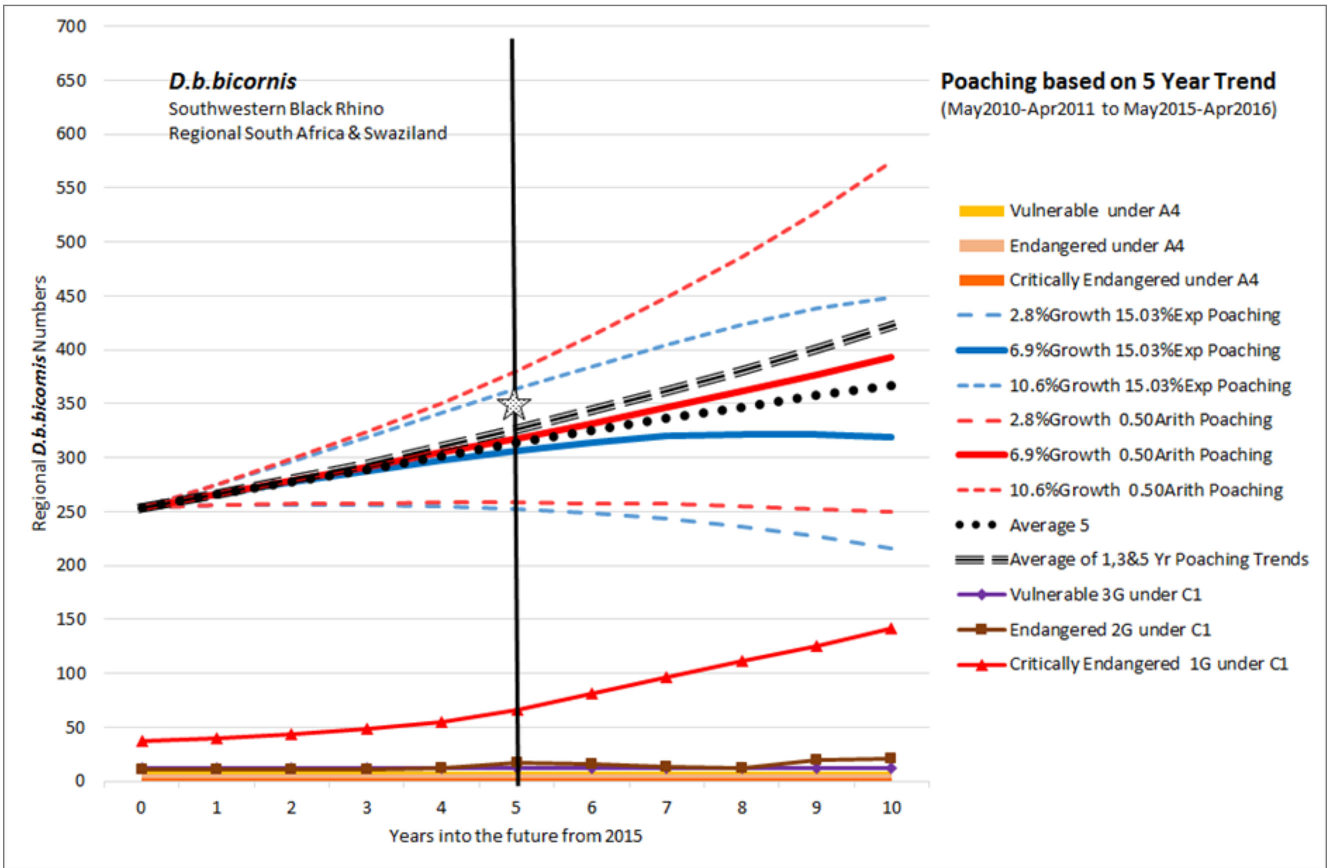

Figure 14. Modelling of *D. b. bicornis* numbers in the region based on regional poaching trends over the last five years and assuming a 100% poaching detection rate.

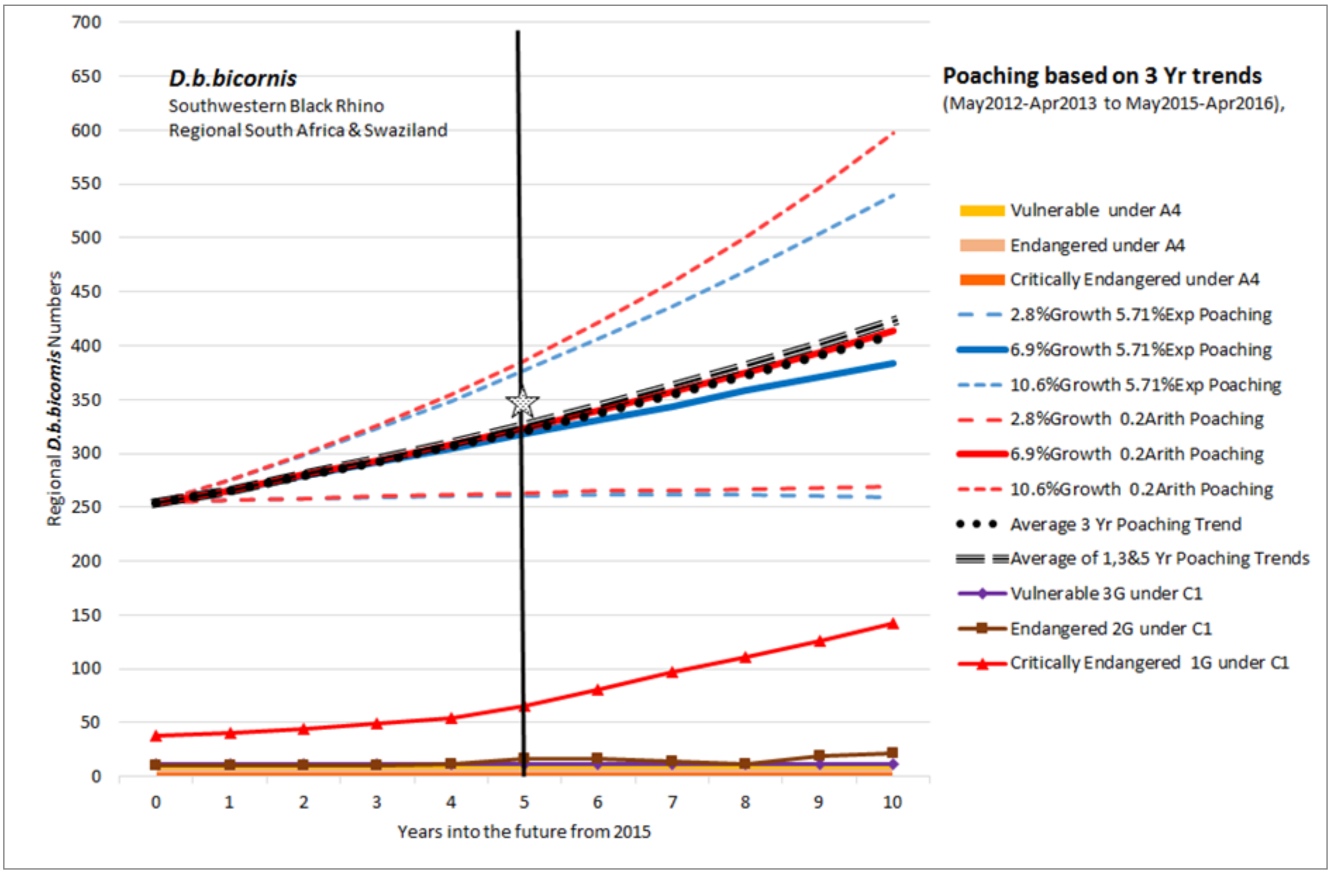

Figure 15. Modelling of *D. b. bicornis* numbers in the region based on last three regional poaching trends over the last three years and assuming a 100% poaching detection rate.

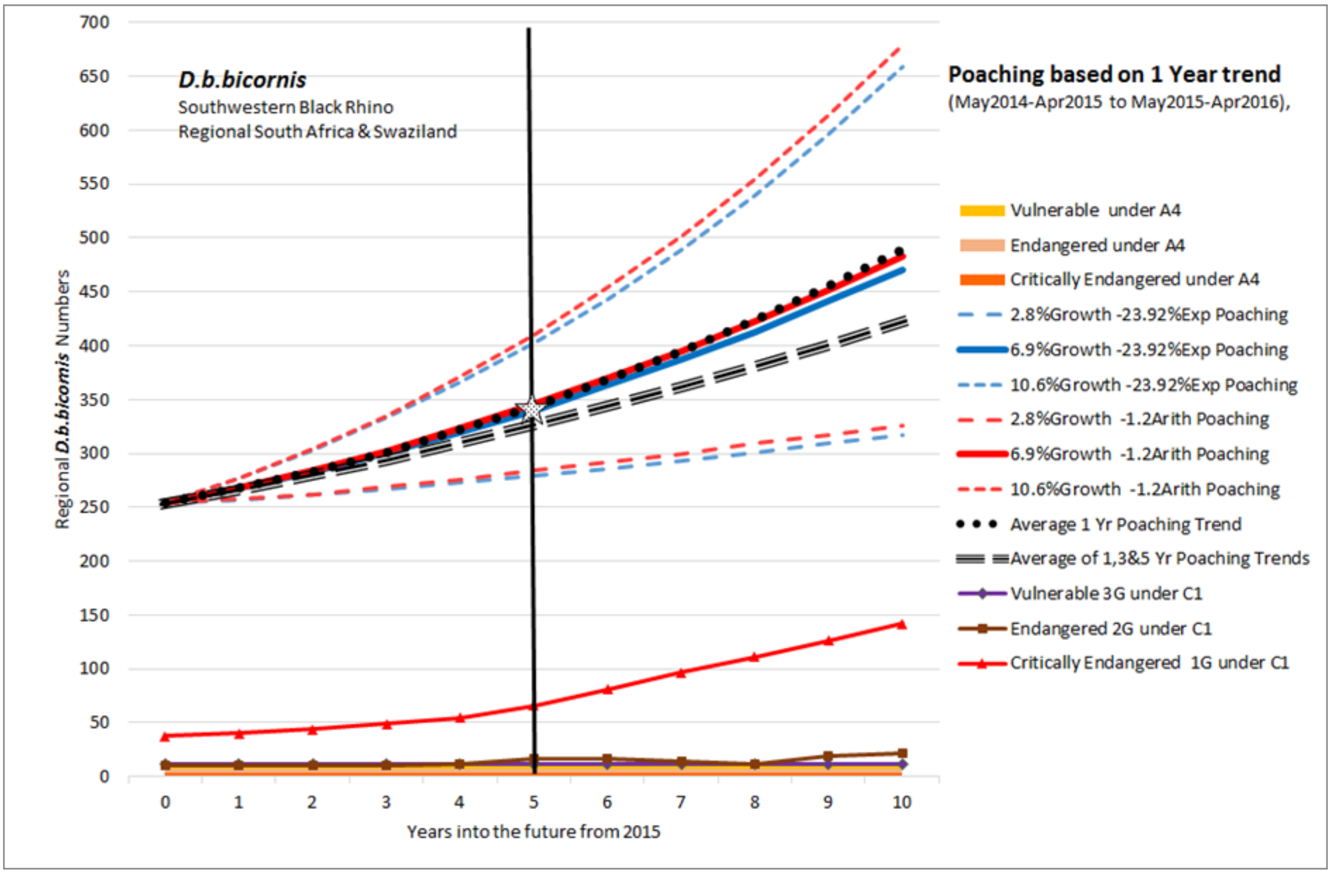

Figure 16. Modelling of *D. b. bicornis* numbers in the region based on regional poaching trends over the last one TTM year and assuming a 100% poaching detection rate.

km². Thus, the Southwestern Black Rhino regionally does not qualify under any of the threatened categories using Criterion B.

In conclusion, this subspecies doesn't qualify for any of the threatened categories under Criterion A4 or C1 or C2, because under all modelled scenarios, future numbers are projected to be significantly higher than 3 generations back from that date. At the end of 2015, there were an estimated 254 D. b. bicornis individuals in South Africa. This is fewer than 448 (<250 mature individuals) meaning the subspecies qualifies to be rated as Endangered under Criterion D.

Eastern Black Rhino – *D. b. michaeli*: Critically Endangered D

Although *D. b. michaeli* is extra-limital to the assessment region, it warrants an assessment as a benign introduction and important source population for reintroduction back into East Africa and potentially to other range states who want to reintroduce Black Rhino but whose indigenous subspecies has gone extinct (for example, Chad). This subspecies is listed globally as Critically Endangered, as numbers have declined by over 90% over the last three generations, with only 886 individuals remaining in 2015. It is the rarest of the three remaining subspecies.

Initial founders were introduced from Kenya to a South African national park in 1962 but starting in 1998 all animals were translocated over a number of years to a single population on private land. There is thus just this one privately owned subpopulation of Eastern Black Rhino in South Africa, currently numbering 93 individuals (April 2016). This subspecies has not suffered from poaching in South Africa and, as Figure 17 shows, numbers have grown steadily. The geometric mean estimated actual growth rate has been just over 7% over 1991–2014. For a number of periods growth exceeded 9% / annum. Rapid growth was achieved despite a temporary flattening off of growth for a few years during the complex transfer of this entire population from the national park to private land.

Using the best long-term estimate of underlying metapopulation growth, the arithmetic and exponential models with last 5 year poaching trends predicted end 2020 numbers at 119 and 111 rhino giving an overall best average of 115 rhino. After 5 years, projected numbers would not decline sufficiently to cross any of the thresholds under Criteria A4 and C1. Up to 10 years, all six scenarios modelled continue to qualify as NT under A4 and C1 (Figure 18).

Using the best long-term estimate of underlying metapopulation growth, the arithmetic and exponential models using the last 3-year regional poaching trends predict end 2020 numbers at 121 and 115 rhino, with an overall best average of 118 rhino. Figure 19 and Figure 20 shows that after 5 years projected numbers would not decline sufficiently to cross any of the thresholds under Criteria A4 and C1. Up to 10 years, all six scenarios modelled continue to qualify as NT under A4 and C1.

In conclusion, the average of all modelling scenarios for three generations using best estimate of underlying growth, gives projected numbers at the end of 2020 of 120 rhino. This represents a 29% increase on estimated end April 2016 numbers. AfRSG data show that the area of occupancy of* D. b. michaeli *in South Africa and Swaziland was estimated at 350 km². This is below the Endangered threshold level of 500 km² under Criterion B2. However, to qualify as Endangered under B2 also requires at least two of three conditions B2(a), (b) and (c) to be satisfied. In this case only one criterion B2(a) is satisfied (there is only a single population). This population has, to date, been increasing rapidly and there have not been extreme fluctuations in numbers so neither (b) nor (c) are satisfied. The Eastern Black Rhino regionally therefore does not qualify under any of the threatened categories using Criterion B. This subspecies does not qualify to be rated in any of the threatened categories under Criteria C1 as under all modelled scenarios up to 5 years into the future numbers are higher than one, two or three generations back. Under all scenarios modelled this subspecies does not qualify under Criterion C2 either as numbers have not, and are not projected to, decline. If they were to decline it would be due to translocation of founder rhinos outside the region, and not due to any process that would threaten future population growth.

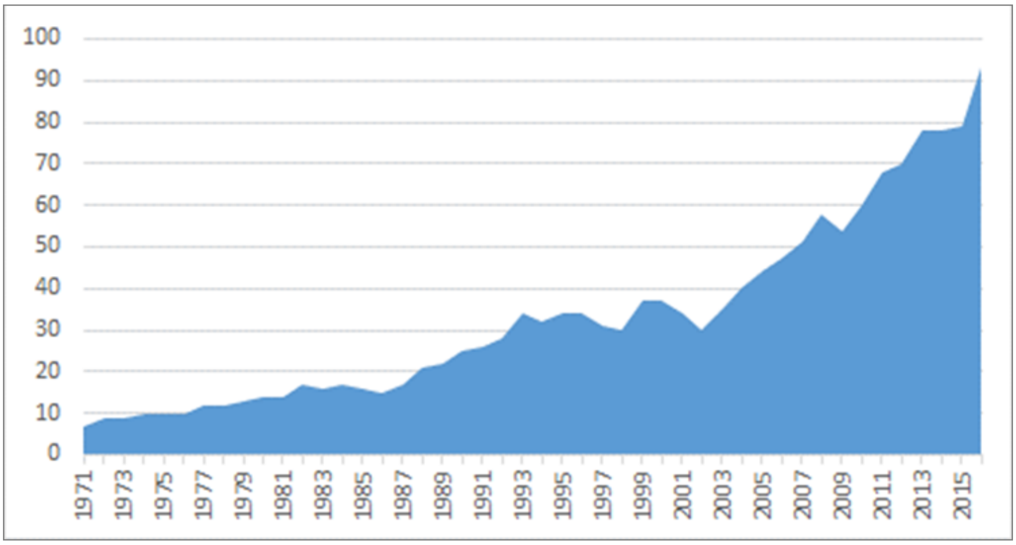

Figure 17. Numbers of *D. b. michaeli* in South Africa going back three generations from 2020. In 1980 South Africa only conserved 0.4% of this subspecies in Africa, but by the end of 2015 conserved 8.9%.

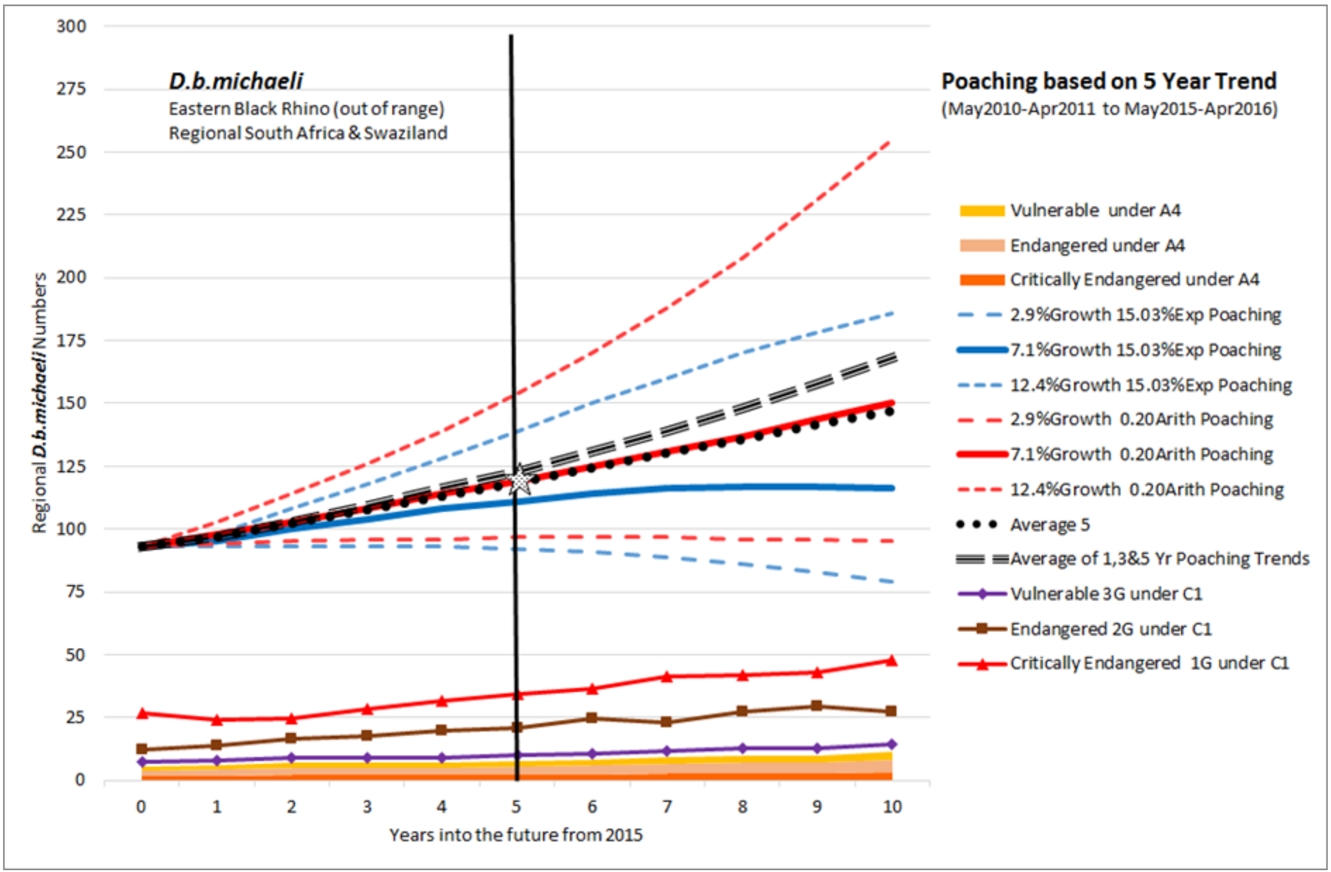

Figure 18. Modelling of *D. b. michaeli* numbers in the region based on regional poaching trends over the last five years and assuming a 100% poaching detection rate.

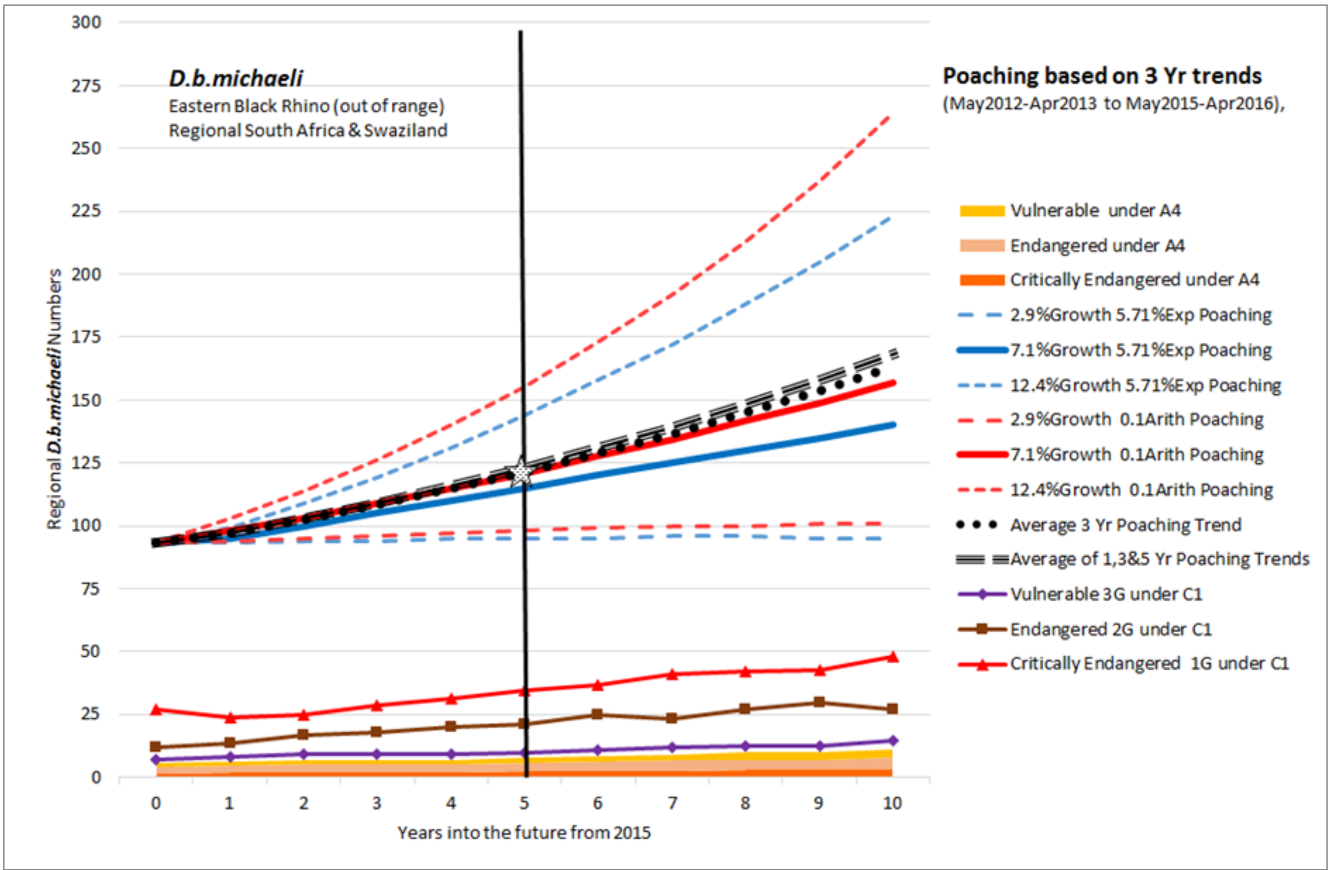

Figure 19. Modelling of *D. b. michaeli* numbers in the region based on modelling poaching trends over the last three years and assuming a 100% poaching detection rate.

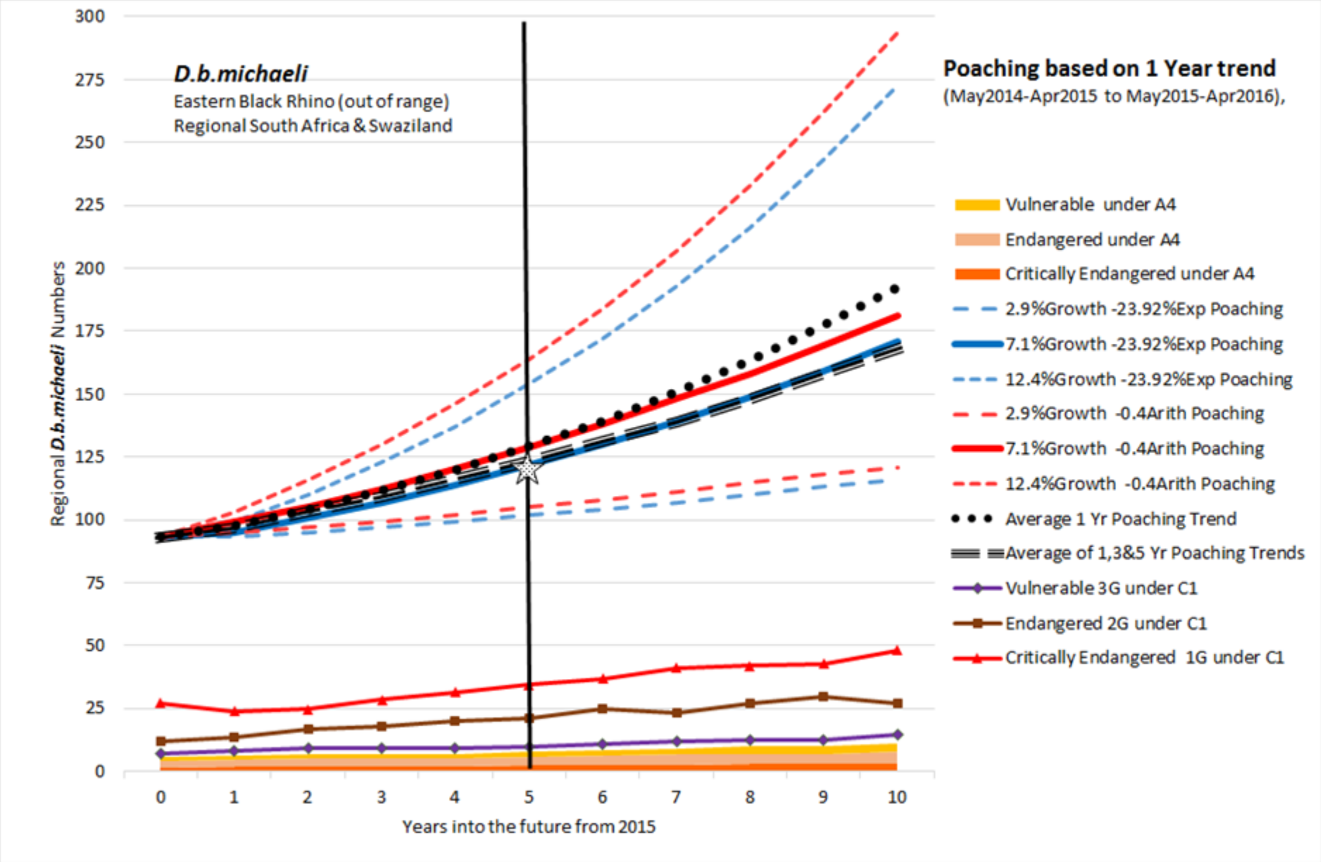

Figure 20. Modelling of *D. b. michaeli* numbers in the region based on poaching trend over the last one year, and assuming a 100% poaching detection rate.

It does, however, qualify to be listed as Critically Endangered under Criteria D. Numbers have continued to increase and very recently numbers have increased over 90 (with estimated 50 mature individuals). However, numbers have not exceeded 50 mature individuals for at least 5 years. While numbers are projected to grow over the next 5 years in the absence of removals, there is a high chance that a number of rhino may well be translocated to East Africa or Chad to create new populations there. Such translocations would be in line with the national South African Black Rhino Biodiversity Management Plan (Knight et al. 2011), which states that this single existing* D. b. michaeli *population in South Africa should ideally be repatriated to its former range and should not be allowed to expand range nationally beyond their current ownership in South Africa. Such translocations most probably will cause numbers in the region to drop back below 90. Thus* D. b. michaeli *will probably continue to qualify as Critically Endangered under criterion D.

Current population trend: Declining at species level due to declines in *D. b. minor*.

Continuing decline in mature individuals: Numbers estimated to be stable for *D. b. minor* with probable decreases in KNP due to ongoing poaching being cancelled out by increases elsewhere. Numbers of the other two subspecies have continued to increase.

Number of mature individuals in population: As of end 2015, population sizes are 93 (*D. b. michaeli*), 254 (*D. b. bicornis*), and 1,580 (*D. b. minor*) with mature individual numbers estimated at 55.8% (SADC RMG unpubl. data) of total numbers.

Number of mature individuals in largest subpopulation: As of end 2015, largest subpopulation sizes in the region are 93 (*D. b. michaeli*), 120 (*D. b. bicornis*) and 384 (*D. b. minor*) with mature individual numbers estimated at 55.8% (SADC RMG unpubl. data) of total numbers.

Number of subpopulations: As of end 2015: *D. b. michaeli* – one; *D. b. bicornis* – nine; *D. b. minor* – 54 breeding, six male only and three rehabilitation centres (SADC RMG unpubl. data).

Severely fragmented: Yes. All subpopulations exist in fenced protected areas or private/community game reserves but with translocations there is genetic interchange between many subpopulations in the metapopulation which is called for as part of species conservation plans.

Habitats and Ecology

Black Rhino occur in a wide variety of habitats from desert areas in Namibia to wetter forested areas. Highest densities are found in savannahs on nutrient-rich soils and in denser succulent valley bushveld areas. They are browsers and favour small Acacias (*Acacia* spp.; preferably <1 m and not hidden by grass) and other palatable woody species as well as palatable herbs and succulents, such as Euphorbiaceae. For example, Southern-central Black Rhino occur in the bushveld habitats of Limpopo, Mpumalanga and KZN (Zululand thornveld and lowveld bushveld). In KNP, it is a low density subspecies (Ferreira et al. 2011), preferring denser habitats (highest densities observed in the dense Sabie/ Crocodile thickets). They require sufficient availability of suitable browse plant species in the right height classes, and permanent water. Intraspecific conflict between rhino individuals may increase in areas where densities are too high (Hitchins & Anderson 1983). High levels of secondary plant chemicals in some browse species and other indigestible components in many evergreen species, means that much of the available browse in some areas can be unsuitable for Black Rhino. Failure to appreciate this has in the past led to carrying capacities being over-estimated in some areas. Apart from plant species composition and size structure, Black Rhino carrying capacity is related to rainfall, soil nutrient status, fire histories, levels of grass interference, extent of frost and densities of other large browsers (Emslie et al. 2009). To maintain rapid subpopulation growth rates and prevent potential habitat damage should rhino numbers overshoot carrying capacity, subpopulations should be managed at densities below long term ecological carrying capacity. For example, in Pilanesberg National Park, North West Province, the amount of reproductive cows successfully reproducing increased with increasing density until 0.085 individuals / km^2 after which it declined (Hrabar & du Toit 2005). Surplus individuals that are removed from such established subpopulations are routinely being invested in new areas with suitable habitat and protection where subpopulations can grow rapidly. Biological management has played a significant role in the expansion of range and numbers of Black Rhino.

Ecosystem and cultural services: Rhinoceroses are ecosystem engineers. Removing rhinos from the ecosystem may thus lead to trophic cascades (Everatt et al. 2016). They have also become a symbol of the fight to conserve natural ecosystems and curb illegal wildlife trafficking.

Use and Trade

The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), in late 2004, approved limited quotas to hunt up to five specific individual surplus Black Rhino males each year for both South Africa and Namibia, to further demographic and/or genetic metapopulation goals. Over the 11 years, 2005–2015, South Africa has hunted a total of 40 males out of a possible quota of 55 (an average of only 3.6 rhino per year which represents only 0.2% of South Africa's current total population). The very little trophy hunting that has taken place has positively impacted on the population, expanding Black Rhino range through translocation and enhancing genetic and demographic conservation whilst also generating valuable income to help fund conservation efforts.

Live Black Rhinos are also currently only openly bought and sold in South Africa. To date, South Africa has donated founder Black Rhino to Botswana, Malawi, Swaziland, Tanzania, Zambia and Zimbabwe, with possible translocations to Rwanda and Chad possible in future. A number of Black Rhinos have also been relocated to zoos across the world (largely *D. b. minor* from South Africa). Some additional founder *D. b. michaeli* and one *D. b. bicornis* have been reintroduced to the wild from zoos. While there is private ownership of Black Rhino in South Africa, in other range states, Black Rhinos on communal or private land are managed on a custodianship basis for the state. Since 2004, several new Black Rhino sites have been established on private and communal land in South Africa with a founder group of rhino from provincial reserves that are being managed on a custodianship basis, but with sharing of progeny between the provincial donor and the site owners. This sharing program is facilitated by the successful World Wide Fund for Nature (WWF) funded Black Rhino Range Expansion Project (BRREP), and has significantly

Table 7. Use and trade summary for the Black Rhinoceros (*Diceros bicornis*)

Category	Applicable?	Rationale	Proportion of total harvest	Trend
Subsistence use	No	-	-	-
Limited legal commercial use	Yes, but very limited hunting does not usually occur in formal protected areas and Black Rhino Range Expansion Programme (BRREP) custodianship sites. Private owners sell limited numbers of surplus rhino. State can sell surplus rhino but most surplus live Black Rhino currently being used as founder rhino on a custodianship basis under BRREP project.	Very limited and strictly controlled trophy hunting that must satisfy criteria to ensure this will benefit metapopulation demographic and genetic conservation. There is little live sale of Black Rhinos currently as by allocating surplus Black Rhinos from established subpopulations through the BRREP project, animals can be allocated to better, bigger areas by state conservation agencies who retain ownership of founders and share progeny.	Minority	Fairly stable. Since 2005 a maximum hunting quota of five allowed each year but for 11 years (2005–2015) only 40 Black Rhino have been hunted in South Africa. Live sales in recent years have dropped as most surplus animals are currently being provided under the BRREP custodianship scheme, where custodians get to keep every second animal born that lives to five years old.
Illegal commercial use (state and private)	Yes, primarily poaching for horn.	For eventual illegal sale in South East Asian end user markets (especially Vietnam and China).	Majority	Increasing due to rising wealth in user countries and new-use demand.
Horn harvest	Yes, but very limited numbers.	Dehorning aims to reduce kg of horn available to poachers and shift the risk: reward away from the poacher (who will get less kg for the same risk).	Minority	Limited currently, and horn cannot be sold internationally.

Table 8. Possible net effects of the private sector on Black Rhinoceros (*D. bicornis*) and subsequent management recommendations. Some private subpopulations are rated by AfRSG as *Key1* subpopulations of continental significance.

Net effect	Positive
Data quality	Generally good, although some private owners/custodians manage, monitor and protect their Black Rhino better than others. Data quality generally excellent with confidential status reporting on populations to SADC Rhino Management Group.
Rationale	Increases in rhino range and numbers, and can also generate revenue for state conservation agencies although few founder rhino are being sold currently as many are being used as founders of custodianship subpopulations. Best privately run operations can provide excellent monitoring and security. The provision of new land for rhinos by private sector and communities allows established subpopulations to remove surplus rhino to maintain breeding rates and expand area of occupancy. Translocation of surplus animals is central to maintaining underlying breeding rates in established rhino areas.
Management recommendation	Continue to encourage Black Rhino range expansion.

increased Black Rhino range and numbers. Ezemvelo KZN Wildlife, and more recently Eastern Cape, have provided founder rhino for this programme. The private sector have generally had a positive effect on this species, as it has been widely reintroduced onto private properties within its natural distribution range. Swaziland's current small Black Rhino subpopulation is managed for the country by Big Game Parks. Black Rhino are primarily threatened by illegal killing for their horns. A small number of private owners have recently removed all or some of their rhino, because the upsurge in poaching has greatly increased the costs and physical risks for rhino owners (although this problem has been more common with White Rhino).

Limited legal commercial use options (Table 7) are restricted to limited live sales and legal hunting of up to a maximum of 5 animals / year in South Africa (and Namibia) under a CITES quota that also must meet stipulated criteria to ensure this will enhance either population demography and/or genetic conservation. Black Rhino also have an ecotourism value, but given their nature and habitat they are not as easily seen (or as suitable for tourism) as White Rhino.

Threats

The current main threat facing the Black Rhino is the demand for rhino horn in parts of Southeast Asia and the increasing scale and involvement of transnational organised crime in poaching for horns to supply this demand. In recent years there has been an upsurge in black market prices for horn which has caused an increase in poaching in some range states (Thomas 2010). Before the onset of mass poaching in 2008, Black Rhinos were performing well in KNP (Ferreira et al. 2011), but are now most likely declining although this is difficult to demonstrate due to sampling error (Ferreira et al. 2015). Statistical bootstrap modelling by the AfRSG however suggests that in all likelihood numbers of Black Rhinos have decreased in KNP from 2012–15 (p = 0.0721). For many other protected areas, declining management capacity and budgets in some formal conservation agencies are reducing the ability of conservationists to effectively counteract poaching (for example Adcock 2016).

In areas where both Black and White Rhinos co-occur, White Rhinos may act as a buffer against Black Rhino poaching as the former historically are more likely to be poached on account of their preference for more open habitats (easier to find), their greater average horn weights, and their more frequent occurrence in larger groups. For example, over the period 2010–2014, available data show that only 4.4% of rhinos poached were Black, and while this proportion recently increased slightly it is unclear if this is a trend or not. No Black Rhino have been poached in Swaziland since reintroduction. However, if a greater proportion of poached Black Rhino carcasses are not being detected in the denser habitats they favour (especially in the region's largest population) the data may be underestimating poaching for these subspecies. Alternatively, small subpopulation sampling effects might be a partial cause of these differences. While recorded rhino poaching in South Africa declined from 2014–2015, the number of Black Rhino poached increased in 2015 due to an increase in KNP. Continentally, the number of Black Rhino poached has also recently increased with increasing numbers being poached in Namibia and Zimbabwe (Emslie et al. 2016). Official poaching data for the first 4 months of 2016 indicate the trend of declining overall rhino poaching in South Africa is continuing.

Corruption can reduce effectiveness of anti-poaching measures and interfere with efforts to convict conservation officials and/or implicated permit officials. Corruption is routinely a problem associated with involvement of transnational organised crime that are involved with rhino horn poaching and subsequent trafficking of illegally sourced horn (and other illegal products). Poaching is simply the first stage of horn trafficking. Corruption in the networks involved in rhino conservation (for example, game farmers, veterinarians and park rangers, as well as law enforcement officials) enhances the resilience of criminal syndicates by supplying criminals with false documentation, laundering facilities for wildlife or products, and transport and holding facilities (Ayling 2013). Corruption is similarly entrenched in the illegal ivory trade (Bennett 2015). However, research into how corruption affects conservation, and thus what interventions should be implemented, is lacking (for example, Smith & Walpole 2005). Further collation of evidence for corruption should be amassed.

Non-range state governments and NGOs are encouraged to consult with range States before making rhino related decisions in order to help ensure rhino conservation in range states will not be negatively affected by those decisions. Increasing militarisation of anti-poaching efforts in the face of an increasing and more aggressive poaching threat also poses a threat to relations with local

Table 9. Threats to the Black Rhinoceros (*Diceros bicornis*) ranked in order of severity with corresponding evidence (based on IUCN threat categories, with regional context)

Rank	Threat description	Evidence in the scientific literature	Data quality	Scale of study	Current trend
1	*5.1.1 Hunting & Collecting Terrestrial Animals*: poaching for horn.	Joint IUCN/TRAFFIC reports to CITES CoPs and AfRSG Chair reports in journal Pachyderm	Empirical	National	Increasing. Rhino poaching has been increasing since 2008.
		Ferreira et al. 2016	Empirical	Local	
2	*12.1 Other Threat*: corruption in the enforcement of anti-poaching programmes.	Bennett 2015	Indirect	Global	Ongoing, and will always be an issue given the involvement of organised crime paying very large sums for horn, and the money to be made from rhino crime.
3	*8.1.2* and *8.2.2 Invasive Non-Native/ Alien Species/Diseases*: habitat changes due to succession, alien plants and competition from other browsers. Current stresses *1.2 Ecosystem Degradation* and *2.3.2 Competition*.	Work by Emslie & Adcock and SADC RMG data	Empirical	Local	Ongoing. Habitat changes negative in some areas but positive in others (management of stocking rates and application of set percentage harvesting to maintain population productivity is the solution).
4	*12.1 Other Threat*: increased costs and risks and declining/limited economic incentives for Black Rhino range expansion.	AfRSG & SADC RMG data	Empirical	National	Increasing. Potentially a threat to future range and numbers (but more of an issue for White Rhino).
5	*12.1 Other Threat*: proposed legislation to limit farm sizes to smaller than desirable for Black Rhino in more arid areas.	-	Anecdotal	-	Unknown
6	*11.2 Droughts*: occasional severe droughts caused by climate change may cause mortality or lowered subpopulation growth rates.	Mortality data SADC RMG	Empirical	National	Ongoing but supplementary feeding can help mitigate in some areas.
7	*2.1.3 Agro-industry Farming* and *2.3.3 Agro-industry Grazing, Ranching or Farming*: historical habitat loss from agricultural expansion leading to isolated and subpopulations. Current stresses *1.3 Indirect Ecosystem Effects* and *2.3.5 Inbreeding*: fragmentation and loss of genetic diversity through inbreeding and small founder size.	Kotzé et al. 2014	Empirical	Regional	Stable and being mitigated through establishment of transfrontier conservation areas and active translocation policies.

communities. Finding ways to increasingly involve and include communities in the rhino conservation effort and associated benefits is being increasingly recognised as very important.

If future legal changes were ever made that might limit private property sizes, this may pose a threat to Black Rhino conservation (especially in arid areas) as large areas are required if one is to reintroduce at least the recommended 20+ founders and have a potential carrying capacity of at least 50 animals. Similarly, biological management for growth has been suboptimal in some subpopulations, due to reluctance of management to translocate adequate founder groups, that may limit subpopulation performance in both the target and host sites (Linklater & Hutcheson 2010).

Current habitat trend and genetic diversity: Historical habitat loss from agricultural and human settlement expansion has led to isolated protected areas and thus the potential for inbreeding amongst small rhino subpopulations in the absence of active metapopulation management. Exchange of at least one breeding animal / generation / subpopulation is recommended by the national Biodiversity Management Plan for Black Rhino (Knight et al. 2011).

Changes in habitat quality may occur in Black Rhino areas due to vegetation changes and/or increasing pressure from other competing browsers. In the country's second largest subpopulation, carrying capacities have declined due to successional vegetation changes, growth of trees into taller less preferred sizes, and increases of unpalatable species at the expense of palatable species in zones closer to permanent water due to increased numbers of competing browsing animal species. However, the application of set percentage harvesting (translocation of surplus animals) has helped improve underlying rhino breeding performance.

In general, suitable habitat exists and while carrying capacities in an area may change over time due to habitat changes, management of stocking rates of Black Rhinos and/or other competing browsers is the key to maintaining good breeding. Some well-established populations of *D. b. minor* in KZN have at times not achieved a desired 5%+ underlying growth rate. While KZN animals display lower genetic diversity than the Zimbabwean *D. b. minor* population (Kotzé et al. 2014), this is not the cause of sub-optimal performance in some well-established subpopulations. This is because when these rhinos have been translocated and reintroduced into areas of good habitat with room to grow, their breeding performance has generally been good. Additionally, as would be predicted under set percentage harvesting, biological management (increased removals in affected populations) in KZN has coincided with improved underlying reproductive performance of remaining animals in these established populations. Translocated rhinos have also bred well in their new subpopulations (a win:win for both donor and recipient populations). If set percentage harvesting is applied (as recommended in South Africa's BMP) then offtakes and numbers of rhinos should automatically adjust up or down in response to any increase or decrease in carrying capacity of the area due to positive or negative habitat changes. KNP (the region's largest) and Swaziland's only subpopulation are both founded with a combination of KZN and Zimbabwean animals and are more genetically diverse.

In addition to poaching, increasing physical risks and costs, there are limited economic incentives for those holding Black Rhino (as these are less easily seen by tourists and where only a very few are hunted and/or sold live each year). As a result of declining risk:rewards a very small number of Black Rhino owners have disinvested in Black Rhino. However to date this has primarily affected White Rhino that have suffered higher levels of poaching. If this trend continues, the rhino range and potential numbers could decline.

A low number of Black Rhino owners have removed some or all of their rhino (SADC RMG data). More new owners have, however, invested in rhino, and the Black Rhino Range Expansion Programme continues to create additional subpopulations. In recent times, there has been a net increase in area with Black Rhinos being reintroduced to additional suitable areas.

Conservation

Black Rhino have been listed on CITES Appendix I since 1977. All international commercial trade in Black Rhinos and their products have been prohibited. To help reduce illegal trade, and complement CITES international trade bans, domestic anti-trade measures and legislation were implemented in the 1990s by a number of consumer states. Since CITES CoP13, limited sport hunting quotas have been approved of up to five surplus males annually (to further genetic and demographic conservation management goals) for the two range states with biggest populations (South Africa and Namibia). Some have proposed that legal international trade in rhino horn could form part of the solution (for example, Biggs et al. 2013; Ferreira et al. 2014), such as through raising capital for reinvestment into rhino conservation. However, others point out that the market is not well understood and/or we should focus on reducing demand through social marketing, education campaigns, lobbying and inter-governmental cooperation (for example, Collins et al. 2013; Nadal & Aguayo 2014; Challender & MacMillan 2014; Olmedo 2015; Crookes & Blignaut 2015). Similarly, there is concern that the capacity to regulate a legal trade is inadequate to prevent the laundering of illegal horn and subsequent increased poaching of wild animals (for example, Taylor et al. 2014; Bennett 2015).

Effective field protection of rhino populations has been critical. Many remaining rhino are now concentrated in fenced sanctuaries, conservancies, rhino conservation areas and intensive protection zones where law enforcement effort can be concentrated at effective levels. However, enforcement alone is not a long-term solution as the scale of the economic drivers behind poaching is likely to overwhelm regulatory mechanisms (Challender & MacMillan 2014). Similarly, anti-poaching campaigns and operations alone may not reverse the poaching trend in KNP (Ferreira et al. 2015), as intensive anti-poaching programmes have at best to date slowed the escalation of poaching rates (Humphreys & Smith 2014). Dehorning of rhino is unlikely to be a viable solution on its own and has to complement anti-poaching patrols (Lindsey & Taylor 2011, Lee & Roberts 2016). Unless fines are very high they may be viewed as a minor tax on turnover of criminal syndicates (and possibly an incentive to poach). Handing down of custodial sentences is more likely to act as a deterrent.

Monitoring has also provided information to guide biological management decision-making aimed at managing the region's Black Rhino populations for rapid population growth. The SADC RMG has since 1989 collated and analysed annual status reports on each population in South Africa, Namibia and more recently Zimbabwe. The resultant information available (confidentially) to guide management is probably better than for almost any other large mammal species. This has helped inform decision-making. Surplus animals have also been translocated to set up new subpopulations both within and outside the species' former range. Following a decline in breeding performance in some areas, increased effort has recently been given to improving biological management with a view to increasing metapopulation growth rates. Reintroductions have proven to be successful (SADC RMG Black Rhino status report summaries, K. Adcock various; Law et al. 2015): positive rhino population growth rates (averaging over 4% regionally in the long term) have been demonstrated in most sites in successive Status Report Summaries from rhino populations data submitted to the SADC RMG. The number of breeding subpopulations has increased from under 20 in 1989 to over 65 in 2014.

Increasing efforts are also being made to integrate local communities into conservation efforts and associated benefits (most notably in the Kunene region of Namibia). BRREP sites include community and privately owned land. In contrast to Southern White Rhino, where individuals on private land are all owned, custodianship of a founder group is used as a way to rapidly increase Black Rhino range and numbers using private and communal land. The private and community landowners under the BRREP own every second male and female offspring once they are over 5 years old.

Management responses that facilitated range expansions have played a key role in recovering both Black (Knight et al. 2011) and White Rhinos (Knight 2013). Strategic rhino removal from focal areas that are heavily targeted by

Table 10. Conservation interventions for the Black Rhinoceros (*Diceros bicornis*) ranked in order of effectiveness with corresponding evidence (based on IUCN action categories, with regional context)

Rank	Intervention description	Evidence in the scientific literature	Data quality	Scale of evidence	Demonstrated impact	Current conservation projects
1	*2.1 Site/Area Management*: employ anti-poaching patrols and increased law enforcement.	Ferreira et al. 2015	Empirical	Local	Poaching increasing despite increased anti-poaching programmes.	SANParks, provincial agencies, private landowners, local and regional police, National Crime intelligence, National Prosecuting Authority.
		Lee & Roberts 2016	Simulation	International	Unfeasible due to high costs.	
2	*5.4 Compliance & Enforcement*: enforce penalties and prosecutions for poaching.	-	Anecdotal	-	-	SANParks, provincial agencies, private landowners, local and regional police, National Crime Intelligence, National Prosecuting Authority.
3	*3.3.1 Species Re-introduction*: continue to increase population size and occupancy through reintroduction.	SADC RMG Black rhino status report summaries (various).	Empirical	National	Positive rhino population growth rates (averaging over 4% regionally in the long term) and increased breeding subpopulations.	Black Rhino Range Expansion Project, WWF Sales of rhino among private owners to establish new sites. Provincial and National conservation agencies each have rhino conservation plans and active management for their rhino areas.
4	*4.2 Training*: train law and customs officials to process rhino crime scenes and detect contraband; train specialist prosecutors, magistrates and police.	Internal and public reports from Provincial and national conservation agencies, and NGOs like WWF and the EWT.	Indirect	National	Increased prosecution of poachers.	Skills Development Unit, Endangered Wildlife Trust
7	*6.5 Linked Enterprises & Livelihood Alternatives*: employ social marketing to reduced demand for rhino horn and instil non-monetary values.	Olmedo 2015	Review	International	Unknown. Campaigns not consistently evaluated.	Chi campaign and others in Vietnam; WWF/TRAFFIC

poachers to areas of lower risk could reduce mortality rates. For example, it may be advisable to move rhinos from poaching hotspots close to international boundaries that provide ample escape opportunities for the poachers towards areas and with easier access for management patrols and anti-poaching operations. Such removals also have the additional benefit of focusing management actions over smaller areas (Ferreira et al. 2015). Strategic rhino removals from landscapes with high densities where environmental and density-dependent population regulation may be operating (Emslie 2001; Greaver et al. 2014), can stimulate growth rates in those landscapes. This is in line with the constant harvest strategy advocated for high-density Black Rhino subpopulations (Emslie 2001; Knight et al. 2011). Such translocations could offset anticipated poaching effects through induced lower mortalities and higher birth rates because of lower local densities (Rachlow & Berger 1998). Additionally, new subpopulations can be established, as well as widening the ownership basis and hence shared interest in protection of the species (Ferreira et al. 2015). Such strategies may thus result in positive growth rates both in the source and in the recipient sites.

In addition to local and national initiatives, there are a number of regional African rhino conservation initiatives: the SADC RMG, and the SADC Rhino and Elephant Security Group (RESG)/Interpol Environmental Crime Working Group. The AfRSG is the continental coordinating body for rhino conservation in Africa. Range states recently (with AfRSG facilitation) produced a draft continental plan for African rhinos.

In the long term, however, integrated approaches, aside from the anti-poaching approach, to reduce the poaching threat are needed (Ferreira & Okita-Ouma 2012; Ferreira et al. 2014). These include:

1. Greater use of technology, especially in very large areas where it is not possible to have one field ranger per 7 to 10 km^2.

2. Disrupting international criminal networks through the use of social network analysis (Haas & Ferreira 2015). Previously, poachers were unsophisticated and informal whereas the current poaching crisis represents highly organised criminal syndicates that are resilient to disturbance (Ayling 2013), which necessitates targeting key players by law enforcers.

3. Congruent legal and extradition agreements between countries targeted by poachers and those harbouring poachers and horn dealers (Ferreira & Okita-Ouma 2012).

4. Demand reduction campaigns for illegal rhino horn (Ferreira & Okita-Ouma 2012; Litchfield 2013; Emslie et al. 2016).

5. Provision of alternative economies in communities where poaching originates (Child 2012). Here it is proposed that devolving the ownership of rhinos to private, community and state landowners and providing bottom-up markets for legal hunting and trade might provide powerful economic incentives for rhino conservation (Child 2012). This also includes ongoing biological management efforts to maximise rhino population growth, coupled with land restitution processes and co-management that support community involvement and benefit sharing from rhino conservation.

The above holistic approach is echoed by the recently released recommendations of the Committee of Inquiry established by the Department of Environmental Affairs (DEA 2016), which comprise:

1. Security, including the adoption and implementation of the National Integrated Strategy to Combat Wildlife Trafficking;

2. Community empowerment, including the development, adoption and implementation of a Community Empowerment Plan;

3. Biological management, including the adoption of an African rhino range States African Rhino Conservation Action Plan;

4. Responsive legislative provisions that are effectively implemented and enforced, including incentives to rhino owners to support continued investment in the conservation of rhino; and

5. Demand management, including information gathering to enhance our knowledge about demand for rhino horn and identifying the most effective interventions to manage demand.

Recommendations for land managers and practitioners:

- Adhere to the draft Continental African Rhino Plan and South African Black Rhino Biodiversity and Management Plan (Knight et al. 2011) and be an active contributor to SADC RMG (confidential) Annual Status Reporting.
- Submit DNA samples collected by trained collectors using RhoDIS kits to a RhoDIS-accredited lab for inclusion in the global rhino DNA database. The RhoDIS rhino DNA project allows the linking of blood and horn samples taken from suspects to known rhino carcasses for court cases, increasing chances of effective prosecution (Harper 2011).
- Conservation agencies, Investigators and police representatives to attend and participate in SADC RESG/Interpol ECWG meetings.
- Invest in monitoring and protection. SADC RMG Black Rhino status reporting has revealed that areas with poor monitoring suffer higher poaching.
- Collaborate with other rhino conservationists in both state, community and private sector and use intelligence-driven law enforcement.
- Authorities need estimates based on consistent and improved sampling techniques to define Black Rhino population trends. Although individual recognition through dedicated observation is not feasible in areas the size of KNP, registration studies in Black Rhino hotspots within KNP may complement aerial survey approaches by using tracking devices fitted to a sample of individuals to monitor subpopulation trends (Ferreira et al. 2015).
- Reintroduction sites should be selected carefully as areas ≤ 11,500 ha and release densities ≤ 9 km^2 / rhino pose an increasing risk to rhino survivorship and thus larger reserves and lower densities than these should be preferred release sites (Linklater & Swaisgood 2008).

Research priorities:

- Effectiveness of strategies to curb poaching and testing of new law enforcement and surveillance methods and equipment.
- Improved intelligence analysis including aimed at identifying and disrupting higher levels in criminal pyramids.
- RhoDIS rhino DNA work for forensic use in court and to help guide biological management.
- Consumer demand profiles.
- Finding ways to substantively get communities more involved in and sharing benefits of rhino conservation.
- Quantification of value and conservation benefits of sport hunting.
- Assessing the effectiveness and impacts of demand reduction and general education campaigns in end user markets.
- Pros and cons of alternative policy options including effects of legalising rhino horn trade.
- Ongoing SADC RMG status report analyses.
- Biological management and security assessments of suitability of potential new areas for reintroducing rhinos.
- Holding a follow-up rhino biological management workshop.

Encouraged citizen actions:

- Provision of financial support for field conservation action – but only to bona fide recognised agencies with a track record.
- Landowners should continue to provide new land to allow for continued expansion of range and numbers (but will to some extent depend upon costs, risks and economic incentives).

Data Sources and Quality

Table 11. Information and interpretation qualifiers for the Black Rhinoceros (*Diceros bicornis*) assessment

Data sources	Census (literature, unpublished), field study (literature, unpublished) – primarily SADC RMG and IUCN SSC AfRSG. From Security perspective SADC RESG/Interpol ECWG.
Data quality (max)	Observed. Most populations are well monitored (mainly using individual identification-based methods with almost every individual animal known due to regular ear-notching programs).
Data quality (min)	Estimated. The largest subpopulation is estimated with confidence levels using intensive helicopter block counting.
Uncertainty resolution	Total count, confidence intervals.
Risk tolerance	Evidentiary

References

Adcock K, editor. 1995. (Confidential) Status and management of black rhino in South Africa and Namibia 1989 to March 1994. SADC Rhino Management Group Report.

Adcock K, et al. 2010. An analysis of 18 years of SADC rhino management group population history data. SADC Rhino Management Group Report, funded by The U.S. Fish and Wildlife Service Rhino and Tiger Conservation Fund.

Adcock K, editor. 2013. (Confidential) Status and management of black rhino in Namibia, South Africa Zimbabwe, Botswana, Malawi and Zambia, January 2006 to December 2011. SADC Rhino Management Group Report.

Adcock K, editor. 2016. Status and management of black rhino in South Africa January 2012 to December 2014. SADC Rhino Management Group Report for the South African Department of Environmental Affairs.

Ayling J. 2013. What sustains wildlife crime? Rhino horn trading and the resilience of criminal networks. Journal of International Wildlife Law & Policy **16**:57–80.

Bennett EL. 2015. Legal ivory trade in a corrupt world and its impact on African elephant populations. Conservation Biology **29**:54–60.

Biggs D, Courchamp F, Martin R, Possingham HP. 2013. Legal trade of Africa's rhino horns. Science **339**:1038–1039.

Challender DWS, MacMillan DC. 2014. Poaching is more than an enforcement problem. Conservation Letters **7**:484–494.

Child B. 2012. The sustainable use approach could save South Africa's rhinos. South African Journal of Science **108**:21–25.

Collins A, Fraser G, Snowball J. 2013. Rhino poaching: supply and demand uncertain. Science **340**:1167–1167.

Crookes DJ, Blignaut JN. 2015. Debunking the myth that a legal trade will solve the rhino horn crisis: A system dynamics model for market demand. Journal for Nature Conservation **28**:11–18.

DEA. 2016, May 8. Minister Edna Molewa on the Committee of Inquiry into the feasibility of a legal trade in rhino horn, or not. Committee of Inquiry recommendations, Department of Environmental Affairs, Pretoria, South Africa.

Emslie R. 2006. Rhino population sizes and trends. Pachyderm **41**:100–105.

Emslie R, Brooks M. 1999. African Rhino. Status Survey and Conservation Action Plan. IUCN SSC African Rhino Specialist Group. IUCN, Gland, Switzerland and Cambridge, UK.

Emslie RH, Amin R, Kock R. 2009. Guidelines for the *in situ* re-introduction and translocation of African and Asian rhinoceros. IUCN, Gland, Switzerland. Available from http://www.iucn.org/dbtw-wpd/html/SSC-OP-039/cover.html.

Emslie RH, Milliken T, Talukdar B, Ellis S, Adcock K, Knight MH. 2016. African and Asian Rhinoceroses - Status, Conservation and Trade. CITES CoP17 Doc 68 Annex 5. A report from the IUCN Species Survival Commission (IUCN SSC) African and Asian Rhino Specialist Groups and TRAFFIC to the CITES Secretariat pursuant to Resolution Conf.9.14 (Rev. CoP15).

Everatt KT, Andresen L, Ripple WJ, Kerley GI. 2016. Rhino poaching may cause atypical trophic cascades. Frontiers in Ecology and the Environment **14**:65–67.

Ferreira SM, Greaver C, Knight GA, Knight MH, Smit IPJ, Pienaar D. 2015. Disruption of rhino demography by poachers may lead to population declines in Kruger National Park, South Africa. PLOS One **10**:e0127783.

Ferreira SM, Greaver CC, Knight MH. 2011. Assessing the population performance of the black rhinoceros in Kruger National Park. South African Journal of Wildlife Research **41**:192–204.

Ferreira SM, Okita-Ouma B. 2012. A proposed framework for short-, medium- and long-term responses by range and consumer States to curb poaching for African rhino horn. Pachyderm **51**:52–59.

Ferreira SM, Pfab M, Knight M. 2014. Management strategies to curb rhino poaching: alternative options using a cost-benefit approach. South African Journal of Science **110**:01–08.

Greaver C, Ferreira S, Slotow R. 2014. Density-dependent regulation of the critically endangered black rhinoceros population in Ithala Game Reserve, South Africa. Austral Ecology **39**:437–447.

Haas TC, Ferreira SM. 2015. Federated databases and actionable intelligence: using social network analysis to disrupt transnational wildlife trafficking criminal networks. Security Informatics **4**:1.

Harley EH, Baumgarten I, Cunningham J, O'Ryan C. 2005. Genetic variation and population structure in remnant populations of black rhinoceros, *Diceros bicornis*, in Africa. Molecular Ecology **14**:2981–2990.

Harper C. 2011. RhODIS–DNA profiling and a DNA database as a tool to protect the rhino. Pages 169–170 in Dean C, editor. Proceedings of the tenth meeting of the IUCN African Rhino Specialist Group. Mokala National Park, South Africa.

Hitchins PM, Anderson JL. 1983. Reproduction, population characteristics and management of the black rhinoceros *Diceros bicomis minor* in the Hluhluwe/Corridor/Umfolozi Game Reserve Complex. South African Journal of Wildlife Research **13**:78–85.

Hrabar H, du Toit JT. 2005. Dynamics of a protected black rhino (*Diceros bicornis*) population: Pilanesberg National Park, South Africa. Animal Conservation **8**:259–267.

Humphreys J, Smith MLR. 2014. The "rhinofication" of South African security. International Affairs **90**:795–818.

IUCN Standards and Petitions Subcommittee. 2014. Guidelines for using the IUCN Red List categories and Criteria. Version 11. Prepared by the IUCN Standards and Petitions Subcommittee.

Knight M. 2013. African rhino specialist group report. Pachyderm **53**:7–24.

Knight MH, Balfour D, Emslie RH. 2011. Biodiversity management plan for the black rhinoceros (*Diceros bicornis*) in South Africa: 2011-2020. Department of Environmental Affairs.

Kotzé A, Dalton DL, du Toit R, Anderson N, Moodley Y. 2014. Genetic structure of the black rhinoceros (*Diceros bicornis*) in south-eastern Africa. Conservation Genetics **15**:1479–1489.

Law PR, Fike B, Lent PC. 2015. Dynamics of an expanding black rhinoceros (*Diceros bicornis minor*) population. European Journal of Wildlife Research **61**:601–609.

Lindsey PA, Taylor A. 2011. A Study on the Dehorning of African Rhinoceroses as a Tool to Reduce the Risk of Poaching. Department of Environmental Affairs, Johannesburg, South Africa.

Linklater WL, Hutcheson IR. 2010. Black rhinoceros are slow to colonize a harvested neighbour's range. South African Journal of Wildlife Research **40**:58–63.

Linklater WL, Swaisgood RR. 2008. Reserve size, conspecific density, and translocation success for black rhinoceros. The Journal of Wildlife Management **72**:1059–1068.

Litchfield CA. 2013. Rhino poaching: apply conservation psychology. Science **340**:1168–1168.

Nadal A, Aguayo F. 2014. Leonardo's sailors: a review of the economic analysis of wildlife trade. LCSV Working Paper Series No. 6. The Leverhulme Centre for the Study of Value, University of Manchester, UK.

Olmedo A. 2015. Evaluating behaviour change interventions: A case study in Vietnam. M.Sc. Thesis. Imperial College London, London, UK.

Owen-Smith RN. 2001. Overview of the population dynamics of large mammals. Pages 9–13 in Emslie R, editor. Proceedings of a SADC Rhino Management Group (RMG) Workshop on Biological Management to meet Continental and National Black Rhino Conservation Goals. Giant's Castle, South Africa.

Rachlow JL, Berger J. 1998. Reproduction and population density: trade-offs for the conservation of rhinos *in situ*. Animal Conservation **1**:101–106.

Schulze RE. 1997. Impacts of global climate change in a hydrologically vulnerable region: challenges to South African hydrologists. Progress in Physical Geography **21**:113–136.

Smith RJ, Walpole MJ. 2005. Should conservationists pay more attention to corruption? Oryx **39**:251–256.

Taylor A, Brebner K, Coetzee R, Davies-Mostert H, Lindsey P, Shaw J, 't Sas-Rolfes M. 2014. The viability of legalising trade in rhino horn in South Africa. Department of Environmental Affairs (DEA) Pretoria, South Africa.

Assessors and Reviewers

Richard Emslie[1†*], Keryn Adcock[2†]

[1]Ecoscot Consultancy Services, [2]Wild Solutions

*†IUCN SSC African Rhino Specialist Group (AfRSG) and SADC Rhino Management Group (SADC RMG), *SADC Rhino & Elephant Security Group/Interpol Environmental Crime Working Group (SADC RESG/IECWG) and CITES Rhino Working Group*

Contributors

Mike Knight[1+,2,3], Dave Balfour[1+,3,4], Michael Hoffmann[1], Resit Akcakaya[5], Matthew F. Child[6], Craig Hilton-Taylor[1], Carlo Rondinini[1], Sam Ferreira[1+,2,3], Ben Okita[1+,7], Rob Brett[1+,8]

[1]International Union for the Conservation of Nature ([+]IUCN SSC African Rhino Specialist Group [AfRSG]), [2]South African National Parks, [3]SADC Rhino Management Group, [4]Private consultant, [5]Stony Brook University, [6]Endangered Wildlife Trust, [7]Save the Elephants, [8]Fauna & Flora International

Species Champion

Guy Ellis, X-Posé Holdings (Pty) Ltd

Details of the methods used to make this assessment can be found in *Mammal Red List 2016: Introduction and Methodology.*

Tetlock P, Gardner D. 2015. Superforecasting: The Art and Science of Prediction. Random House, London, UK.

Thomas R. 2010. Surge in rhinoceros poaching in South Africa. TRAFFIC Bulletin **23**:3.

Endnotes

1. The average proportion of rhinos poached in KNP that were Black Rhino over the previous 6 years (2010-2015) was very similar to the estimated average % of rhinos in the Park over the period that were Black (4.2% vs. 4.1% respectively). In KZN the average proportions of Black Rhinos poached and in the population were also very similar over the 6.33 years Jan 2010–April 2016 (13.2% vs 13.8% respectively). By way of contrast over the 5 years 2010–2014, a disproportionately higher number of White Rhinos were poached compared to their relative abundance. The average proportion of rhinos poached in the rest of South Africa (excluding KNP and KZN) that were Black Rhino was 5.6% despite accounting for an estimated 9.5% of the rhinos (7.8% if excluding the other two Black Rhino subspecies that were not poached in the region over the period). In part this may be due to Black Rhinos being harder to find (given their preference for thicker bush or because being browsers, and in some cases living in more arid habitats they can occur at very low densities). White Rhinos on average carry more kg of horn, are easier to find as they favour more open habitats and generally occur at higher densities, and sometimes their group sizes can also be larger. On private land there are some small populations of White Rhino in smaller areas that are also more vulnerable to hit and run poaching, and that are much less cost effective to protect / km^2.
2. Two White Rhino were poached in Swaziland in 2011 (May 2011–Apr 2012) and one in 2014 (May 2013–Apr 2014).
3. Only *D. b. minor* occurs in KNP, KZN and Swaziland, with this subspecies making up an estimated 82.4% of the Black Rhino in South Africa.
4. A breakdown was not available for the rest of South Africa outside of KNP and KZN for the 16 months Jan 2015–Apr 2016, and for KNP for the first 4 months of 2016. The numbers of Black Rhinos poached for these 16 and 4 month periods for these areas was estimated on a pro rata basis using the average % rhinos poached that were Black Rhino for Jan 2010–Dec 2014 for Rest of South Africa and for Jan 2010–Dec 2015 for KNP. While the proportion of Black Rhino to White Rhino poached in KNP was higher than usual in 2015 (5.2%), this has varied over the years without showing any obvious consistent trend up or down over time. Thus it was decided to use the longer term average 4.2% rather than most recent proportion to on a pro rata basis estimate the numbers of Black Rhino poached in the park for the first 4 months of 2016.
5. Historically KNP's reports of natural Black Rhino mortalities to the SADC RMG have been lower than would be expected based on average natural adult mortality rates suggesting a proportion of carcasses in the park is being missed (due to sheer size and lower field ranger density). However, recently with increased manpower being deployed to address poaching and a doubling of aerial helicopter capacity, Frik Roussouw (pers. comm. 2016) believes carcass detection has improved with few now being missed. He points to only a few rhino now being found many months after death. Park staff are looking at how best to determine what proportion of carcasses may be being missed.
6. Due to its vast size, less precise monitoring methods have to be used, and it is not possible to have the same field ranger density as in other smaller parks with the result that some poaching may not be detected.
7. When given the choice, all the AfRSG members canvassed supported and felt more comfortable predicting 5 years ahead rather than 10 years. The proposed Red Listing

approach was also presented to members at the February 2016 AfRSG meeting; and no one objected to the proposal to model 5 years into the future.

8. Linton Wells raised similar concerns, pointing out the great difficulty in accurately predicting 10 years into the future in a letter to the 2001 US Quadrennial Defence Review (Tetlock & Gardner 2015). Wells' letter makes a powerful case that in general humans probably greatly overestimate their ability to predict what is going to happen as far as 10 years into the future. In investing, John Price's (2011) Conscious Investor approach also uses a default 5-year period in projected rate of return calculations. Phillip Tetlock also concluded from his 20 year Expert Political Judgement research, that the accuracy of expert predictions declined toward chance 5 years out (Tetlock & Gardener 2015). In the book "*Superforecasting – The art and science of prediction*" (Tetlock & Gardener 2015). Phillip Tetlock (who has specialised in assessing the accuracy of predictions and what makes a good forecaster), writes that "*Taleb, Kanheman and I agree that there is no evidence that geopolitical or economic forecasters can predict anything like ten years out*".

9. For example, suppose there were 2,000 rhino in year one and 2,400 3 years later (in year 4). To get this 20% overall increase would require an average annual growth of 6.266% / year compounded over the 3-year period (calculated as [2,400/2,000] ^ [1/3]). In this case interpolated estimates for years 2 and 3 would be 2,125 (2,000*1.06266) and 2,258 ($2{,}000*1.06266^2$). Applying another year's growth would give 2,400.

10. Previously poaching has tended to increase later in the year but this was not the case in 2015 when poaching rates declined towards the end of the year (when they have generally increased in previous years).

11. Supposing current poaching was 4% or 1,000 of 25,000 rhinos / year. If one were to model an arithmetic increase of +100 / year over 10 years and a +25% / year exponential increase in absolute numbers the predicted number of rhinos poached in year 10 respectively would be 2,000 versus 9,313.

12. This is because eventually after rhino numbers have been significantly depleted, despite the % of the population poached / year continuing to increase, the number poached actually starts to decline slightly (in contrast to exponential increases in absolute numbers poached where numbers poached continue to escalate at probably unrealistically high levels).

13. This estimate was deemed reasonable by SANParks' Drs Mike Knight and Sam Ferreira (pers. comm. 2016)

14. Expressed as a % of the sum of the estimated numbers of rhino present at the end of each year and the number of rhinos estimated poached that year.

15. The *D. b. minor* modelling in contrast to the other two subspecies assumed that all poaching would continue to be of this subspecies.

16. Supposing an analysis period was 3 years and the calculated underlying growth for that period was 7.8% per annum then in the dataset 7.8% would be put for each of the 3 years with the same approach taken for all seven analysis periods. Geometric means, and quartile values were the obtained from this dataset giving a growth rate for each year over the period.

17. Given the trade-off between statistical Type I and Type II errors, and in order to boost the statistical power to reliably detect differences deemed of practical importance, it was decided to use a 90% rather than 95% significance level. This is also a more precautionary approach.

18. Such a distribution was modelled by bootstrapping 10,000 sample estimates based on estimates and standard deviations around these estimates. Estimates of standard deviations were derived from: 1) confidence levels around KNP estimates (assuming a normal distribution as an approximation); 2) assuming 95% confidence levels were ± 5% of current estimated total numbers of *D. b. minor* numbers outside KNP and estimated numbers in the largest *D. b. bicornis* population; and 3) assuming that numbers of *D. b. michaeli*, *D. b. minor* in Swaziland and other smaller *D. b. bicornis* populations are known exactly. Numbers were bootstrapped separately for KNP, the largest *D. bicornis* population and total *D. b. minor* numbers in the rest of South Africa and added together with known numbers from other populations to produce bootstrapped species and subspecies estimates.

19. In the case of *D. b. michaeli* an updated population estimate was available for the end of April 2016 (93) and this was used as the starting point and only two rather than 6 months of growth were modelled in the first 6-month period. Two months growth was calculated as [((1+x%) ^ (1/6))-1].

20. Thus for an annual growth rate of 5%, half a year's growth would be 2.47% (not ½ of x% or 2.5%). In this case 2.47% compounded over two 6-month periods gives a CAGR of 5%.

21. In the case of negative changes in arithmetic poaching the number modelled as poached was not allowed to drop below zero.