African Rhinos (*Ceratotherium simum* and *Diceros bicornis*, including the subspecies)

Top: Black Rhino *Diceros bicornis* (photo © Steve Garvie BY-NC-SA 2.0) and **Bottom:** White Rhino *Ceratotherium simum* (photo © Craig Hilton-Taylor)

Details of modelling used to predict future numbers when moving a three-generation window into the future under criterion A4.

There is uncertainty in predicting the future, 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) and future poaching rates which may improve or decline. Measurement error around population sizes and poaching estimates also needs to be factored into the assessment process. According to the Red List Guidelines "*uncertainty may be represented by specifying a best estimate and a range of plausible values for a particular quantity*" and by modelling a range of possible scenarios. An attempt has been made to do this. The Guidelines for Using the Red List Categories and Criteria Version 14 were consulted (IUCN Standards and Petitions Subcommittee 2014) [1].

In the interests of transparency, the modelling approaches taken (and rationale for them) are outlined below in some detail[2]. The modelling approaches taken were discussed with some IUCN SSC African Rhino Specilaist Group (AfRSG) members and several of IUCN's recognised Red List experts. The assessments have sought to follow the Red List Guidelines' advice, and adopt "*a moderate attitude, taking care to identify the most likely plausible range of values, excluding extreme or unlikely values"*.

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"). He concluded that better forecasters tended to be more granular in their thinking/modelling and invariably considered a range of alternative possibilities (Tetlock and Gardner 2015). Where possible we have tried to follow this more detailed approach to try to ensure that future predictions and hence the Red List assessments under criterion A4 are as good as they can be.

Given the increased African rhino poaching from 2008 to peak in 2015, followed by declining poaching levels since (Emslie *et al.* 2019), it was decided to model possible future changes in rhino numbers under a range of poaching and underlying biological population growth scenarios. The results of these models allow one to predict whether any taxa would cross an assessment threshold in the future under a moving three-generation window under criterion A4.

To allow assessments under criteria A2, A4, C1 and C2, several questions needed to be addressed:

1. What generation time should be used for African rhino species?
2. How many years should the three-generation 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 changes in rhino numbers with a reasonable degree of confidence.
3. What estimated numbers in the past should be used to compare against under criterion A?
4. Recorded African rhino poaching increased rapidly from 2007 to peak in 2015 (2014 for White Rhino and 2015 for Black Rhino) but has declined by a third since. How should

[1] For those unfamiliar with the IUCN Red List Categories and Criteria, Table 2.1 in these Guidelines summarises the criteria used to evaluate if a taxon belongs in a threatened category.

[2] The Red List 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".

poaching be modelled when predicting future rhino numbers using a moving window analysis under criterion A4?

   a. What kind of annual rate of increase or decrease in poaching should be modelled - exponential, arithmetic or a combination of the two?
   b. If modelling exponential increases, is it better (i.e. more realistic) to model increases in absolute numbers poached or increases in the % of the population that is poached each year?
   c. How far back in time should one look at past poaching trends when determining how to model future poaching?
   d. What is the poaching detection rate? In other words, how much might official reported poaching statistics underestimate actual losses from poaching including subsequent rhino deaths associated with poaching (such as undetected deaths of orphaned young calves that may have initially survived poaching of their mothers)?

5. What range of underlying population growth (net annual population growth in the absence of poaching) should be modelled when predicting future numbers using a moving window analysis under criterion A4?
6. What demographic model has been used to use to estimate future rhino numbers given a range of possible poaching and underlying growth rates?
7. How can one deal with uncertainty around population estimates, and especially whether or not there has been a significant decline (necessary under criteria A4, C1, and C2)? [3]
8. Red Listing requires assessments of changes in numbers of mature individuals, but African rhino abundance data available primarily are of total numbers of individuals (i.e. of all age classes). What rule of thumb should be used to convert threshold numbers of mature adult individuals into equivalent total numbers of rhino?[4]
9. Should the last remaining Northern White Rhino in the wild, and the largest private semi-wild White Rhino subpopulation be included in the assessments?

Each of these questions and approaches used is discussed in more detail below.

Generation Length used

The 2016 Regional South Africa, Lesotho and Eswatini (formerly Swaziland) Red List Mammal Assessments (Emslie and Adcock 2016 a, b) used SADC RMG data to determine the average age of Black Rhino breeding females as ~14.5 years (K. Adcock unpublished based on SADC RMG status reporting data). At the time, a three-generation window of 43.5 years was used to assess Regional changes in numbers of both African rhino species under criteria A2 and A4.

Since the Regional Assessment was undertaken, the number of calving records on the South African Development Community (SADC) Rhino Management Group (RMG) Black Rhino database has continued to increase. At the time of this current assessment, there were 2,170 rhino calving

[3] While point estimates are often referred to in these assessments, readers should not get the idea that numbers are known precisely to the nearest rhino. They are not. Bootstrapped 90% confidence levels around end 2017 continental point estimates give ranges of 17,212 to 18,915 for White Rhino and 5,366 to 5,627 for Black Rhino.

[4] Or alternatively what total rhino numbers (all age classes) are equivalent to 50, 250,1000, 2500 and10,000 mature individuals?

records[5] on the SADC RMG database where the age of the mother was known. Keryn Adcock reported that the average of this larger sample gives an updated average age of Black Rhino cows when giving birth of 14.69 years. This is marginally higher than previously estimated.

Estimated generation times from Pacifici *et al.* (2013) were a little longer at 18.8 years for White Rhino and 17.8 for Black Rhino. However, the maximum longevities used to estimate these must have been 48.3 years and 47.6 years, respectively. In the wild, it would be unusual for a wild rhino to live longer than about 42 years, and if a reproductive span of 35.25 years (using an average age of first calving of 6.75 years) was used instead; the generation length would reduce to 16.97 years. Furthermore, SADC RMG data shows that birth and survival rates of calves born to older females are lower than for younger animals. This should presumably bring the average age of cows at birth down further, and closer to the 14.69 years derived from the SADC RMG known age female birth dataset.

When approximate rhino life table parameters were input into the Red List *Generation Length Calculation* spreadsheet, the estimated generation length came out at ~20 years.
For these assessments, 1) given the large sample size of known ages of Black Rhino cows at birth available[6] (SADC RMG data); 2) to be consistent with the generation lengths used in previous assessments; and 3) because the further back one goes (i.e. if using a slightly longer generation length) the less confidence there is in estimated rhino numbers, it was decided to ***continue to estimate generation length using the empirically derived latest average ages of cows when giving birth of 14.69 years***[7]**.**

***While derived from Black Rhino data, this generation length was also used when assessing White Rhino given the similar demography of the two species*.**

Rounding this off to the nearest year gives one, two and three-generation assessment periods of 15, 29 and 44 years respectively. Thus comparing the latest population estimates from end 2017 against numbers three, two and one generations back requires comparisons against 1973, 1988 and 2002 population estimates respectively. Moving a three-generation window into the future by ***x*** years simply requires a comparison of projected future numbers with previous population estimates from 1973 + ***x*** years[8].

How far to model numbers into the future

Other IUCN SSC African Rhino Specialist Group members (Michael Knight, Keryn Adcock, Rob Brett, Ben Okita and Dave Balfour) and IUCN Red List experts (Mike Hoffman, Reşit Akçakaya, Craig Hilton-Taylor, Matthew Child and Carlo Rondinini) were consulted when developing and agreeing on a methodology for the 2016 Regional assessments. Those consulted *agreed* with the Red List Authority Coordinator's contention that it was only reasonable for the Regional Red List assessment to ***use predicted population sizes up to five years into the future (from the latest population estimate)***. ***When given a choice, all the AfRSG members canvassed, supported and felt more comfortable***

[5] Age at calving data were compiled and provided by Keryn Adcock with acknowledgements to all those who have contributed SADC RMG Black Rhino status reports since 1989.
[6] For clarity, these data are for any calf born to known-aged females, and not just their first calf.
[7] Using the updated 14.69 years instead of 14.5 years does not change the two generation period (to the nearest half year) and only increases the three generation period by ½ a year to 44 years compared with the 2016 regional re-assessment.
[8] For example when modelling numbers five years into the future (i.e. for end 2022 given that 2017 estimates are the most recent available for both African rhino species) one would compare estimated numbers in 2022 against 1978, 1993 and 2007 estimates.

predicting up to five years ahead rather than ten years. The proposed Red List approach was also presented to AfRSG members at the February 2016 AfRSG meeting; and no one at this meeting objected to the proposal only to use modelled estimates up to five years into the future for Red Listing assessments under criterion A4.

For the same reasons as the Regional Red List assessments (Emslie and Adcock 2016 a, b) the latest revised continental (global) Red List assessments only uses assessed changes in numbers up to five years into the future under criterion A4. Changes in excess of five and up to 10 years into the future were, however, calculated and have been displayed for heuristic reasons in the modelling results graphs for each taxon assessed below.

The rationale behind projecting forward only five years under criterion A4 was because...

- **Rhino population estimates are revised by IUCN SSC AfRSG every 1–3 years. It thus will be possible to keep a watching brief on the situation and to regularly re-assess the Red List status of African rhino at frequent intervals in future.** An analysis and results graphic production spreadsheet and new consolidated AfRSG historical African rhino numbers database have been developed by the African Rhino Red List Authority Coordinator. These should facilitate regular Red List revisions going forward whenever updated poaching and numbers data are compiled by AfRSG.
- **History has shown that there can be marked negative or positive changes in poaching and rhino numbers over short time periods[9].** Future modelling needs to be responsive to any recent changes in trends, and this can be achieved by regularly revising the assessments every time continental poaching statistics are updated by the AfRSG going forward.
- The variable trends in poaching levels over time create a wide range of possible outcomes and **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 five-year period is also suggested for other predictive fields where little confidence can often be placed in predictions as far as ten years out.**
    - Phillip Tetlock concluded from his 20-year Expert Political Judgement research that the accuracy of expert predictions declined toward chance five years out (Tetlock and Gardener 2015). In the book "*Superforecasting – The art and science of prediction*" (Tetlock and Gardener 2015) Phillip Tetlock (who has specialised in assessing the accuracy of non-trivial predictions and what makes a good forecaster) wrote that "*Taleb, Kahneman and I agree that there is no evidence that geopolitical or economic forecasters can predict anything like ten years out*".
    - Linton Wells raised concerns, pointing out the great difficulty in accurately predicting ten years into the future in a letter to the 2001 US Quadrennial Defence Review[1] (Tetlock and 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 ten years into the future.
    - In investing, John Price's (2011) also uses a default five-year period for projected rate of return calculations.

[9] For example, while African rhino poaching increased from 2007 to 2015, by 2018 poaching had declined by a third and reported poaching in the first half of 2019 for the major Range State (South Africa) suggests the recent declining poaching trend is continuing.

    - Transnational organised crime is behind the poaching, and these syndicates are effectively illegal businesses. Just as other legal businesses cannot be expected to exponentially increase earnings by 30–50% / year for long periods, it is also probably not reasonable to model a very high exponential increase in poaching for more than about five years.
- There is also a need to consider messaging (Sam Ferreira personal communication). Continual negative messages that rhinos are getting rarer may have the unintended consequence of increasing demand for illegally-sourced horn and hence black-market prices. Consumers and any speculative buyers might then be further incentivised to secure horn if they perceive it will get rarer and go up in price in future. The rarer rhino horn is perceived, potentially the higher the status of luxury goods made from (it in the eyes of current buyers). If this were to boost demand for illegal horn, poaching pressure would probably increase[10], thus making the situation worse. For the good of the rhinos, a balance, therefore, needs to be struck between being overly evidentiary and over precautionary; and to try to honestly assess a species' prospects, without being overly negative or optimistic. It is therefore probably better to estimate a range of possible outcomes with greater confidence over a shorter-term and update these at frequent intervals, rather than speculating over a longer-term.

<u>**While these African rhino Red List assessments only move the three-generation assessment window under criterion A4 up to five years into the future; for purely heuristic purposes, possible outcomes up to 10 years into the future have been modelled and are shown for the scenarios modelled in results graphs below**</u>. Readers can then see a full range of possible outcomes that might occur further into the future under different scenarios; as well as the possible range within which the Red List assessments might perhaps fall in future should modelled trends continue. After ten years, it would be necessary to redo Red List assessments. For the reasons given one can have little confidence predicting as far as this into the future.

Population estimates used for assessing changes over one, two and three generations

Many rhino subpopulations are monitored using individual identification (ID) methods, and numbers are known exactly, or to within a few rhinos. Where ID monitoring is less intensive, some individual rhinos may go unseen for some time, while others may also not have easily identifiable ID features. Population estimates based on such data have much wider confidence levels. However, in the largest subpopulations in very large areas (where ID-based monitoring of so many animals over such large areas is not usually feasible) other methods have been used to estimate numbers (such as intensive helicopter block counts and distance-sampling line-transect surveys). Strip or total aerial counts have also been used to estimate numbers in some subpopulations.

For many species, measurement error *"is often the largest source of uncertainty"* (IUCN Standards and Petitions Subcommittee 2014). Fortunately, this is less of a problem for African rhino than many other mammals. While there is still a range of uncertainty around point estimates of rhino numbers, overall, numbers of White and Black Rhino are known more precisely than for many other large

[10] It was estimated that around 95% of the rhino horn sourced for illegal markets in 2016 and 2017 was from rhino poached for their horn (Emslie *et al*. 2019).

mammal species. Bootstrapped estimates of 90% confidence levels around continental point estimates for end 2017 (based on actual calculated confidence levels or best estimates of likely estimate precision for each population) ranged from 5,366 to 5,627 for Black Rhino and from 17,212–18,915 for White Rhino**.**

Just as one does not need an accurate weight to know if someone is significantly overweight; it is usually very clear whether or not a taxon qualifies to be listed in a threatened category or not under criteria A2 and A4[11].

The AfRSG with the assistance of Range States has routinely compiled Black and White Rhino estimates by population every one to three years since 1992 (in 1992, 1993, 1995, 1997, 1999, 2001, 2003, 2005, 2007, 2010, 2012, 2015 and 2017). While complete 2018 estimates have been compiled for Black Rhino, at the time of assessment complete 2018 White Rhino population estimates were not available due to incomplete reporting of numbers in three provinces in South Africa (the Range State with the largest population). A breakdown of poaching by subspecies is also still awaited for South Africa for 2018. For this reason, this assessment has used the compiled estimates of numbers as of the end of 2017 and reported poaching by subspecies. AfRSG continental totals do not include "*Speculative Guesstimates*" where there is insufficient evidence or where estimates are older than five years.

The SADC Rhino Management Group has had a system of annual status reporting for Black Rhino populations since 1989. This has allowed annual Black Rhino estimates (and much other detailed demographic data) to be compiled for every year going back to 1989 for many Black Rhino populations in Southern Africa. In addition to providing more frequently updated population estimates, these SADC RMG data allowed the Black Rhino generation time and the average proportion of adults in the population to be empirically estimated.

Eleven surveys of the status of White Rhino on private land in the major Range State South Africa from 1987 to 2017 (Buijs (1988), Emslie (1994), Buijs amd Papenfus (1996), Buijs (1998) Buijs (2000), Hall-Martin and Castley (2001), Castley and Hall-Martin (2004), Hall-Martin *et al.* (2009), Shaw *et al.* (2017), Balfour *et al.* (2015, 2018) have also contributed to the compilation of South Africa's White Rhino estimates over the years. Estimating numbers of White Rhino in South Africa has proved to be challenging over the years, and the AfRSG Scientific Officer/African Rhino Red List Authority Coordinator has worked closely with South Africa's official country representative on the AfRSG to do this as best as possible over the years.

[11] In the event that point estimates are ever close to threshold levels, bootstrapping could be used to determine whether numbers of a taxon are significantly greater or lower than a specified threshold population size.

Table 1. Estimated numbers of White and Black Rhino by species and subspecies/genetic management cluster and by country as of the end of 2017, with marginally revised continental totals for end of 2012 and 2015. (From Emslie *et al*. 2019 and based on AfRSG data in collaboration with Range States). Country trends are over the five-year period 2012–2017. These estimates are unrounded point estimates. Readers should not mistakenly interpret these figures as indicating a precision that is not there. Bootstrapped 90% confidence levels around 2017 continental species totals gave an estimated range of numbers from 17,212 to 18,915 White Rhino and 5,366 to 5,627 Black Rhino (Emslie *et al*. 2019).

Species	White rhino (WR) *Ceratotherium simum*				Black rhino (BR) *Diceros bicornis*					Total
Subspecies/ Management Cluster	*C.s.cottoni (Northern)*	*C.s.simum (Southern)*	TotalWR	Trend	*D.b.bicornis (South-western)*	*D.b.michaeli (Eastern)*	*D.b.minor (South-eastern)*	TotalBR	Trend	*Both species*
Botswana		452	452	*Up*			50	50	*Up*	502
*(Côte d'Ivoire) ** *		1	1							1
Kenya	3	510	513	*Up*		745		745	*Up*	1,258
Malawi							28	28	*Up*	28
Mozambique		29	29				1	1		30
Namibia		975	975	*Up*	1,857			1,857	*Up*	2,832
Rwanda						19		19	*Up (New)*	19
*(Senegal)** *		3	3							3
South Africa		15,625	15,625	*Down*	331	83	1,632	2,046	*Up*	17,671
eSwatini		66	66	*Down*			21	21	*Up*	87
Tanzania						155	5	160	*Up*	160
Uganda		22	22	*Up*						22
Zambia		14	14	*Up*			48	48	*Up*	62
Zimbabwe		367	367	*Up*			520	520	*Up*	887
End 2017 total	**3**	***18,064***	***18,067***	*Down*	***2,188***	***1,002***	***2,305***	***5,495***	*Up*	***23,562***
End 2015 total*	3	*20,053*	*20,056*	*Down*	*2,212*	*887*	*2,115*	*5,214*	*Up*	*25,270*
End 2012 total*	4	*21,316*	*21,320*	*20,165 in 2010*	*1,968*	*799*	*2,078*	*4,845*	*4,880 in 2010*	*26,165*

African rhino population estimates become less reliable and less regular the further back in time one goes.

Prior to the formation of IUCN SSC's African Rhino Specialist Group (AfRSG), its predecessor the African Elephant and Rhino Specialist Group compiled continental estimates for each country for 1980, 1984 and 1987 (Hillman (1980; 1981a, b), Western and Vigne (1985a, b, c) and Cumming *et al.* (1990).

Estimates of numbers were hardest to compile for the 1970s.

There may still have been as many as 100,000 Black Rhinos in Africa in 1960, but by 1970 these had been reduced by poaching to an estimated 65,000 Black Rhinos; with an estimated 16,000 to 20,000 in Kenya at that time (Martin and Martin 1982). Attempts to find out the details of how these earlier continental estimates had been produced were unfortunately unsuccessful.

A historical numbers database was created to compile annual point estimates of numbers by subspecies by country by year since 1973 to allow comparisons up to three generations back from end 2017. This new historical African rhino numbers database will also facilitate regular Red Listing revisions in the future.

One of the reasons for developing a historical database of African rhino estimated numbers up to three generations back was because there initially appeared to be a significant difference between that the sum of estimated Black Rhino numbers from the early to mid-1970s compared to the oft-quoted approximate 1970 continental estimate of 65,000. However, modelling of a consistent % net decline in numbers per annum over the 1970s produced annual estimates for the early to mid-1970s that were similar, and only a little higher compared with those compiled for the new historical database[12].

Numerous data sources were used to try to come up with the best possible estimates for the period 1973–1979. Klingel's (1979) survey of African rhinos provided estimates for many subpopulations across Africa in the late 1970s. Martin (1994), Joubert (1969, 1971, 1984), Loutit (1980), Owen-Smith (1984) provided useful historical estimates for individual populations in Namibia. Sources of useful historical Tanzania estimates included Borner (1981) and Heyworth *et al*. (1993). Some older Kenyan estimates were found in Hillman and Martin (1979a, b). Martin and Martin (1982), Western (1982). Some historical estimates of Zambian rhino numbers were recorded by Chomba and Matakdiko (2011). Kees Rookmaaker's online Rhino Resource Centre literature database was a particularly useful source of additional references containing historical population estimates. Emslie and Brooks (1999) also provided some additional historical estimates. National Rhino Plans were also sometimes a useful source of additional data.

Point estimates of rhino numbers for "missing" years between available population estimates were interpolated by applying appropriate average annual exponential rates of population increase/decrease for each period for which estimates were not available; and that when compounded annually would produce the same estimate as the next available population estimate[13].

In some cases, country subspecies total estimates were interpolated for missing years. However, in other cases, such as for Tanzanian Black Rhino estimates in the 1970s, individual reserve estimates were only available for different years. In such instances, individual park population estimates within a country were first interpolated for missing years and then resulting actual and interpolated annual estimates for each population were summed at a national level to produce total annual subspecies estimates for that country.

[12] On average annual historical database Black Rhino estimates for 1973–79 were only 8.1% lower than ones produced by modelling the constant average annual (13.76%) rate of decline that would get numbers from the estimated 65,000 in 1970 to the AfERSG estimated 14,785 in 1980. Thus the estimated lower numbers for the early to mid 1970s in the new historical numbers database were fairly consistent with the 1970s approximate continental estimate of 65,000 rhino.

[13] For example, supposing one only had estimates for a population of 211 in year 0 and 249 in year 3 (i.e. there were no estimates for years 1 and 2). This represents a total increase over the three years of 18.00948%. Raising 1.1800948 to the power of (1/number of years) gives 1.0567 or an average annual compounded increase of 5.67%. Applying this annual growth rate gives rounded interpolated estimates for year 1 of 223 and 236 for year 2. Applying this annual growth rate for a third year returns 249 – the same as the recorded population estimate for year 3.

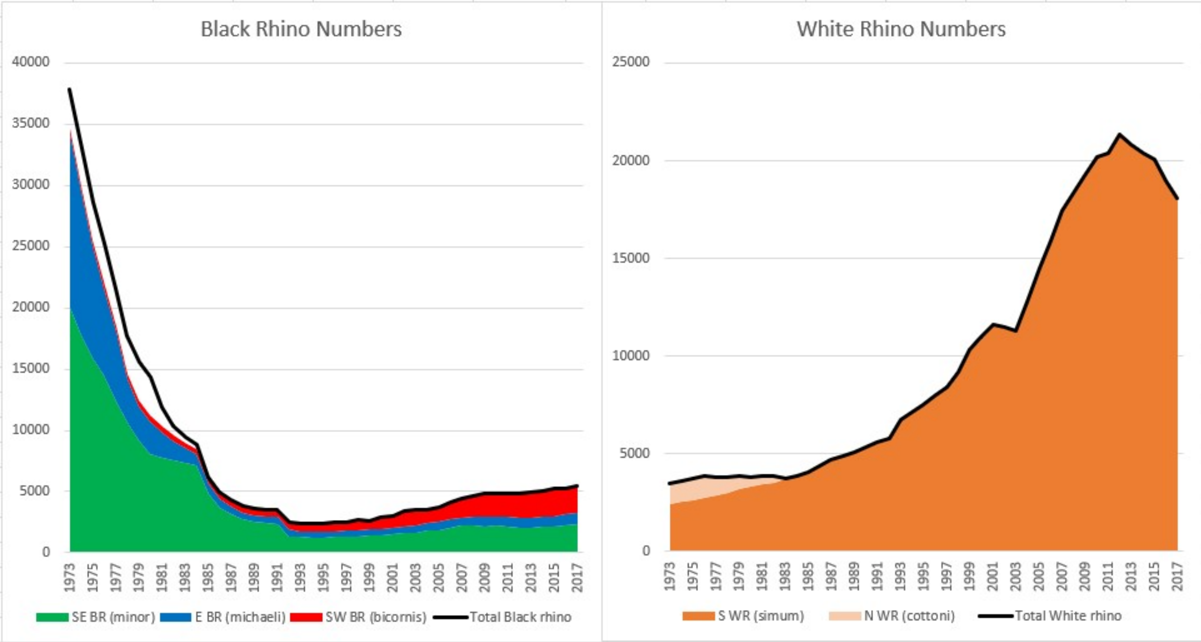

Figure 1. Graph of estimated Black and White Rhino numbers by subspecies/genetic management cluster from the African rhino historical numbers database developed used to assess changes in numbers over three generations (44 years) under Criteria A2 and A4.

Figure 1 shows how estimates of rhino numbers by subspecies have changed over three generations (using actual and interpolated population estimates from the African rhino Red List historical numbers database). These data should also help facilitate regular revisions of Red List assessments for African rhinos going forwards.

Genetic classification and management of rhinos was a major focus at one East African Rhino Management Group meeting (Emslie 2017). IUCN SSC's Conservation Genetics Specialist Group advises that thinking has moved on from the more static concept of subspecies to the more dynamic identification of Genetic Management Units (ESU's) and nested within them Genetic Management Units or Clusters (GMUs) (Emslie 2017, Balfour *et al.* 2019). Results from analyses of different DNA data sets by different researchers (Moodley *et al*. 2017, Harley *et al*. 2005, Harper *et al*. 2018, le Roex 2018, Emslie 2018) using different methods all came to the same conclusion that there were three surviving Black Rhino GMU's. The three consistently identified Black Rhino GMU's fortunately map almost exactly on to and strongly support the existing three surviving subspecies classification (Emslie 2017). The only real potential difference with the previous Black Rhino subspecies classification was due to haplotypes found in a small number of historical Zambian horn samples analysed by Moodley *et al*. (2017) that suggested Black Rhino from Zambia from 1973 to 1994 should perhaps be classified as Eastern rather than South-eastern Black Rhino. In Figure 1 above, historical Zambian Black Rhino estimates from 1973–94 have been classified as South-eastern Black Rhino (*D. b. minor*) as they have been in previous Red List assessments[14]. The Black Rhinos successfully reintroduced back into Zambia were also *D. b. minor*. The unshaded area below the

[14] However, haplogroups of a very small number of historical Zambian horn samples (Moodley *et al*. 2017) suggest that perhaps these historical samples might on genetic grounds be better classified as Eastern Black Rhino (*D. b. michaeli*), even though climatically and habitat wise *D. b. minor* would seem to be better adapted to Zambian conditions than *D. b. michaeli*. For the purposes of this Red List revision, given the small sample sizes of historical Zambian samples, it was decided after consultation to continue to review this issue but for now to continue to classify historical Zambian samples as *D. b. minor*. As there were an estimated 12,000 Black Rhino in Zambia three generations ago (1973) how one allocates these animals affects the Red List assessment of *D. b. minor* but not *D. b. michaeli* (see later).

Black Rhino total numbers line in Figure 1 reflects estimated numbers of the now-extinct Western Black Rhino (*D. b. longipes*).

Genetic analyses by Harley *et al*. (2016) and Moodley *et al*. (2018) also supported the continued classification of two White Rhino GMU's. These GMU's were the same as existing subspecies.

Modelling future poaching

Uncertainty about future population trends across the region (for a moving window analysis projecting into the future under criterion A4) does not just depend upon uncertainty around population estimates. Uncertainty around predicted numbers in the future will to a large extent also depend on 1) actual poaching trends going forward, 2) the degree of poaching under-detection, and 3) levels of underlying net population breeding performance and mortality rates from non-poaching causes. Reported poaching data are given below.

Table 2. Recorded numbers of African Rhino poached per year, showing how total poaching increased rapidly from 2008 to peak in 2015 before declining by a third over the next three years. These numbers represent minimum numbers given the likelihood of some carcass under-detection (especially in very large areas). Source: Based primarily on AfRSG data as well as SADC Rhino Management Group, TRAFFIC and CITES Rhino Working Group data in collaboration with Range States.

Country	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Total 2008-18
Botswana	0	0	0	0	0	0	2	2	1	0	1	0	18	24
Chad													0	0
DR Congo	0	0	2	2									0	4
Kenya	3	1	6	21	22	27	29	59	35	11	10	9	4	233
Malawi	0	0	0	0	0	0	2	1	1	1	1	1	0	7
Mozambique	0	9	5	15	16	10	16	15	19	13	5	4	8	126
Namibia	0	0	0	2	2	1	1	4	30	97	61	44	57	299
Rwanda												0	0	0
South Africa	36	13	83	122	333	448	668	1004	1215	1175	1054	1028	769	7899
Swaziland	0	0	0	0	0	2	0	0	1	0	0	0	0	3
Tanzania	0	0	2	0	1	2	2	0	2	2	0	2	0	13
Uganda	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Zambia	0	1	0	0	0	0	0	0	0	0	0	0	2	2
Zimbabwe	21	38	164	39	52	42	31	38	20	50	35	36	34	541
Total	**60**	**62**	**262**	**201**	**426**	**532**	**751**	**1123**	**1324**	**1349**	**1167**	**1124**	**892**	9151
Poached/day	0.16	0.17	0.72	0.55	1.17	1.46	2.05	3.08	3.63	3.70	3.19	3.08	2.44	2.28

Table 3. Breakdown of reported White and Black Rhino poaching by subspecies/genetic management cluster since 2010. While a total of 769 rhino were reported poached by South Africa in 2018, the subspecies breakdown in the country for this year still has to be confirmed. These numbers represent minimum numbers given the likelihood of some carcass under-detection (especially in very large areas).

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018
Country All *C.s.simum*	White rhino reported poached								
Botswana	0	0	2	2	1	0	1	0	16
DR Congo									0
Kenya	6	11	12	29	14	2	4	4	0
Mozambique	16	10	16	15	19	13	5	4	8
Namibia	0	0	0	2	2	8	7	12	6
South Africa	321	414	643	966	1161	1113	1011	970	tbc
Swaziland	0	2	0	0	1	0	0	0	0
Uganda	0	0	0	0	0	0	0	0	0
Zambia	0	0	0	0	0	0	0	0	2
Zimbabwe	20	8	8	17	5	8	12	9	6
Total White Rhino	363	445	681	1031	1203	1144	1040	999	
Poached/day	0.99	1.22	1.86	2.82	3.30	3.13	2.84	2.74	

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018
Country Subspecies	Black rhino reported poached								
Botswana *D.b.min.*	0	0	0	0	0	0	0	0	2
Kenya *D.b.mic.*	16	16	17	30	21	9	6	5	4
Malawi *D.b.min.*	0	0	2	1	1	1	1	1	0
Namibia *D.b.bic.*	2	1	1	2	28	89	54	32	51
South Africa *D.b.min.*	12	34	25	38	54	62	43	58	tbc
South Africa *D.b.bic.*	0	0	0	0	0	0	0	0	tbc
South Africa *D.b.mic.*	0	0	0	0	0	0	0	0	tbc
Swaziland *D.b.min.*	0	0	0	0	0	0	0	0	0
Tanzania *D.b.mic*	1	1	2	0	2	2	0	2	0
Tanzania *D.b.min*	0	1	0	0	0	0	0	0	0
Zambia *D.b.min*	0	0	0	0	0	0	0	0	0
Zimbabwe *D.b.min*	32	34	23	21	15	42	23	27	28
Total *D.b.min*	44	69	50	60	70	105	67	86	
Total *D.b.bic*	2	1	1	2	28	89	54	32	
Total *D.b.mic*	17	17	19	30	23	11	6	7	
Total Black Rhino	63	87	70	92	121	205	127	125	
Poached/day	0.17	0.24	0.19	0.25	0.33	0.56	0.35	0.34	

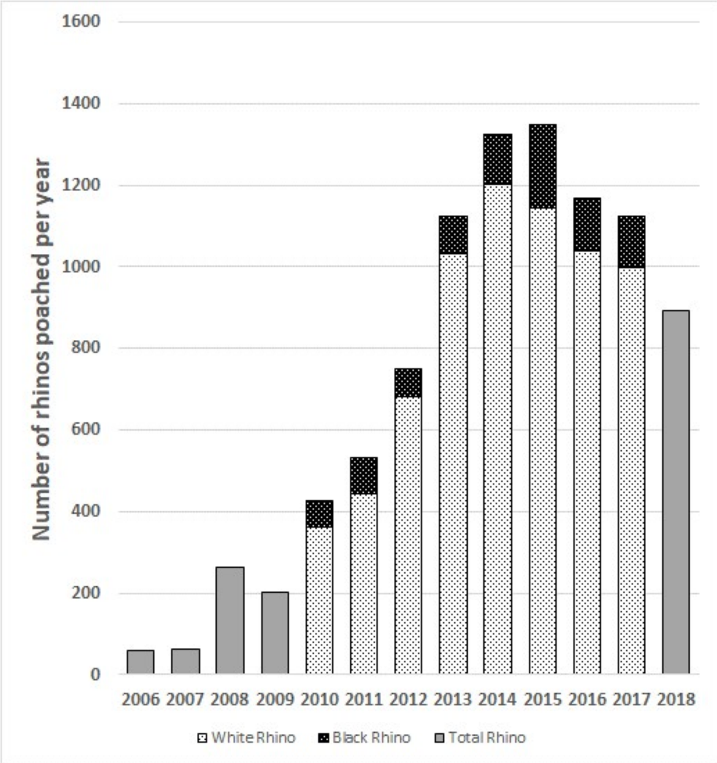

Figure 2. Trends in reported African rhino poaching since 2006, showing a breakdown by species from 2010–2017.

Precis of the approach taken to model poaching

In predicting future rhino numbers to be able to assess changes over a moving three-generation window under criterion A4, it was decided to model future poaching based on recent poaching trends up to five years back. The average of the effects of arithmetic and exponential changes in poaching based on recent poaching trends on numbers over the last five, three and one years were modelled, and the results averaged. "Best" estimates of future numbers, were derived modelling poaching based on observed poaching trends for each taxon over the last five years, but with a greater weighting for more recent trends. Modelling was undertaken assuming both no and significant poaching under-detection.

A total of twelve poaching scenarios were modelled for each of the three modelled underlying population growth rates. These consisted of modelling recorded poaching trends over three time periods (one, three and five years) two types of annual change in poaching (arithmetic change in numbers poached/year and exponential change in % of population poached/year) and with or without a 27% poaching under-detection.

For transparency, the rest of this Modelling Future Poaching section provides more detail on the methods used to model poaching and the rationale behind them. Those not interested in these details can skip to the next section that discusses underlying population growth rates modelled.

Use of a hybrid arithmetic/exponential approach to model future changes in poaching levels

- *Modelling a very high annual exponential increase in absolute numbers poached may be appropriate for shorter periods.*

- *Modelling exponential rates of change many years into the future is not likely to be justified. Therefore, in the longer-term, it may be more realistic to model an average annual arithmetic increase in poaching[15].*
- *Just as with the Regional Red Listing in 2016* (Emslie and Adcock 2016 a, b)*, both exponential and arithmetic changes in rates of poaching were modelled.*
- Average *Arithmetic* annual changes in numbers poached over the three previous one, three and five years periods (used in modelling) are easily calculated from compiled reported annual poaching numbers by taxon[16].
- The *Exponential* annual changes in % of population poached modelled over five and three years were estimated by fitting exponential trend lines to percentages of population poached over time in Excel and using the resultant exponents from the trend line equations to model exponential poaching changes[17]. The observed % change in % of population poached over one year can be simply calculated[18].
- The summary graphs of results of Red List population modelling up to ten years into the future (Figures 4 to 19 below) show averages of the two estimates produced from separate modelling of the two types of poaching change (arithmetic and exponential) for each of the nine combinations of underlying population growth rate (three different underlying growth rates x three poaching trend time-period scenarios modelled)[19].
- *The best estimates of future population sizes used in these Red List assessments used average estimates of future numbers modelled using both types of poaching change.* ***Thus in effect, a hybrid arithmetic/exponential approach was used to model changes in future poaching.***

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[15] This was illustrated by a Kruger National Park example in Emslie and Adcock (2016a).

[16] For example, from Table 3 total White Rhino reported poached for 2012 to 2017 were 681, 1031, 1203, 1,144, 1040 and 999. The arithmetic changes over each of the five years 2012–2017 were +350,+172,-59,-104 and -41 averaging +63.6, -68.0 and -41.0 per year over five, three and one year periods respectively. Given poaching in 2017 (t0) of 999, numbers poached modelled for year 1 in the future would be 1062.6, 931 and 958 based on 5, 3 and 1 year arithmetic trends. All modelled poaching was deemed to have occurred mid-year.

[17] The %'s of the estimated populations poached for each year 2012–2017 were calculated as the numbers poached that year expressed as a % of the end year population estimate (from the historical numbers database) plus the numbers poached that year. For White Rhino, based on the best available updated annual population estimates the estimated %'s poached/year for 2012–2017 were 3.095%, 4.712%, 5.565%, 5.396%, 5.191% and 5.240%. Exponents from fitting exponential trends lines to these data over 5 and 3 periods gave average annual changes of in % of the population poached of +8.26% and -2.20%. The % change on a 1 year basis can be simply calculated as 5.240/5.191 – 1 or +0.94%. The numbers poached in any year were estimated as the modelled number of rhinos after half a years' growth that year, times the % poaching modelled for that year. All poaching was modelled to occur mid-year after half a year's underlying growth and an additional half a year's underlying growth was modelled for the second half of the year (after poaching removals) to get an estimate of numbers at the end of the year.

[18] If 5% of the population was poached in 2016 and 6% in 2017 the exponential rate of poaching change (% increase to be applied to % of population poached) based on a one year trend would be 20%. In this example 7.2% of the population would be "poached" in year 1 (6% of population * 1.2), 8.64% in year 2 (7.2% * 1.2) etc.

[19] For example rounded estimates of White Rhino numbers five years into the future (t5) with no poaching under-detection, high underlying growth rate of 7.5% and based on last five year poaching trend were 18,823 (based on arithmetic annual changes in poaching) and 18,340 (based on exponential annual changes in % of population poached). Results graphs show the rounded average of results based on these two (arithmetic and exponential) poaching change approaches – which in this case was 18,582.

Modelling exponential changes in future poaching

- The Regional Red List exercise found that modelling rapid exponential increases in absolute numbers poached can result in Red List assessments under criterion A4 changing very rapidly; and sometimes very unrealistically, from Near Threatened to Critically Endangered and/or Possibly Extinct in the Wild in only one or two years. In reality, one would expect the last few rhinos to be very well protected and harder to find and poach. In practice, numbers are almost certainly not going to go from Near Threatened to Possibly Extinct in the Wild in only one or two years.
- ***If we instead model an exponential increase in the proportion of the population poached each year rather than an exponential increase in absolute numbers poached each year, the results appear more realistic.*** It then takes longer to progress from Near Threatened to Critically Endangered and close to extinction under heavy and increasing poaching [20].
- For this reason, ***when modelling exponential increases in poaching scenarios, it was decided,*** as was done with Regional African rhino Red Listing, ***to exponentially change the % of the population poached each year (rather than exponentially changing the absolute numbers poached each year***).

Modelled poaching used for Red List assessments reflected recent poaching trends over the last five years but with a greater weighting for recent poaching trends

- Poaching trends change and it was decided it would be most appropriate to model future poaching levels based on poaching trends over the last five years, rather than trends over longer periods of a decade or more***.***
- ***In order to also determine the impacts of most recent trends in poaching, it was decided to separately model poaching based on historical poaching trends over the last five, three and one year periods.***
- ***Results of modelling for these periods are differentiated on results graphs by using different line styles:***
    - dotted lines (based on 5-year poaching trend),
    - short dashed line (3-year poaching trend), and
    - long dashed line (1-year poaching trend).
- ***The averages of the outcomes based on modelled poaching over these three periods are shown as solid lines. This effectively represents modelling of poaching based on trends over the last five years but with a greater weighting for recent changes in poaching.***
- ***"Best estimates" for use in Red List assessments used the average of outcomes when assuming a moderate underlying growth rate of 5% (solid orange line on results graphs).***

[20] 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. When modelling an exponential change in % of population poached after rhino numbers have been significantly depleted the number poached actually starts to decline slightly despite the % of the population poached/year continuing to increase. This is in contrast to exponential increases in absolute numbers poached where numbers poached continue to escalate to very high levels causing unrealistically fast declines in numbers.

Poaching was modelled for three different underlying population growth rates

- Future numbers were modelled for scenarios with three different "good", intermediate" and "poor" underlying growth rates of 7.5%, 5% and 2.5% per annum.
- The summary graphs of projected future rhino numbers use solid lines to show the average estimated rhino numbers across all three poaching trend time periods for each of the three underlying growth rates modelled.

Poaching scenarios were modelled assuming that reported poaching numbers accurately reflected losses (no under-detection) and also assuming a significant 27% poaching under-detection

- Many subpopulations have high field ranger densities, and carcass recovery rates in these more intensively patrolled and monitored reserves are generally higher. However, in very large reserves with lower field range densities, it appears there may be a significant under-detection of carcasses. Thus total recorded poaching figures in Tables 2 and 3 and Figure 2 are simply minimums.
- Natasha Anderson and Raoul du Toit (personal communication 2019) estimated that as many as 27% of mortalities of known animals in a large individually monitored Zimbabwe Lowveld conservancy population may go undetected. This is similar to the around 20% under-detection rate estimated for potentially detectable carcasses in Kruger National Park by Ferreira *et al.* 2019 (which did not include additional undetected deaths of young calves orphaned by poaching and which subsequently die and whose smaller carcasses are unlikely to persist for long and be detectable after being scavenged).
- Given that ***reported poaching numbers represent a minimum and the true number poached is likely to be higher given probable under-detection of some carcasses (Emslie et al. 2019) in addition to modelling numbers based on reported poaching, models were also run assuming that 27% of poaching went undetected (as estimated by Natasha Anderson and Raoul du Toit).***
- ***A 27% under-detection of poached carcasses translates into modelling 37% more rhino poached***[21].
- Given that carcass detection rates are likely to be better than this in smaller reserves with higher field ranger densities, applying a 27% under-detection rate to all rhinos provides a severe test. True total poaching numbers may lie somewhere between poaching modelled under the two carcass detection rate assumptions.

Results graphs show a range of possible outcomes under different scenarios

- Results graphs show the results of modelling poaching based on past trends over three different time periods and under three different underlying population growth rates.
    - Results of modelling different poaching trend periods are differentiated by different line styles on graphs.
    - The average outcomes of the three different periods poaching trends were modelled for are depicted as solid lines (in essence reflecting the last five year's poaching trends but with a greater weighting given to more recent trends).

[21] Calculated as (1/(1-0.27)) or (100/73)-1

- The results of modelling different underlying growth rates are differentiated using intuitive “traffic light” colours with *good* green, *intermediate* orange and *poor* red.

“Best” estimates used to assess changes in population size under criterion A4

- While the graphs show a possible range of outcomes based on modelling a range of different poaching and underlying growth scenarios; future estimated numbers used to assess changes in population size under criterion A4 were taken as the average estimated numbers at times t1 to t5 (for all six poaching trend time period and type of poaching change scenarios modelled for the given rate of poaching under-detection modelled (either 0% or 27%) and assuming an intermediate 5% underlying growth rate (shown as a solid orange line on results graphs).
- The latest population estimate at t0 was used to assess changes under criterion A2.
- These “best estimate” numbers that were used in Red List assessments under criteria A2 and A4 are shown as blue markers on the solid orange lines on the results graphs that follow (Figures 4-19).

Modelled future underlying population growth rates

In modelling future rhino numbers, it is also necessary to decide on what underlying biological population growth rates to apply (i.e. the biological growth rates that would occur if there was no poaching[22]). ***We modelled a range of high, medium and low underlying biological growth rates, namely 2.5%, 5% and 7.5%/year***.

- The latter can be achieved (exceeded) in rapidly growing populations and represents a healthy average overall rate of growth for a metapopulation.
- 5% is the minimum target growth rate in many rhino plans and represents a moderate underlying growth rate.
- 2.5% reflects poorly performing populations (likely to be overstocked).
- On the results graphs (Figures 4 to 19), projected trends based on these different underlying growth rates are shown in different intuitive “traffic light” colours with green for *good* (7.5%), orange for *intermediate* (5%) and red for *poor* (2.5%).

Recap - Multiple Scenarios were modelled for each Taxon

In summary, future rhino numbers were modelled up to five years ahead for Red Listing assessment purposes (and up to 10 years for heuristic purposes) using:

- Three underlying annual biological population growth rates, 2.5% (low), 5% (medium) and 7.5% (high).
- Two poaching carcass detection rates.
- For each detection rate, poaching was modelled based on trends observed over 3 time periods (one, three and five years back) and using two types of change rates (arithmetic changes in numbers poached and exponential changes in the % of population poached each year).

[22] In the case of these continental assessments, translocations in or out do not need to be factored in when estimating underlying population growth rates.

- Results were also averaged across all three poaching trend periods to give a five year modelled poaching but with greater weighting given to recent changes in poaching.
- For each taxon separate modelling (and graphs of results) was undertaken 1) assuming reported poaching figures are accurate (i.e. a 0% under-detection) and 2) assuming a significant 27% poaching under-detection (effectively modelling poaching 37% higher than reported)[23].

For ***these Red List Assessments, the "best" estimates used to assess changes in number under criterion A4 were the average of outcomes of the six (poaching trend period/underlying growth rate combination poaching scenarios for a given poaching detection rate and given medium 5% underlying biological growth.*** These are shown by the five blue marker circles for t1 to t5 on each results graph below (Figures 4 to 19). ***The modelling of only a 5% underlying growth when deriving "best" estimates for use in Red List assessments is conservative and somewhat precautionary. One would hope that with good biological management (and use of translocations to prevent overstocking) populations can achieve better than a 5% level of underlying growth.***

Numbers of mature individuals

SADC RMG data indicated that, on average, about 55.8% of Black Rhino populations are adult (K. Adcock personal communication based on unpublished SADC RMG 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.

Equivalent threshold numbers of total rhino (compared to threshold numbers of mature individuals) under criterion C using taking 55.8% of populations to be adult were <448 (<250); <4,480 (<2,500) and <17,920 (<10,000).

Treatment of last Northern White subpopulation and largest semi-wild Southern White Rhino subpopulations

The last living Northern White Rhino in the wild

The last two surviving Northern White Rhino females in the wild were translocated from a Zoo in the Czech Republic. As these ex-Zoo animals have not yet bred in the wild, under Red List rules, they cannot be included in the wild population for this Red List assessment.

The largest private semi-wild White Rhino subpopulation

The largest private White Rhino subpopulation that currently conserves over 1,700 White Rhinos is semi-wild. However, as animals in this subpopulation:
- get at least half their diet from grazing natural veld in extensive areas (rather than in small paddocks) (see Figure 3),
- genetically are the same as the metapopulation (with over 700 founders from over 90 different source subpopulations with no selective breeding), and
- are kept as wild and un-domesticated as possible, and

[23] Only detecting 73% of poached carcasses (a 27% under-detection rate) translates to actual poaching being almost 37% higher than recorded (100/73).

- despite female-biased skewed sex ratios in breeding areas, mating is natural (with no regular invasive reproductive procedures such as the use of ultrasound probes),
- breeding cows still have some mate selection choice as the animals can choose which animals they wish to associate with and mate with,
- are managed to reduce the risk of inbreeding by occasional movement out of breeding bulls from breeding areas to allow other non-related younger bulls growing up in the area to take over breeding,
- are breeding well (Adcock *et.al.* 2018), and
- have suffered much lower poaching than the country average (due to high security)

these animals could act as “insurance” rhinos.

Although wild subpopulations remain the conservation priority, such semi-wild operations were recognised as a possible option in the latest approved South African White Rhino Biodiversity Management Plan. Provided there is no selective breeding and animals are not overly domesticated in this semi-wild subpopulation; they could potentially in future be re-wilded – providing founder rhino to restock or boost other wild populations as needed. The semi-wild Black Rhino from this same subpopulation were recently translocated out to help found a new Black Rhino subpopulation in the wild. One of the semi-wild Black Rhino founder cows introduced back to the wild was observed mating with a wild-sourced founder male within only two months of translocation to the new subpopulation. It seems highly probable that White Rhino from this semi-wild subpopulation could also be successfully re-introduced back into a wild subpopulation. Thus, the animals in this subpopulation functionally can be considered part of the local national metapopulation. It, therefore, was decided to include them in the White Rhino numbers being used in this Red List assessment.

However, whether or not these semi-wild animals are included in assessed White Rhino numbers in practice would not change any of the White Rhino Red List assessments[24].

[24] Due to the very large increase in numbers of wild subpopulations and wild rhino in other reserves over the last three-generations.

Figure 3. Some photos of habitat in the largest private Southern White Rhino subpopulation that is semi-wild. Supplementary feeding is restricted to short periods of the day and except under extreme drought conditions provides less than 50% of the diet. Animals are free to wander and graze natural veld grasses for most of the day, and at some times of the year, there may be no supplementary feeding with natural grazing providing all their food at these times. Circles in photos above show White Rhinos. Thus this operation is very different from the usual much more intensive and non-wild captive set up.

Demographic model used to predict future numbers

For each of the 36 options modelled (three underlying growth rates x three poaching trend time periods x two types of poaching change x two poaching detection rates), a spreadsheet population model was used.

The steps for each scenario modelled were as follows:

1) Start with the estimate of current rhino numbers.
2) Add half a year's growth (thus if modelling a 5% annual growth this would represent 1.05^(1/2) or an increase in numbers by 2.4695% over half the year.
3) Estimate numbers poached under the poaching scenario being modelled. In the case of modelling exponential changes in poaching, this was a two-step process. Firstly the % of the population poached was estimated, and secondly, this was then used to determine numbers to be poached.
4) Deduct the estimated number poached from the population mid-year (i.e. assuming all poaching occurs mid-year).
5) Add a further half year's growth to get an end of year population estimate.
6) Repeat the process for a further nine years to get estimated numbers 10 years out (although estimates from years six to 10 are for illustrative purposes only and not used in Red List assessments (for the reasons outlined earlier).
7) For each level of poaching under-detection modelled (0% or 27%), summarise the results graphically averaging results for exponential and arithmetic poaching for each of the nine poaching time period (one, three or five years) and underlying growth rate (2.5%, 5% and 7.55) scenarios.
8) Also, calculate the average across all three poaching trend time periods for each of the three underlying growth rates.
9) Summarise results modelled with and without poaching under-detection on separate graphs
10) Graph the results of modelling future rhino numbers for each taxon:
    a. Produce two separate graphs for each taxon – one with modelled significant poaching under-detection and one without to facilitate a determination of the effect of potential poaching under-detection on future numbers of each taxon assessed.
    b. Differentiate the results of modelling trends based on different underlying growth rates by showing predicted trends in intuitive "traffic-light" colours with
        i. green for good 7.5%,
        ii. orange for intermediate 5% and
        iii. red for poor 2.5% growth.
    c. For each scenario shown, only the averages of estimates derived from separately modelling of both arithmetic and exponential changes in poaching are graphed in Figures 4 to 19. Thus results shown, therefore represent a hybrid of modelling arithmetic and exponential changes in annual poaching.
    d. Differentiate between results based on different poaching trend time-periods using different line styles with
        i. dotted lines (**……….**) to show estimated numbers based on modelling a five-year average poaching trend,
        ii. small dashes (**- - - - - -**) for results based on a three-year average poaching trend
        iii. big dashes **(**— — —) for results based on a one-year poaching trend.
        iv. solid lines (———) showing the average of results under all three above poaching trend time-periods.
    e. Averages of modelling all three poaching trend time-periods with an intermediate 5% modelled underlying growth were used as "best" estimates up to five years into the future (t1 through to t5) for assessing changes under criterion A4.

f. Also, use the current estimate (t0) as the best estimate for use in assessing changes under criterion A2.

g. Show these six "best estimates" for t0 through to t5 as blue circle markers on a solid orange line ( ).

h. Shaded blue areas on the graphs to represent critical zones for each of the three Threatened Red List categories. Should a blue circle marker cross a threshold and fall into a critical zone of a higher threat category the taxon should immediately be uplisted to a higher category of threat

   i. The darkest blue area represents a Critically Endangered classification zone,
   ii. The intermediate blue area – an Endangered classification zone, and
   iii. The lightest blue area – a Vulnerable classification zone.

   However, if a "best" estimate moves up into a zone of lower threat, this does not result in an immediate Red List re-assessment under a lower category of threat. This is because, according to the Red List rules, to be reassessed in a lower category of threat requires that the criteria for downlisting to the lower category have been met for at least five years[25].

11) For information, additional modelling was undertaken to illustrate what would happen if historical Zambian Black Rhino from 1973-94 were instead allocated to Eastern Black Rhino (*D. b. michaeli*) instead of South-eastern Black Rhino (*D. b. minor*). Results are shown in Figures 12, 13, 16 and 17.

Results of modelling African rhino numbers into the future as part of Red List assessments under criteria A2 and A4

- The African rhino Red List modelling shows point estimates in the graphs below. However, this should not be interpreted as indicating a level of estimate precision that does not exist. There is a degree of uncertainty around population estimates (especially in larger populations in large areas not monitored using individual ID-based methods). Based on separate bootstrapping of individual population estimates (using actual calculated or likely estimate precision for each population as of the end of 2017), 90% confidence levels around total White Rhino numbers at the end of 2017 were estimated to range from 17,212 to 18,915 (Emslie *et al.* 2019).

[25] Unless the re-assessment is due to a mistake and correcting a previous assessment.

White Rhino – *Ceratotherium simum*

Figure 4. Projected trends in numbers of White Rhino, assuming reported poaching accurately reflects actual poaching levels (i.e. assuming no-poaching under-detection). For an explanation of the graph, see the key and earlier explanatory text in methods description.

- **Figure 4 shows that given the large increase in White Rhino numbers over the last three generations, White Rhino (assuming no-poaching under-detection) do not come close to qualifying under any of the threatened categories as of the end of 2017 (under criterion A2) or any time over the next five years (under criterion A4).**
- In recent years the underlying growth will have been lower than average due to the effects of a particularly bad drought on mortalities and calving rates in some populations (Ferreira *et al.* 2018a; Mick Reilly personal communication).
- White Rhino historically have shown underlying growth rates in excess of 7.5% in populations stocked well below carrying capacity. Prior to the start of the upsurge of poaching in 2007, total White Rhino numbers had been increasing at an estimated 7.1% per annum (Emslie *et al.* 2019). Thus provided drought conditions do not persist over the longer term the green projections may be more realistic.
- A significant proportion of Africa's White Rhino occur in the Kruger National Park which in the face of heavy poaching has suffered a significant decline in numbers since 2012 (Ferreira *et al*. 2018a, Emslie *et al.* 2019). Potentially one could model Kruger NP separately. This was not done for this assessment, as even if this subpopulation were to decline to zero over the next five years, the species would still not come close to qualifying under criterion A4. As it becomes harder to poach rhinos in Kruger, one could also expect poachers to shift their

attention to other areas and countries; and therefore modelling overall poaching may better handle this.

- Overall, recorded White Rhino poaching (in absolute numbers) has been declining since 2014 (Table 3). Projections based on the last year (long dashed lines) or last three years' poaching trends (shorter dashed lines) are more optimistic than those based on average poaching trends over the last five years (dotted lines).
- If the trend of rapidly increasing reported poaching from 2008 had not been slowed and then reversed the modelled situation would have been significantly worse than it currently is.
- While White Rhino numbers have been increasing in many populations (especially on private land), numbers have been declining in the largest population despite recorded absolute poaching levels in this population declining every year since 2014. This is because with fewer rhinos, as a % of the population, poaching levels have remained at unsustainable levels in this population.
- Uncertainty increases the further into the future one projects (one of the reasons for only projecting up to five years into the future). Spreadsheets have been set up to automate and expedite these analyses in future; it is planned to redo analyses every time continental estimates are updated by the AfRSG (which has been done every one to three years since 1992). In this way, assessments can be responsive to any negative or positive changes in the situation.

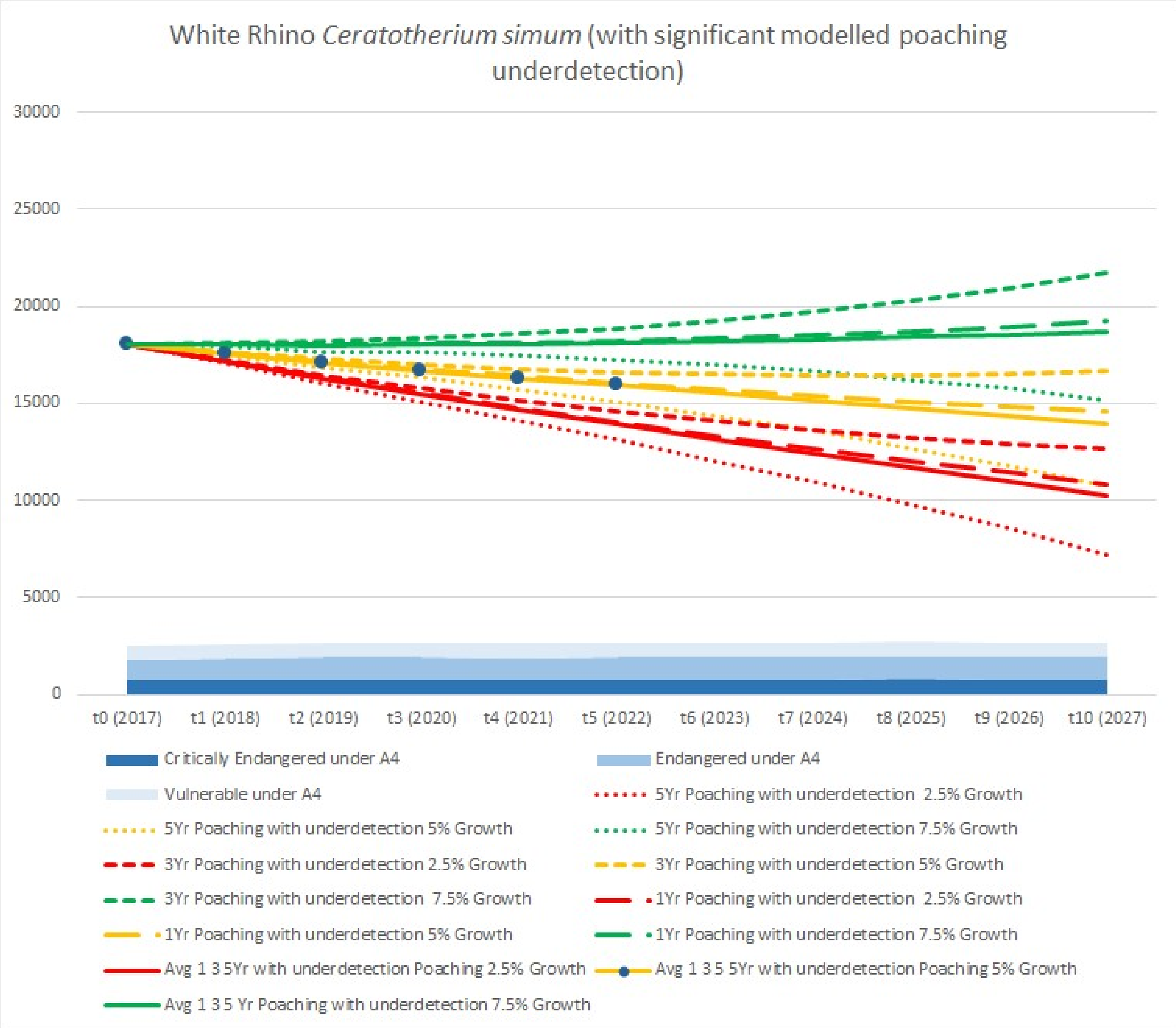

Figure 5. Projected trends in numbers of White Rhino assuming a 27% poaching under-detection (and actual poaching levels 37% higher than recorded levels). For an explanation of the graph, see the key and earlier explanatory text in methods description.

- ***Figure 5 shows that modelling significant poaching under-detection of White Rhino gives a more negative prediction***. With a 5% underlying growth rate, modelled estimates decline to 15,920 by the end of 2022. ***This, however, is still well in excess of threshold levels to qualify in any of the threatened categories up to five years into the future.***
- It had been hoped to model based on end 2018 estimates, but reporting on White Rhino numbers in three provinces in South Africa at the time of assessment was not complete enough to estimate 2018 numbers (although estimates were available for the majority of the White Rhino in the country and all other Range States). If one were to best-guess numbers for the South African subpopulations we have not yet got estimates for in 2018, the continental total for White Rhino is likely to fall around the middle of the 2018 estimates modelled with and without poaching carcass under-detection in Figures 4 and 5.

Southern White Rhino – *C. s. simum*

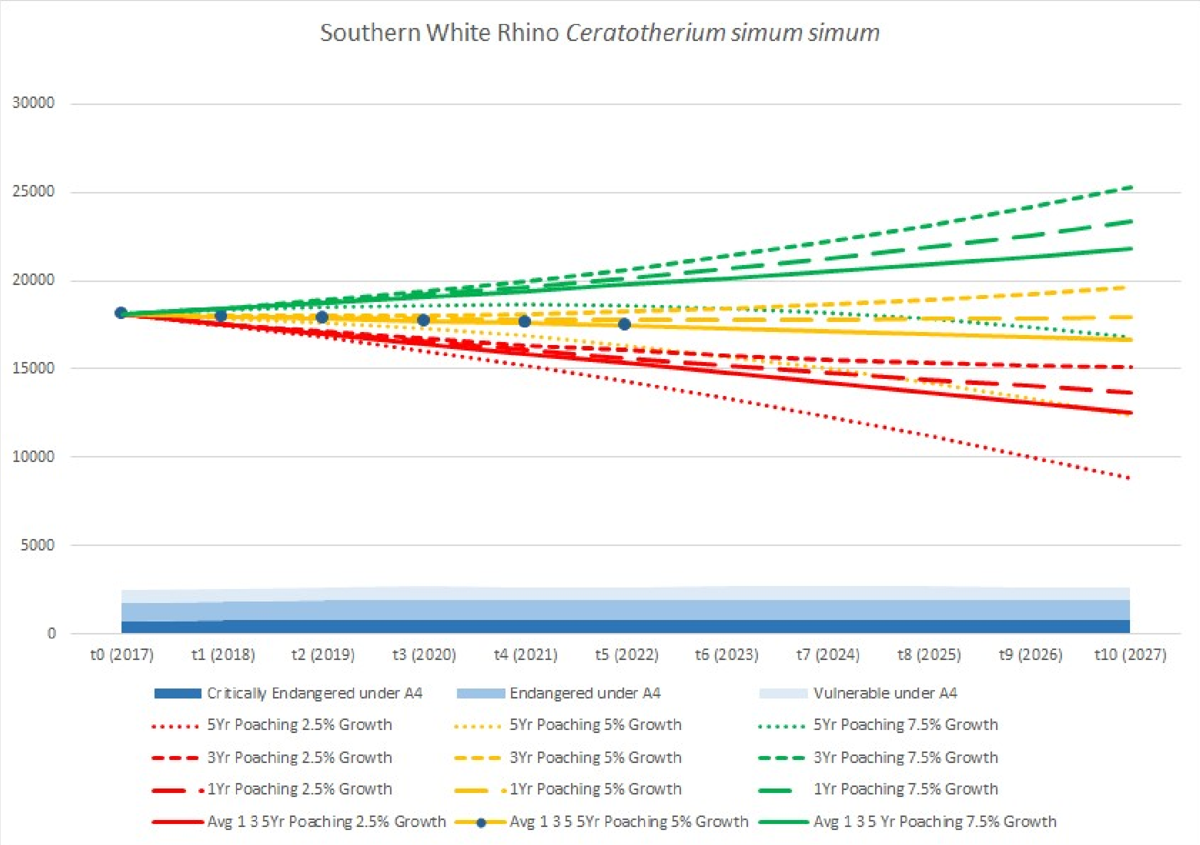

Figure 6. Projected trends in numbers of Southern White Rhino assuming reported poaching accurately reflects actual poaching levels (i.e. assuming no-poaching under-detection). For an explanation of the graph, see the key and earlier explanatory text in methods description.

- When modelling Southern White Rhino numbers, the threshold levels to qualify under one of the threatened categories under criteria A2 and A4 (shaded blue zones in Figures 6 and 7) are lower than at a species-level (Figures 4 and 5). ***However, the conclusions for Southern White Rhino remain the same as those at a species-level. Southern White Rhino do not qualify for any of the threatened categories under criteria A2 and A4 irrespective of whether one models significant poaching under-detection or not.***

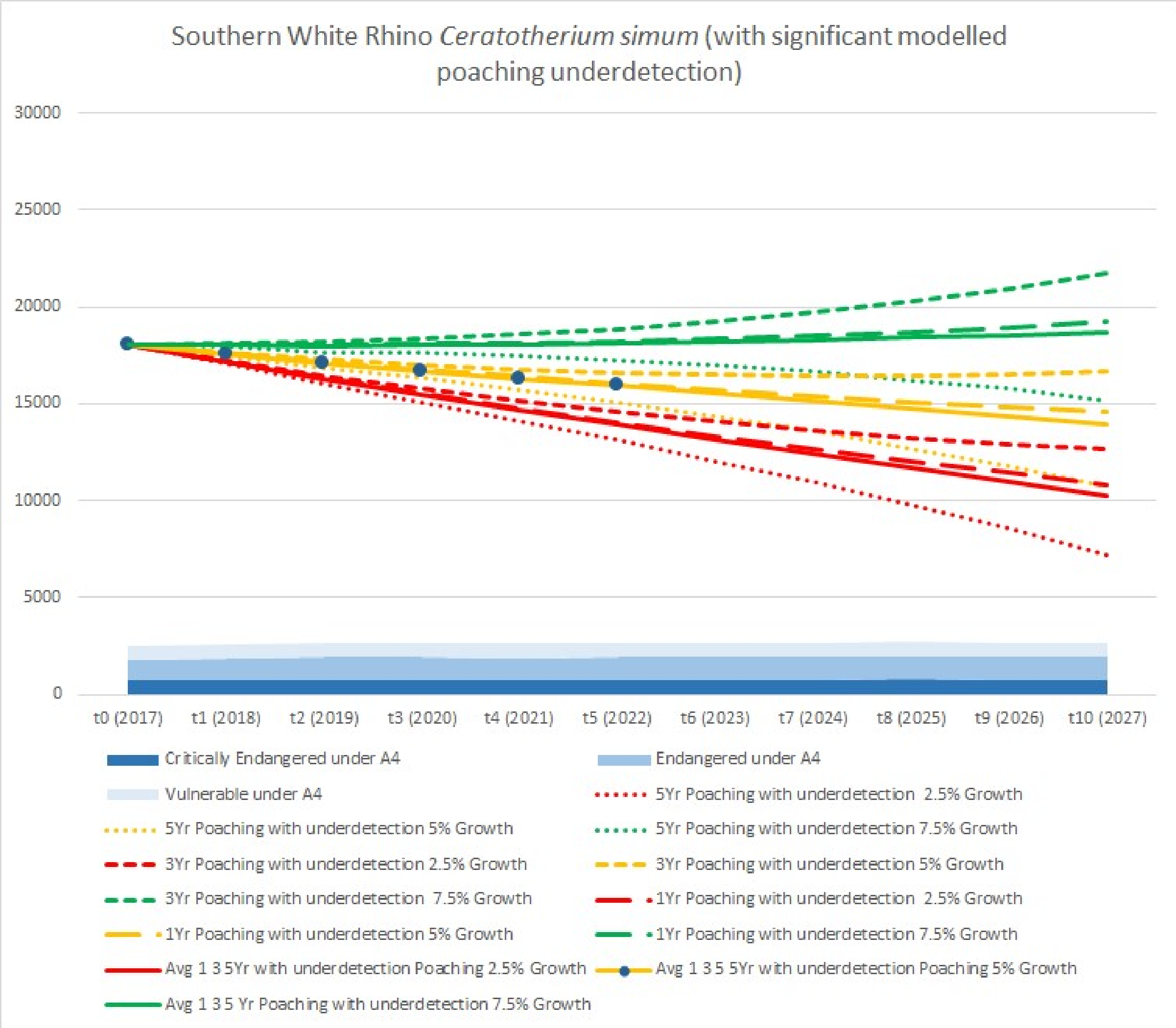

Figure 7. Projected trends in numbers of Southern White Rhino assuming a 27% poaching under-detection (and actual poaching levels 37% higher than recorded levels). For an explanation of the graph, see the key and earlier explanatory text in methods description.

Black Rhino – *Diceros bicornis*

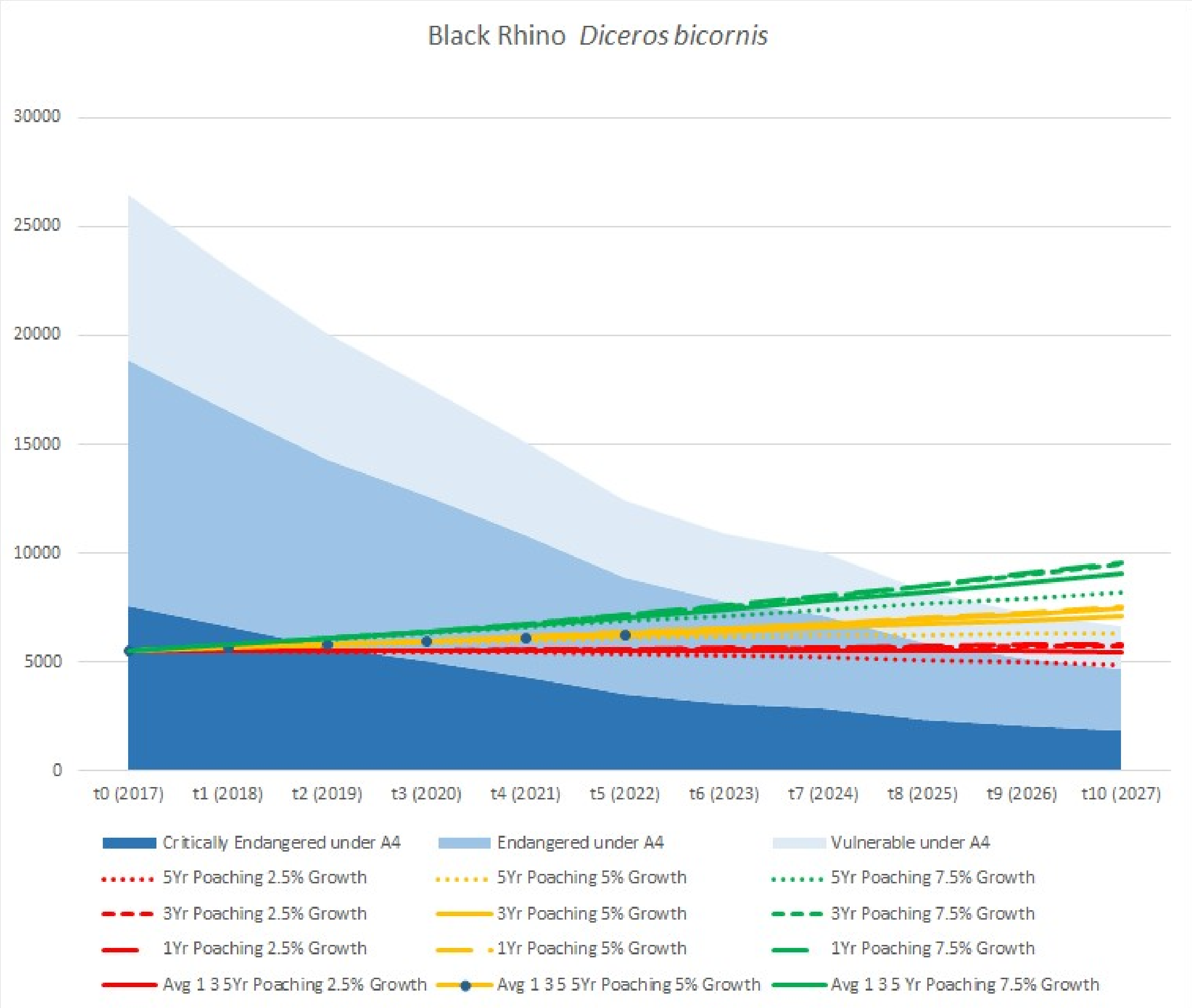

Figure 8. Projected trends in numbers of Black Rhino assuming reported poaching accurately reflects actual poaching levels (i.e. assuming no-poaching under-detection). For an explanation of the graph see above key and earlier explanatory text in methods description.

- As with White Rhinos, there is a degree of uncertainty around point estimates of Back Rhino numbers. Based on separate bootstrapping of individual subpopulation estimates (using actual calculated or likely estimate precision for each subpopulation), 90% confidence levels around total Black Rhino numbers at the end of 2017 were estimated to range from 5,366 to 5,627 (Emslie *et al.* 2019).
- ***At a species level, the Black Rhino (as of the end of 2017) continue to qualify as Critically Endangered (CR) under criterion A2 (estimate falling within the dark blue shaded CR zone)***. Its numbers have continued to increase, albeit at a slower rate due to the effects of poaching (Emslie *et al.* 2019). The revised continental estimate for end 2018 is 5,630 which is similar to the 2018 modelled estimates in Figure 8 of 5,640 (assuming no-poaching under-detection) and in Figure 9 of 5,593 (with modelling of significant poaching under-detection).
- By the end of 2019 (t2) due to a combination of continued limited population growth and declining threatened category threshold values under criterion A4, Figure 8 shows that the projected number of Black Rhino at the end of 2019 (5,789) marginally exceeds the CR threshold level for that year of 5,735 rising up into the medium-blue Endangered shaded

zone from the darker blue Critically Endangered zone. However, unless one is correcting a mistake; before a species can be uplisted to a lesser category of threat it has to have satisfied the criteria for the uplisting for at least five years***. Thus while currently qualifying to be categorised as CR; by the end of 2024 (five years after crossing into the intermediate blue Endangered shaded zone) the species may qualify to be reassessed as Endangered (assuming all poached carcasses are being found)***.

- ***If these trends were to continue, the graphs suggest that Black Rhino might qualify to be assessed as Vulnerable in 2030 and Near Threatened in 2032***.
- The reason that the blue shaded threshold threatened category zones under A4 in Figures 8 and 9 decline sharply over time is due to very heavy poaching of Black Rhinos from 1973 to 1983, which caused a marked decline in Black Rhino point estimates over that period from 37,807 to 9,444. Numbers of Black Rhino over three generations show a classic "ski jump effect" pattern of very large longer-term declines followed by recent increases.

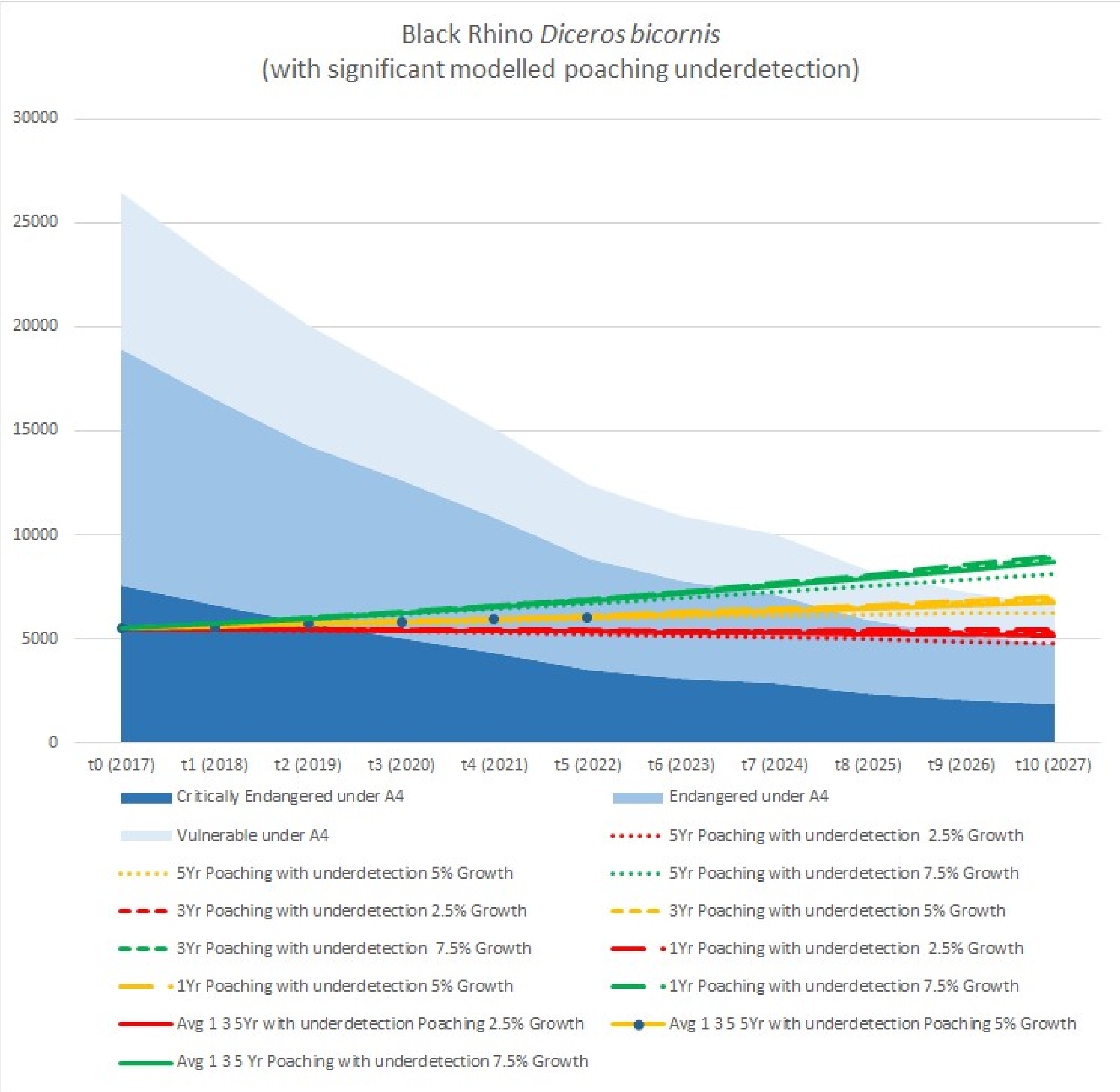

Figure 9. Projected trends in numbers of Black Rhino assuming a 27% poaching under-detection (and actual poaching levels 37% higher than recorded levels). For an explanation of the graph, see the key and earlier explanatory text in methods description.

- ***Based on modelling a significant poaching carcass under-detection rate, Black Rhino are projected to enter the Endangered shaded zone a year later (in t3 or by end 2020). Thus by the end of 2025, the species might qualify to be re-assessed as Endangered (based on modelling a significant carcass under-detection).***
- ***If these trends were to continue into the future, Figure 9 suggests that Black Rhino might qualify to be listed as Vulnerable in 2030 and Near Threatened by 2032.***

South-eastern Black Rhino – *D. b. minor*

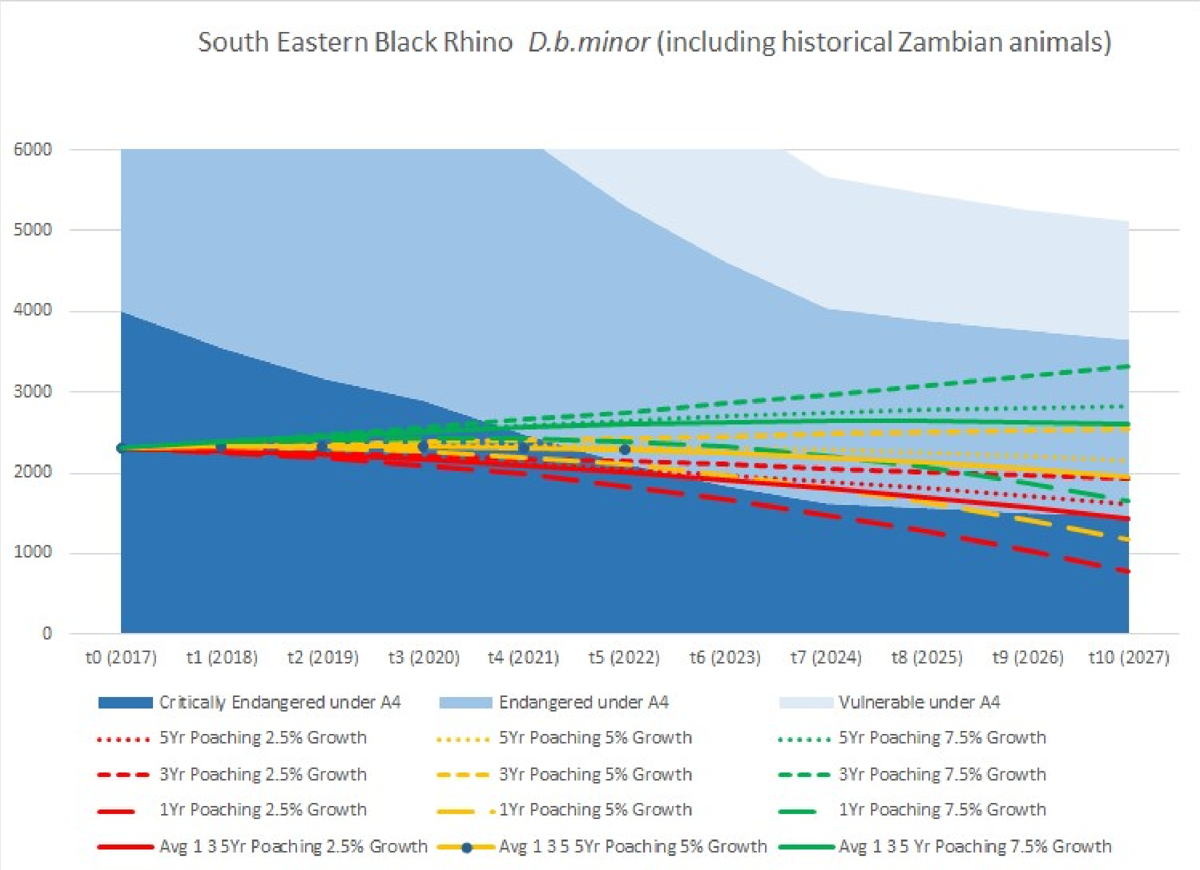

Figure 10. Projected trends in numbers of South-eastern Black Rhino assuming reported poaching accurately reflects actual poaching levels (i.e. assuming no-poaching under-detection). Historical Zambian Black Rhino from 1973–94 continue to be classified as South-eastern Black Rhino. For an explanation of the graph, see the key and earlier explanatory text in methods description.

- The South-eastern Black Rhino has also been called Southern-central Black Rhino.
- In Red List assessments, a decision needed to be made on what subspecies/genetic management cluster to allocate historical estimated numbers of Black Rhino in Zambia. In 1973 there were an estimated ~12,000 Black Rhino in Zambia. However, by 1980 poaching had reduced their numbers to ~2,750 and only an estimated 106 in 1987. The species had gone extinct in the country by the end of 1995. Black Rhino have since been re-introduced into the country with *D. b. minor* founder animals (from 2003). Historically Black Rhinos in Zambia had always been considered *D. b. minor* (which occur in areas with a single wet season and also in some areas with similar miombo woodland). Thus, *D. b. minor* has historically been considered the most suitable subspecies to reintroduce back into Zambia (which is what happened). However, a recent continental genetic study of Black Rhino by

Moodley *et al*. (2017) based on nuclear and mitochondrial DNA from horn samples from both current populations and from historical horn samples taken from animals from areas where the species has been extirpated has cast doubt on this classification. Historical haplogroups detected in a small number of Zambian historical samples in Moodley *et al*.'s (2017) analysis suggest that perhaps historical Zambian animals might be better classified as Eastern Black Rhino (*D. b. michaeli*). Because there were so many Black Rhinos in Zambia three generations ago, how one allocates these historical Zambian animals makes a difference to the South-eastern Black Rhino assessment.

- The results of analyses allocating the historical Zambian Black Rhino to either South-eastern or Eastern Black Rhino are provided for information.
- Given 1) given the small sample size of historical Zambian horn samples; 2) the historical classification of Zambian animals as *D. b.minor;* 3) the greater similarity of some South-eastern Black Rhino climatic and habitat conditions to Zambia (and hence possibly better ecological adaptation to local conditions) and 4) the use of South-eastern Black Rhino to restock Zambia from 2003 onwards; a decision was made for this assessment to continue with the historical allocation of Zambian animals to South-eastern Black Rhino. The situation should continue to be reviewed and might change in future.
- ***Figure 10 shows that if historical Zambian animals continue to be classified as South-eastern Black Rhino, the subspecies/genetic management cluster continues to qualify as Critically Endangered.***
- In part due to declining threatened category threshold values under criterion A4[26] ; Figure 10 shows that by the end of 2022 (t5); the projected t5 "best" estimate (2,291) marginally exceeds the CR threshold level for that year of 2,125, thus crossing up into the medium-blue Endangered shaded zone. However, in order for a subspecies/genetic management cluster to be uplisted to a lesser category of threat it has to have satisfied the criteria for the uplisting for at least five years***. Thus by the end of 2027 (i.e. five years after crossing into the Endangered shaded zone), the subspecies may qualify to be reassessed as Endangered under A4 (based on assuming all poached carcasses are being found).***
- ***Given poaching levels and the lower population growth rates achieved by the South-eastern metapopulation, one can expect the subspecies/genetic management cluster will not qualify to be reassessed as Vulnerable under A4 over the next 15 years***.

[26] The reason the blue-shaded threshold Threatened category zones under A4 decline sharply over time is due to very heavy poaching of Black Rhinos from 1973–83 that caused a marked decline in South-eastern Black Rhino point estimates over that period (from 19,994 to 7,307).

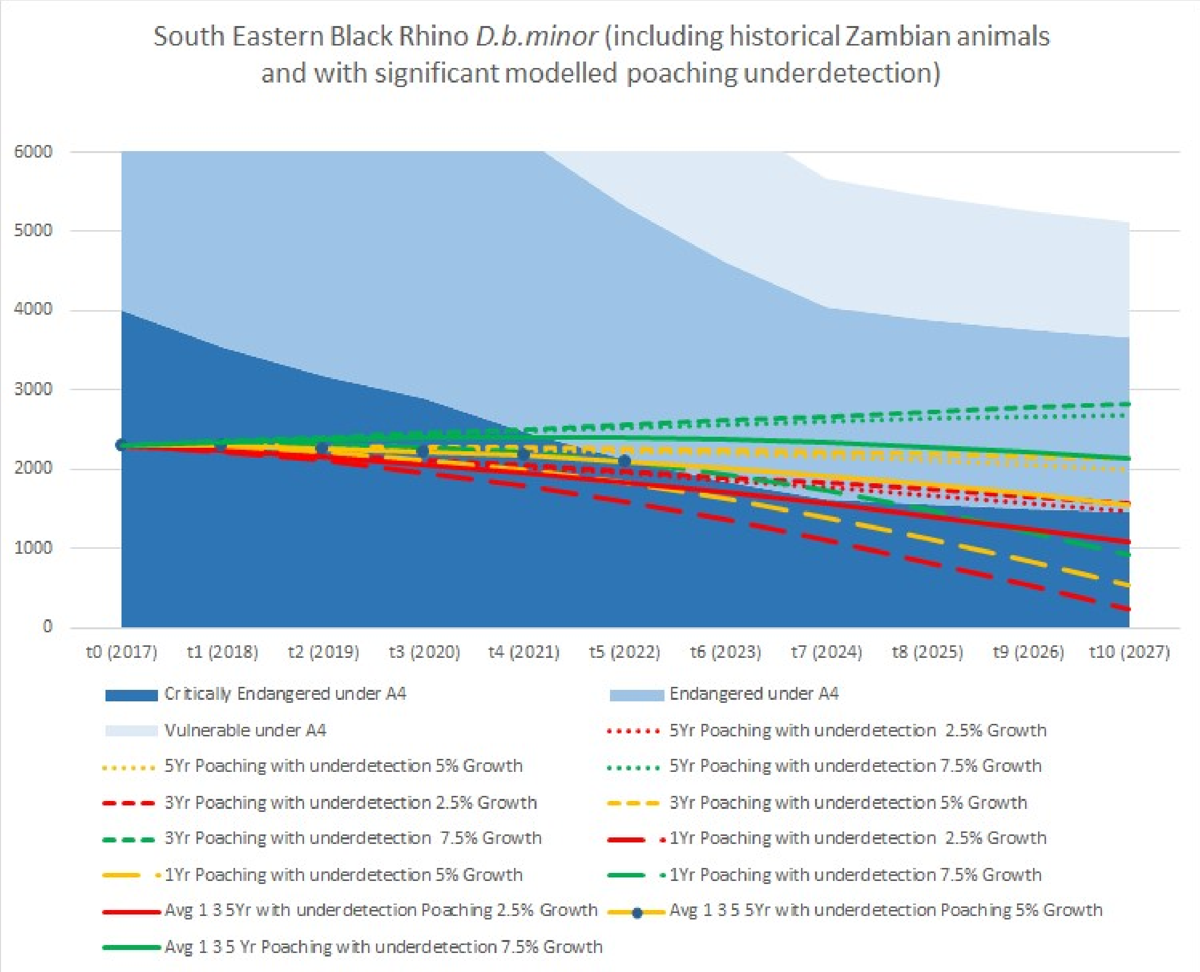

Figure 11. Projected trends in numbers of South-eastern Black Rhino assuming a 27% poaching under-detection (and actual poaching levels 37% higher than recorded levels). Historical Zambian Black Rhino from 1973–94 continue to be classified as South-eastern Black Rhino. For an explanation of the graph, see the key and earlier explanatory text in methods description.

- ***With modelling of significant poaching under-detection, if historical Zambian animals continue to be classified as South-eastern Black Rhino, the subspecies/genetic management cluster continues to be classified as Critically Endangered.***
- By the end of 2023 (t6) due in part to declining threatened category threshold values under criterion A4, the graph shows that the projected number (2,018) marginally exceeds the CR threshold level for that year of 1,845 entering the medium-blue Endangered shaded zone (a year later). Given that, for a taxon to be uplisted to a lesser category of threat it has to have satisfied the criteria for the uplisting for five years***, it is estimated that by the end of 2028 (five years after crossing into the Endangered shaded zone), the species may qualify to be reassessed as Endangered (based on assuming a significant under-detection of poached carcasses).***

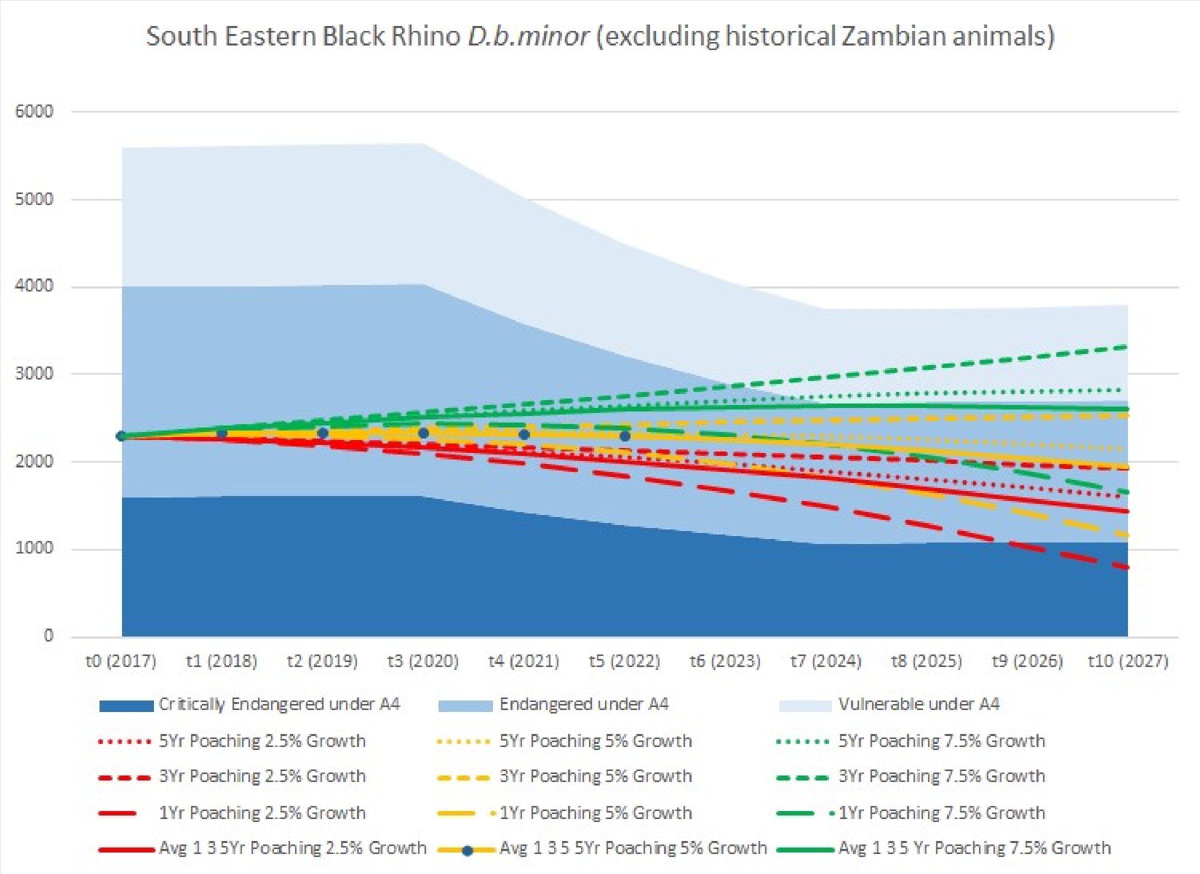

Figure 12. Projected trends in numbers of South-eastern Black Rhino assuming reported poaching accurately reflects actual poaching levels (i.e. assuming no-poaching under-detection). In this graph (for illustrative purposes) historical Zambian Black Rhino from 1973–94 were re-classified as Eastern Black Rhino. For an explanation of the graph, see the key and earlier explanatory text in methods description.

- ***The above graph shows that should a decision be made in future to change the allocation of historical Zambian animals (to Eastern Black Rhino) this would change the assessment of the South-eastern Black Rhino from Critically Endangered to Endangered. The same would be the case under modelled scenarios assuming a significant poached carcass under-detection (see graph below)***
- ***The same is the case if one models significant under-detection of poaching (see graph below).***

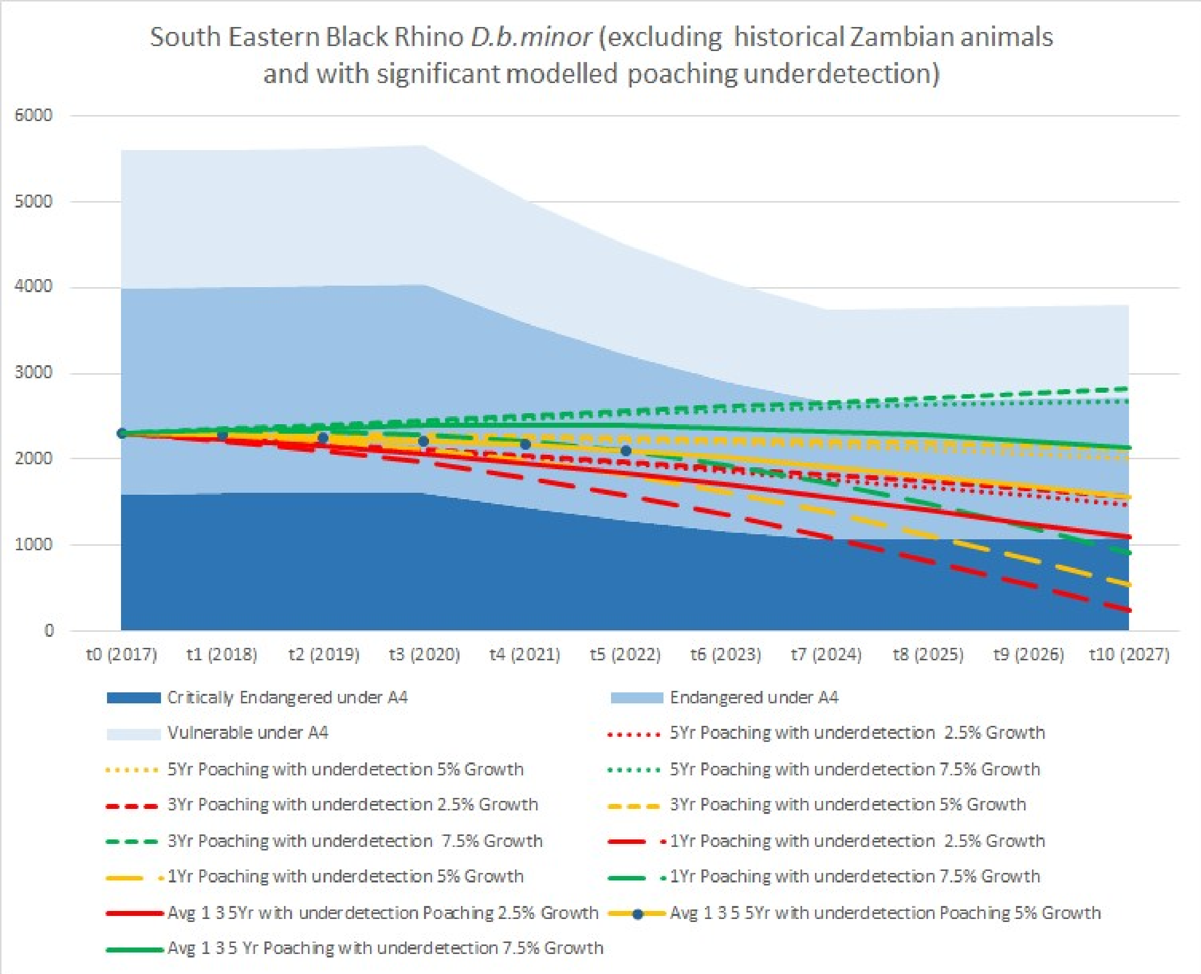

Figure 13. Projected trends in numbers of South-eastern Black Rhino assuming a 27% poaching under-detection (and actual poaching levels 37% higher than recorded levels). In this graph (for illustrative purposes) historical Zambian Black Rhino from 1973–94 were re-classified as Eastern Black Rhino. For an explanation of the graph, see the key and earlier explanatory text in methods description.

Eastern Black Rhino – *D. b. michaeli*

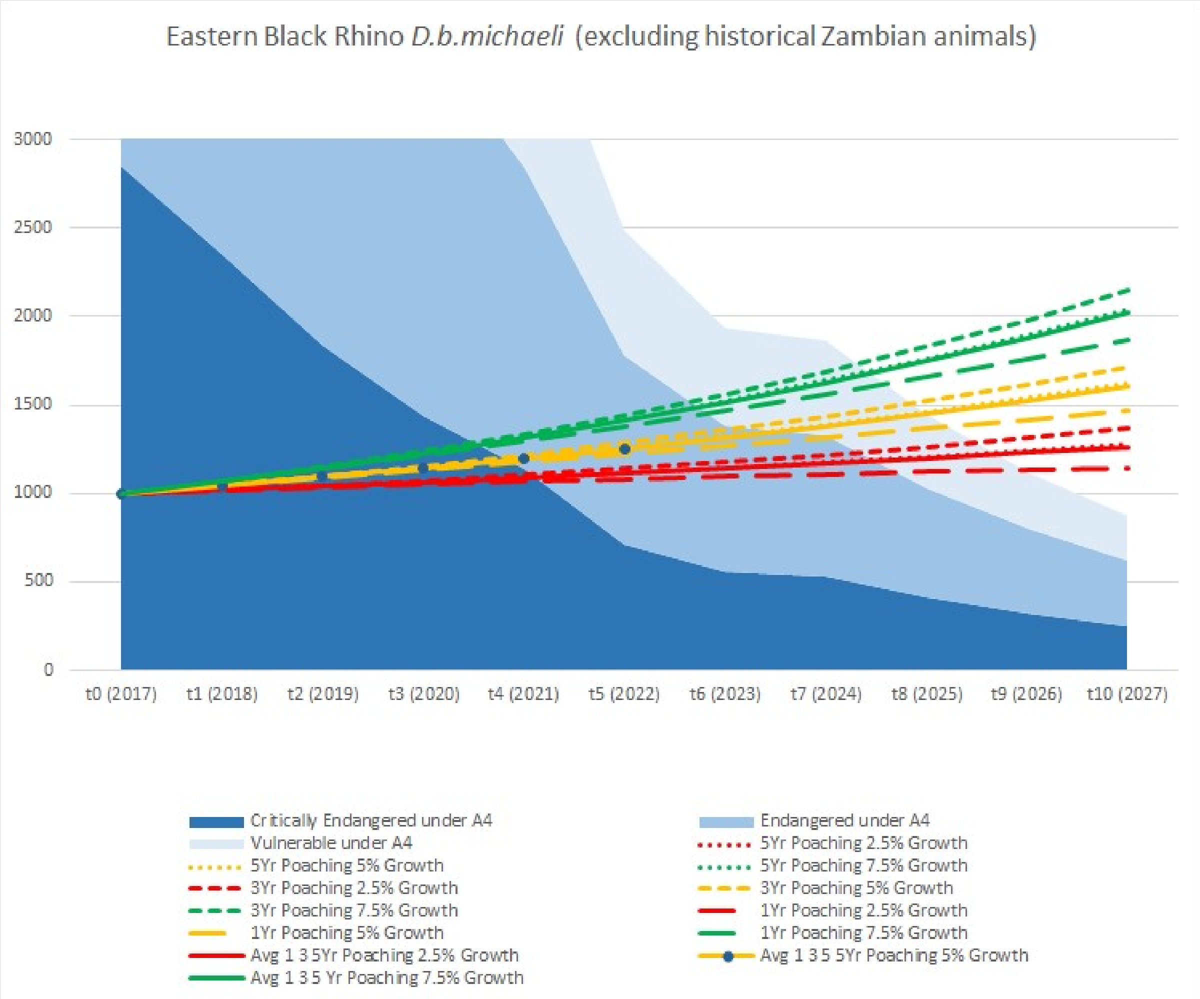

Figure 14. Projected trends in numbers of Eastern Black Rhino assuming reported poaching accurately reflects actual poaching levels (i.e. assuming no-poaching under-detection). Historical Zambian Black Rhino from 1973–94 continue to be classified as South-eastern Black Rhino. For an explanation of the graph, see the key and earlier explanatory text in methods description.

- For the reasons outlined above, for this Red List assessment, it was decided to continue to allocate the historical Zambian animals to South-eastern and not to Eastern Black Rhino. However, ***in the case of the Eastern Black Rhino, the following graphs show that how one allocates historical Zambian Black Rhino makes no difference to the current Eastern Black Rhino subspecies/genetic management cluster Red List assessment. In all cases, the Eastern Black Rhino continues to qualify as Critically Endangered under A2***.
- However ***if one assumes zero poaching under-detection, the graph above shows that the Eastern Black Rhino enters the medium blue shaded Endangered zone in t4 (by end 2021) and would qualify to be uplisted as Endangered after five years (by the end of 2026).***
- ***Projecting further into the future suggests that possibly the Eastern Black Rhino under this modelled scenario may qualify to be reassessed as Vulnerable by the end of 2029 and Near Threatened by 2031.***
- By virtue of recent lower poaching rates, the projected trends for Eastern Black Rhino are more positive than for South-eastern Black Rhino. This could of course change in future.

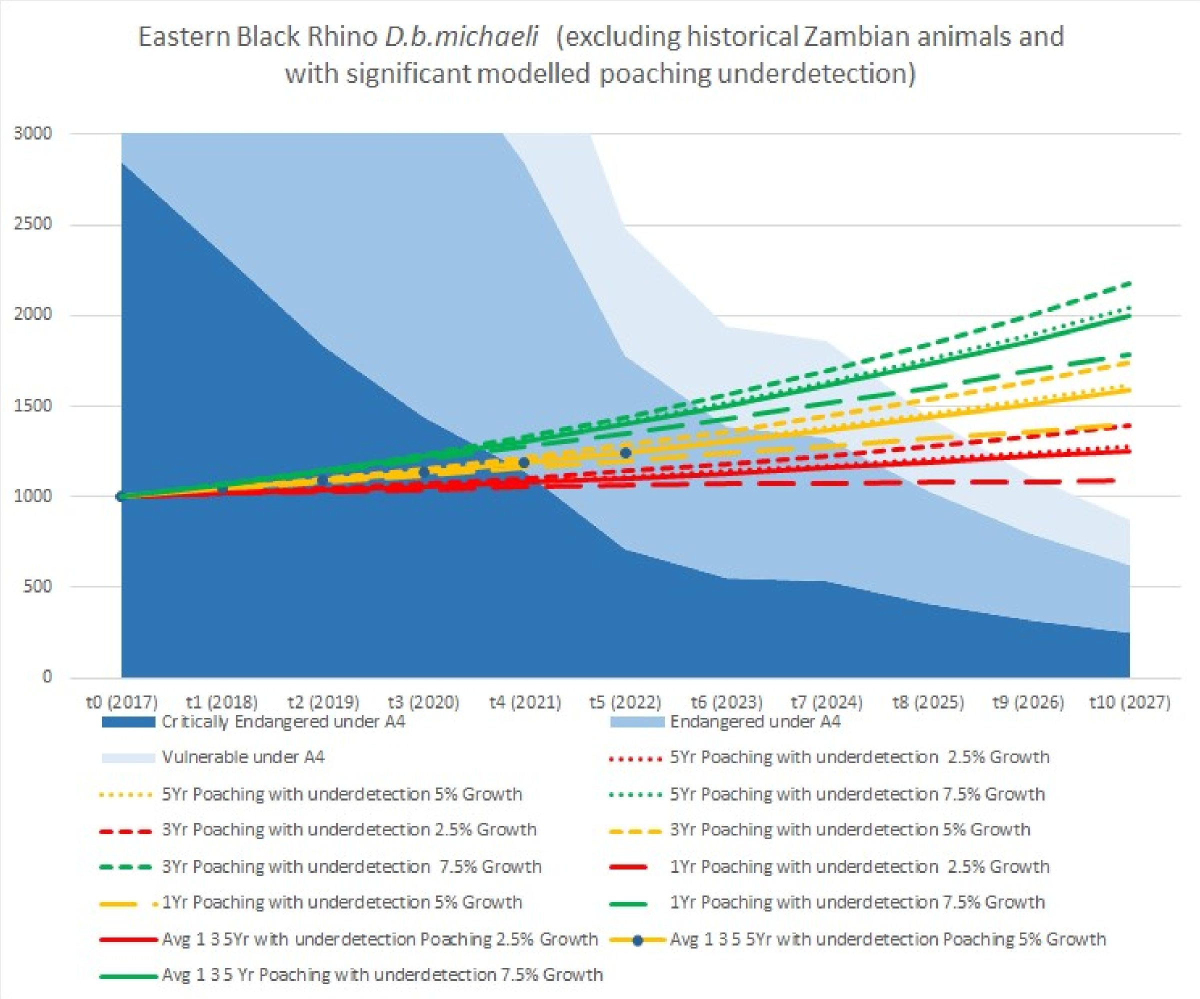

Figure 15. Projected trends in numbers of Eastern Black Rhino assuming a 27% poaching under-detection (and actual poaching levels 37% higher than recorded levels). Historical Zambian Black Rhino from 1973–94 continue to be classified as South-eastern Black Rhino. For an explanation of the graph, see the key and earlier explanatory text in methods description.

- ***There are no changes to the Red List assessment if one models significant carcass under-detection in this subspecies/genetic management cluster.***

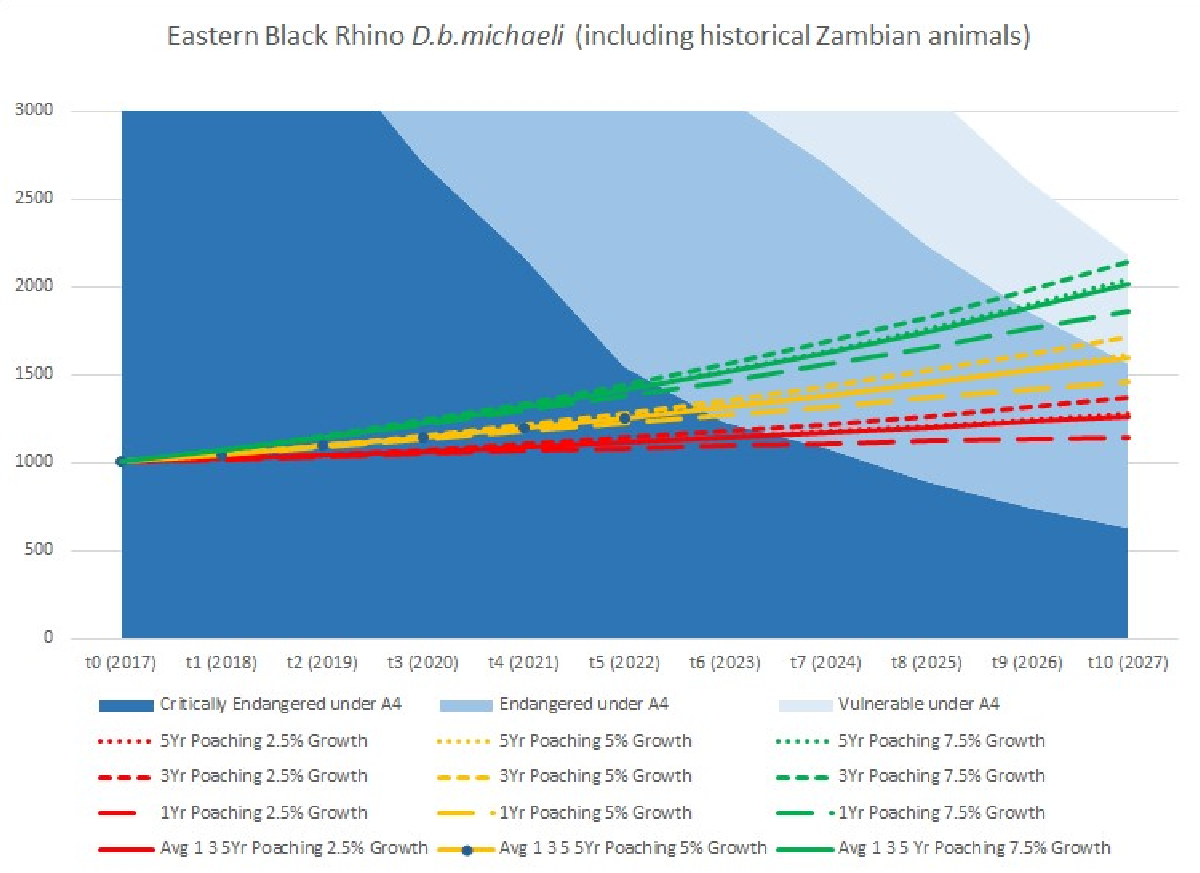

Figure 16. Projected trends in numbers of Eastern Black Rhino assuming reported poaching accurately reflects actual poaching levels (i.e. assuming no-poaching under-detection). In this graph (for illustrative purposes) historical Zambian Black Rhino from 1973–94 were re-classified as Eastern Black Rhino. For an explanation of the graph, see the key and earlier explanatory text in methods description.

- ***Even if one were to allocate historical Zambian animals to the Eastern Black Rhino, this does not change the assessment under A2 which remains Critically Endangered.***
- ***However, the subspecies/genetic management cluster would cross into the medium-blue shaded Endangered zone a year later (2023) and would qualify to be Endangered by 2028.***
- ***It also just crosses into the light-blue Vulnerable shaded zone by the end of 2027 and would thus possibly qualify as Vulnerable by the end of 2032.***
- ***In this case, the subspecies/genetic management cluster would not qualify as Near Threatened under A4 in the next 15 years.***

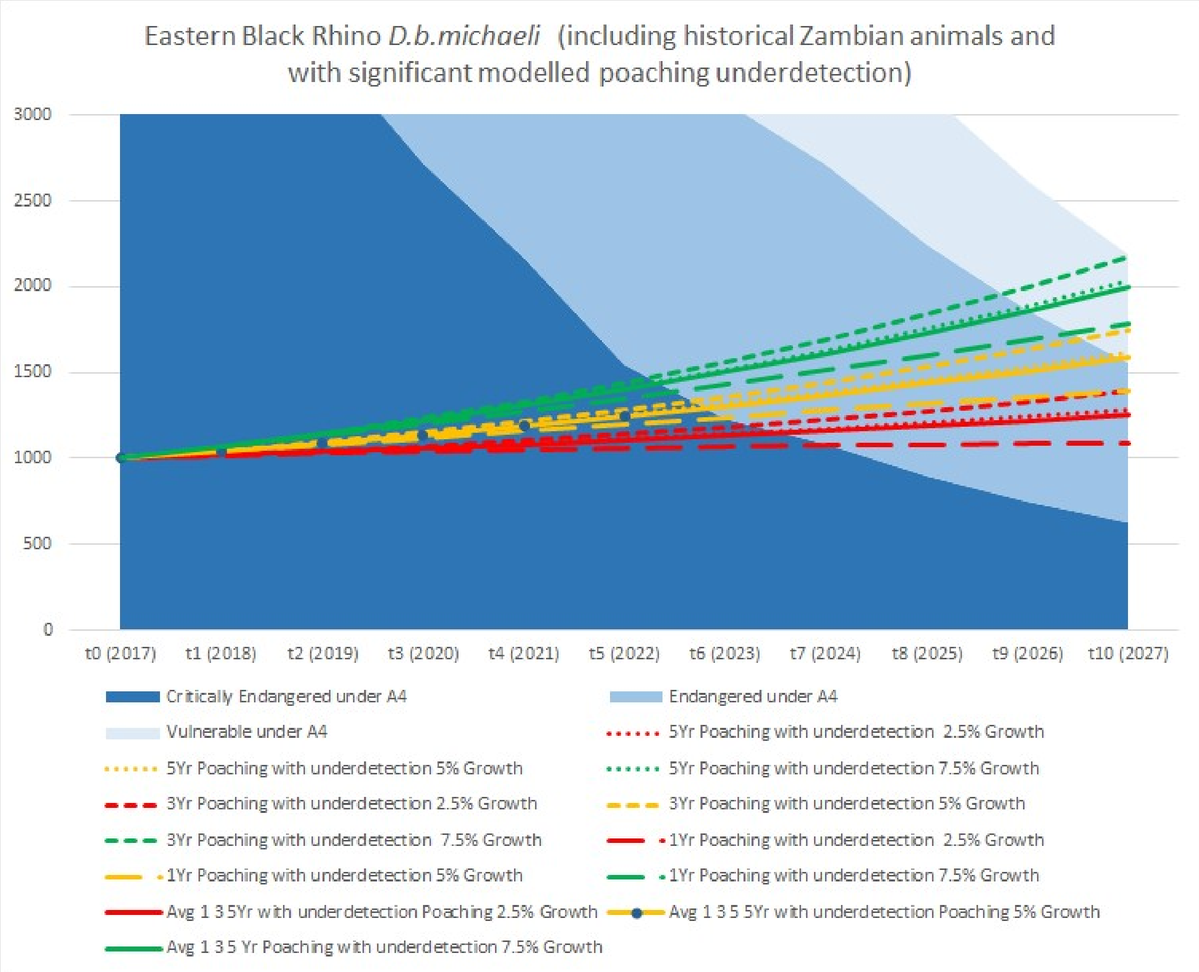

Figure 17. Projected trends in numbers of Eastern Black Rhino assuming a 27% poaching under-detection (and actual poaching levels 37% higher than recorded levels). In this graph (for illustrative purposes) historical Zambian Black Rhino from 1973–94 were re-classified as Eastern Black Rhino. For an explanation of the graph, see the key and earlier explanatory text in methods description.

- ***There are no changes to the conclusions if one models significant carcass under-detection in this subspecies/genetic management cluster.***

South-western Black Rhino – *D. b. bicornis*

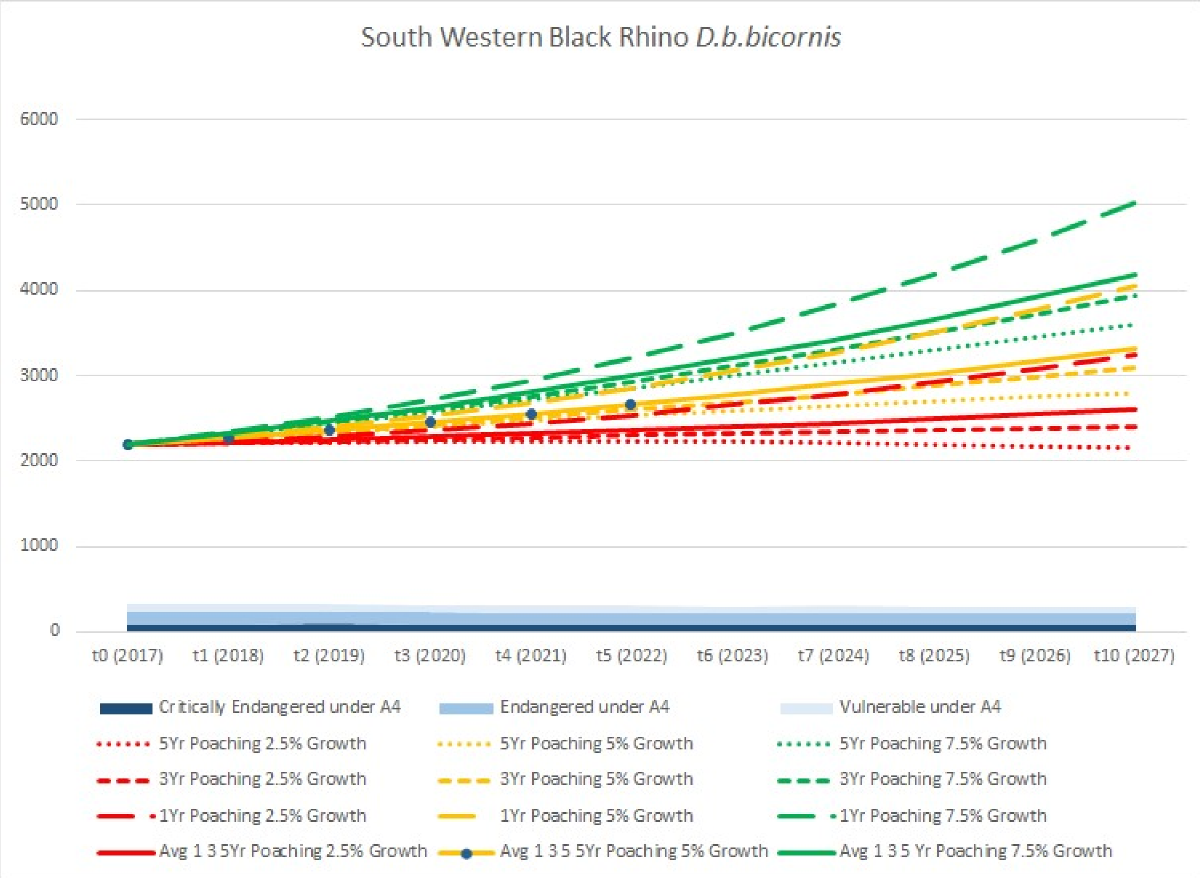

Figure 18. Projected trends in numbers of South-western Black Rhino assuming reported poaching accurately reflects actual poaching levels (i.e. assuming no-poaching under-detection). For an explanation of the graph, see the key and earlier explanatory text in methods description.

- Unlike the other two assessed surviving Black Rhino subspecies/genetic management clusters, numbers of this subspecies have shown a steady increase over the last three generations in both Namibia and more recently also in South Africa where the South-western Black Rhino has been reintroduced since 1985.
- ***Despite occurring in fewer countries and fewer subpopulations than the Critically Endangered D. b. minor; because its numbers did not decline significantly in the 1970s, 1980s and early 1990s (like the other two surviving Black Rhino subspecies/genetic management clusters) this taxon does not qualify to be rated in any of the threatened categories under criteria A2 or A4. It also no longer qualifies to be rated as Vulnerable D1 as the number of mature individuals has now exceeded 1,000 for over five years (Table 5). The subspecies/genetic management cluster instead should therefore be reassessed as Near Threatened (NT) – conservation dependent because if protection measures were removed, poaching could escalate rapidly and start to threaten this taxon. At the species-level Black Rhino remain Critically Endangered (see above).***

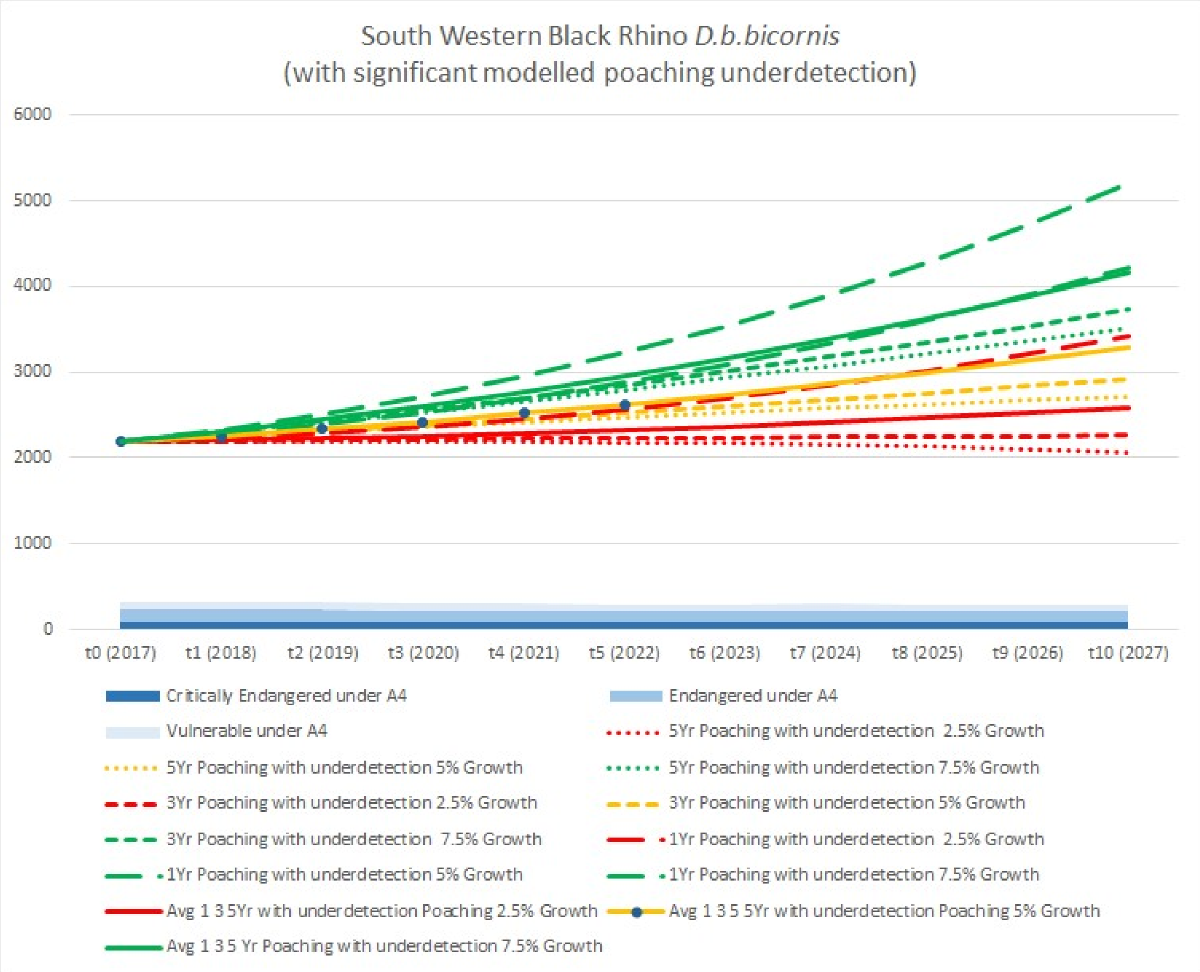

Figure 19. Projected trends in numbers of South-western Black Rhino assuming a 27% poaching under-detection (and actual poaching levels 37% higher than recorded levels). For an explanation of the graph, see the key and earlier explanatory text in methods description.

Assessments based on all Criteria

Summary of assessments under Criteria A above

In summary, the above graphs allowed for the assessment of each taxon under criteria A2 (t0) and A4 (t1 to t5). Current assessments under criterion A (with the allocation of historical Zambian animals to South-eastern Black Rhino) shown in the above graphs were as follows:

- **White Rhino - *Ceratotherium simum* - Near Threatened (Figures 4 and 5)**
- Southern White Rhino – *C. s. simum* - Near Threatened (Figures 6 and 7)
- **Black Rhino – *Diceros bicornis* - Critically Endangered (Figures 8 and 9)**
- South-eastern Black Rhino – *D. b. minor* - Critically Endangered (Figures 10 and 11)
- Eastern Black Rhino – *D. b. michaeli* - Critically Endangered (Figures 14 and 15)
- South-western Black Rhino – *D. b. bicornis* - Near Threatened (Figures 18 and 19)

N.B. The current assessments under criterion A4 were not affected by whether or not one models a significant under-detection of poaching, or whether one includes the one very large semi-wild White Rhino subpopulation in assessments.

Additional information used to assess against criteria B, C and D

The available land area of the majority (but not all) of rhino subpopulations is recorded in the AfRSG's confidential rhino numbers database. Un-usable areas such as the Pan in Etosha National Park or the Lake in Lake Nakuru National Park are not included as they do not provide rhino habitat. Summing these areas provides minimum area of occupancy (AOO) for each taxon needed to assess under criteria B2 and D2.

The number of discrete subpopulations (=locations) needed to assess under criterion B2(a) is also recorded in the AfRSG rhino numbers database. Numbers of private White Rhino subpopulations in South Africa are estimated as best as possible based on results of private land surveys, and information provided by provinces. The AfRSG treats a contiguous area where rhinos can move across or which is actively managed as a single subpopulation even if rhinos in the population may fall under different management (e.g. State or Private) or different countries. Thus, Greater Kruger Park (Kruger National Park and adjoining Private Nature Reserves) and Serengeti-Mara (Serengeti National Park, Masai Mara Reserve and Ikorongo and Grumeti Game Reserves) are treated as single subpopulations.

Table 4. Estimates of numbers of subpopulations and minimum area of occupancy (AOO) areas for different African rhino taxa (based on AfRSG data with assistance from Range States).

Taxon	Number of subpopulations	Minimum known area of potential rhino habitat
Southern White Rhino	~422	85,705+ km^2
Northern White Rhino	0 (as ex zoo animals have not bred in the wild)	N/A
White Rhino	~422	85,705+ km^2
South-eastern Black Rhino	65	103,347+ km^2
Eastern Black Rhino	20	25,916+ km^2
South-western Black Rhino	41	49,873+ km^2
Black Rhino	126	179,136+ km^2

Using the AfRSG individual population numbers database it is also possible to estimate the total number of mature individuals (as 55.8% of total estimated numbers – see above for further details), the maximum number of mature individuals in a single subpopulation, and the maximum % of mature individuals in a single population to assess under criteria C, C2a (i) and C2a(ii) as needed.

Assessments based on all criteria A, B, C and D

Table 5 summarises the results of assessments of each taxon under criteria A, B, C and D.

Table 5. Summary of Red List assessments under the different criteria.

Species/ Subspecies	Criterion A	Criterion B	Criterion C	Criterion D	Assessment
White Rhino – *Ceratotherium simum*	Does not qualify under A2 or A4 (a) and (b) – see Figures 4 and 5.	Does not qualify under B as minimum AOO of 85,705+ km^2 in 2017 greatly exceeds the 2,000 km^2 threshold and the species occurs in ~422 subpopulations and has not suffered extreme fluctuations.	Does not qualify under C as the estimated number of mature individuals (10,080) is slightly above the threshold of 10,000. However, even if numbers were to fall below 10,000 mature individuals in the near future, the species would not qualify as Vulnerable under C1 (as numbers have substantially increased over three generations). While numbers have declined by 15% from 2012–17, overall poaching has declined since 2014 and Figures 4 and 5 indicated it is not almost certain that the population decline will	Does not qualify under D as a very small or restricted population given the large number of mature individuals and over an estimated 400 subpopulations spread across multiple countries.	**Near Threatened -** conservation dependent as potentially could quickly become threatened if existing biological management, monitoring and protection efforts were stopped or significantly reduced.

			continue into the future (although it might). For example, if poaching continues to decline and underlying growth rates are high numbers may once again begin to grow. Even if White Rhino were deemed to be showing a continuing decline based on the 15% 2012–17 drop in estimated point estimates the species would not qualify under C2 as none of the additional conditions a(i), a(ii) or b are met. There are more than 1,000 mature individuals in two wild subpopulations, and there are many subpopulations.		
Southern White Rhino – *C. s. simum*	As above – see Figures 6 and 7	As above	As above	As above	**Near Threatened -** conservation dependent as above

Northern White Rhino – *C. s. cottoni*	**Critically Endangered (Possibly Extinct in the Wild) under A2abcd** No sign of any surviving animals in Garamba NP or surrounding areas since 2007. There has been no confirmation of possible rumoured surviving individuals in Sudan, The ex Zoo animals taken to the wild in Kenya (while mating) have not produced any offspring in the wild. Only two non-breeding females survive. The subspecies is functionally extinct in the wild. The only hope of conserving *C. s. cottoni* genes depends upon successfully developing and using assisted reproductive techniques (ART's) with stored	**AOO unknown as potential range in South Sudan still has to be surveyed.**	**Critically Endangered (Possibly Extinct in the Wild) under C1, C2a(i) and C2a(ii).**	**Critically Endangered (Possibly Extinct in the Wild) under D.**	**Critically Endangered (Possibly Extinct in the Wild)** **A2abcd;** **C1+2a(i (ii);** **D.**

	reproductive material. This will include embryo transplantation into surrogate Southern White Rhino cows. These ART's are still in development, but some progress has been made. Even if successful, it will take a long time before any animals with *C. s. cottoni* genes could ever be re-introduced back into the wild.				
Black Rhino – *Diceros bicornis*	**Qualifies as CR under A2 (a) (b) and (d) and A4 (a) (b) and (d).** See Figures 8 and 9.	Does not qualify under B as minimum AOO of 179,1365+ km^2 in 2017 greatly exceeds the 2,000 km^2 threshold and the species occurs in 126 subpopulations and has not suffered extreme fluctuations.	While there are an estimated 3,066 mature individuals (<10,000 threshold) **the species would qualify as VU under C1** as rhino numbers have declined by over 10% over three generations (from an estimated 37,807 to 5,495). It does not qualify under C2 as the population Has been increasing for many years - more than doubling since bottoming	Does not qualify as a very small or restricted population given there are more than 1,000 mature individuals.	**Critically Endangered A2abd+4abd.**

			out in the mid-1990s and projections suggest a continued increase rather than decline.		
South-eastern Black Rhino – *D. b. minor*	**Qualifies as CR under A2 (a) (b) and (d) and A4 (a) (b) and (d).** See Figures 10 and 11.	Does not qualify under B as minimum AOO of 103,347+ km^2 in 2017 greatly exceeds the 2,000 km^2 threshold and the subspecies occurs in 65 subpopulations and has not suffered extreme fluctuations.	Given an estimated 2,305 South-eastern Black Rhinos in 2017, the estimated 1,286 (55.8% of 2,305) mature individuals is <2,500. However, the subspecies does not qualify to be assessed as EN under C1 as the estimated number (2,305) just exceeds the threshold number of 2,226 that would represent a 20% decline in total numbers over two generations (given an estimated 2,783 rhino in 1988). This difference above the threshold level under C1 for EN of 79 rhinos (+3.5%) is just bigger than the approximately ± 2.8% 95% confidence levels around 2017 total Black	Does not qualify as a very small or restricted population given there have more than 1,000 mature individuals since 2004	**Critically Endangered[27] A2abd+4abd.**

[27] As discussed earlier would potentially qualify as Endangered if the historical Zambian numbers from 1973–94 were allocated to Eastern Black Rhino

			Rhino estimates. **The population would, however, qualify as VU under C1** as the 2017 population estimate is well below the three generation 10% decline threshold estimate of 17,995 (given an estimated 19,994 in 1973). Overall numbers have increased by over 1,000 from an estimated low of 1,218 in 1994. However, if one assumes a significant poaching under-detection Figure 9 suggests numbers of this subspecies may well decline slightly in future (Figure 9). With recent increases in continental numbers the subspecies may not almost certainly experience a continuing decline in future and therefore probably does		

			not qualify under to be rated VU under C2. The largest subpopulation in 2017 was estimated to have just over 250 mature individuals and so this the subspecies does not qualify as either EN or VU under C2a(i).		
Eastern Black Rhino – *D. b. michaeli*	**Qualifies as CR under A2 (a) (b) and (d) and A4 (a) (b) and (d).** See Figures 14 and 15.	Does not qualify under B as minimum AOO of 25,916+ km^2 greatly exceeds the 2,000 km^2 threshold and the species occurs in 20 subpopulations and has not suffered extreme fluctuations.	Given an estimated 1,022 rhinos in 2017, the estimated 559 mature individuals is <2,500. However, estimated numbers have almost doubled over two generations from 524 in 1988 to 1,002 in 2017 so it does not qualify for assessment as EN under C1. Despite no subpopulations having over 250 mature individuals it also does not qualify under C2a(i) as numbers have been increasing since the mid-1990s rather than	**Qualifies as VU under D1** as there are only an estimated 559 mature individuals.	**Critically Endangered A2abd+4abd.**

			declining and numbers are also projected to continue increasing in future (Figures 14 and 15).		
South-western Black R**hino** – *D. b. bicornis*	Does not qualify under A2 or A4. See Figures 18 and 19.	Does not qualify under B as minimum AOO of 49,873+ km^2 in 2017 greatly exceeds the threshold 2,000 km^2 and the species occurs in 41 populations and has not suffered extreme fluctuations.	While the estimated 1,221 mature individuals in 2017 is less than the threshold 2,500 the population of 2,188 does not qualify under C1 as it has increased over the last two and three generations from an estimated 498 and 456. Despite no populations having over 250 mature individuals under C2a(i) it also doesn't qualify under C2, as the population has been increasing rather than declining and numbers are also projected to increase in future (Figures 18 and 19.	**No longer qualifies as VU under D1** as there have been more than 1,000 mature individuals for more than five years.	**Change from Vulnerable under D1 to Near Threatened** – conservation dependent, as it potentially could quickly become threatened if existing biological management, monitoring and protection efforts were stopped or significantly reduced.
Western Black Rhino - *D. b. longipes*					**Extinct** – no individuals remain in the wild or in captivity.

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