Population dynamics of the White Rhino at Rockwood Conservation

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07/11/2022, Ede

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Research Report

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Major: Applied Biology

Photos front cover
All photos are taken by staff from Rockwood Conservation, 2021

Preface

This research proposal is commissioned by Aeres University of Applied Sciences as a bachelor thesis.

My name is Myrthe Bakker, last year student of the study Applied Biology. I have written my bachelor thesis in cooperation with Rockwood Conservation to get a better view of their rhino population dynamics.

This report is written for the staff of Rockwood, wildlife conservationists and anyone who is interested in this subject.

I would like to thank Danny Merién for supervising me and providing feedback, Ciska Scheijen for providing me with this research, the information about Rockwood and the feedback. Also Amy Oostveen for doing a thorough language check and Tineke Kraan for feedback. Lastly, I would like to thank my fellow students for providing feedback as well.

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Abstract

The white rhino is a keystone species and an ecosystem engineer. Though there have been conservation efforts to protect this species, the current red list status of the white rhino is "Nearly threatened". The biggest threat that rhinos are facing nowadays is poaching for their horns. The rhino population in the South Africa National parks are declining, mostly due to the aforementioned poaching. In contrast, the populations of white rhinos on private land have been growing in the last couple of years. However, it is getting harder for private owners to keep rhinos due to high security costs and threats to the owner's safety. Also, the South-African government may be enacting a law that will no longer allow the keeping of rhinos in an intensive-managed system. One of the private game reserves where the population of white rhinos has grown over the last couple of years is Rockwood Conservation. The population growth shows that there could be differences in population dynamics between Rockwood's system and a more natural system with less management. Therefore, the aim of this study was to gain a clearer understanding of the population dynamics of Rockwood's white rhino population and compare these dynamics with more natural parks/reserves.
The methods were divided into two parts: an analysis of Rockwood's data and a literature study. During the data analysis, several reproductive performance parameters were calculated. The literature was done to compare data with similar studies. The results of the birth parameters were somewhat conflicting, with a high age at first calving and low inter-calf interval. Few rhinos died at Rockwood, most of which were calves. The population grew steadily over the course of this study. The literature study was faced with limitations due to the absence of existing literature on this topic. Some of the reproductive performance parameters could not be included in the literature study. This lack of literature highlights the importance of this study.
Overall, the results of this study, when compared to other studies, showed signs of a population that is growing very well.
Though these results imply that the population at Rockwood is growing faster than at other parks/reserves, further investigation is needed to draw a well-rounded conclusion. It is recommended to share information between parks to gain more insight of how population dynamics differ and to do further research.

Samenvatting

De witte neushoorn is een belangrijke diersoort en een ecosystem engineer. Hoewel er inspanningen zijn geleverd om deze soort te beschermen, is de huidige status van de witte neushoorn op de rode lijst "Near threatened". De grootste bedreiging waarmee neushoorns tegenwoordig worden geconfronteerd is stroperij voor hun hoorn. De neushoornpopulatie in de nationale parken van Zuid-Afrika neemt hierdoor af. De populaties witte neushoorns van privé eigenaren zijn daarentegen de laatste jaren toegenomen. Voor particuliere eigenaren wordt het steeds moeilijker om neushoorns te houden vanwege de hoge beveiligingskosten en bedreigingen voor de veiligheid. Bovendien is er momenteel een wetsvoorstel van de Zuid-Afrikaanse regering die ervoor zou zorgen dat het particulier houden van neushoorns niet weer wordt toegestaan. Eén van deze particuliere eigenaren waar de populatie witte neushoorns is gegroeid, is Rockwood Conservation. Deze populatiegroei suggereert dat er verschillen kunnen zijn in populatiedynamiek tussen het systeem van Rockwood en een meer natuurlijk systeem. Daarom was het doel van deze studie om een duidelijker inzicht te krijgen in de populatiedynamiek van de witte neushoornpopulatie van Rockwood, en deze te vergelijken met meer natuurlijke parken/reservaten. De methoden waren verdeeld in twee delen: analyse van de data van Rockwood en een literatuurstudie. Tijdens de data-analyse werden verschillende parameters voor reproductieve prestaties berekend. Bij het literatuuronderzoek werd gezocht naar vergelijkbare studies. De resultaten voor de geboorteparameters lieten enigszins tegenstrijdige resultaten zien, met een hoge leeftijd bij age at first calving en een laag inter-calf interval. Tijdens de studieperiode stierven er niet veel neushoorns op Rockwood en de meeste waren kalfjes. De populatie groeide gestaag gedurende de studieperiode. Tijdens de literatuurstudie bleek dat er zeer weinig literatuur over dit onderwerp beschikbaar was, dus er is niet veel vergelijkingsmateriaal gevonden. Sommige parameters voor de voortplantingsprestaties konden bijvoorbeeld niet in de literatuurstudie worden opgenomen. Over het algemeen vertoonden de resultaten van deze studie, in vergelijking met andere studies, tekenen van een populatie die zeer goed groeit. Hoewel deze resultaten impliceren dat de populatie in Rockwood sneller groeit dan in andere parken/reservaten, is verder onderzoek nodig om een goed onderbouwde conclusie te kunnen trekken. Het wordt aanbevolen om informatie tussen de parken uit te wisselen om een beter beeld te krijgen van de verschillen in populatiedynamiek en om meer onderzoek te doen.

1. Introduction

Humans benefit in several ways from a healthy ecosystem and the species providing ecosystem services. Examples are; providing food (pollinators), nutrient cycling (freshwater mussels and oysters) and disease control (large herbivores). Furthermore, species play an important role in balancing an ecosystem which humans are dependent on (Gauscon et. al, 2015). However, worldwide many species are going extinct at an accelerating rate due to anthropogenic threats like climate change, habitat loss for agriculture, invasive species and poaching. Up to one million species are threatened with extinction (United Nations, 2020).
The white rhino (*Ceratotherium simum*) is a megaherbivore and an example of an animal that plays a significant role in its ecosystem (Owen-Smith, 1988). According to Owen-Smith (1988) the term megaherbivore includes plant-feeding mammals that attain an adult body mass of at least 1000kg. The size of these animals makes them rather immune to (non-anthropogenic) predation. Moreover, the amount of food the megaherbivores eat allows them to tolerate low quality foods (Owen-Smith, 1988). White rhinos are terrestrial grazers and have a distinct way of foraging in comparison to other megaherbivores. For example, African elephants (*Loxodonta africana*) are browsing megaherbivores. The hippo (*Hippopotamus amphibius*) and the Indian rhinoceros (*Rhinoceros unicornis*) are the only other grazing megaherbivores. However, Indian rhinoceroses also eat seasonal browse and fruit, and the range of the hippo is limited to areas that are only a few kilometres from the water. That makes the white rhinoceros the only terrestrial grazing megaherbivore (Waldram et al., 2008).
The white rhino influences its ecosystem in several ways: by grazing the grasslands they keep the grass short which positively affects the fuel loads for fires (Waldram, 2005; Waldram et al., 2008). The fires become more patchy and shorter and therefore have less impact on the landscape (Waldram et al., 2008). Moreover, the white rhino is suggested to have an impact on other grazers, facilitating those grazers in one area and competing with them in another (Hayes, 2019). The grazing creates and maintains stable short grass habitats (Malmström, 2019) that facilitate other species such as birds and insects (Hayes, 2019), influences the soil and water composition (Veldhuis et al., 2014) and lastly, alters the landscape (Cromsigt & te Beest, 2014). Therefore, the white rhino is considered an ecosystem engineer and keystone species (Waldram et al., 2008).
The white rhino occurs in eleven different countries in Africa, with the majority of rhinos (99,3%) living in only five of these countries. South-Africa has by far the biggest number of white rhinos, followed by Kenya, Namibia, Botswana and Zimbabwe (Emslie et. al., 2019). Emslie (2020) assessed the current conservation status of the white rhino for the IUCN. This report states that there are an estimated 10,080 white rhinos living in the wild and that the population trend is decreasing. The white rhino is assessed to be Near Threatened due to the high poaching trend that continues to prove difficult to combat. The illegal demand for the rhinos' horn in South-East Asia is high and there is an involvement of international organized crime in the poaching (Emslie, 2020). Not only does poaching have a direct impact on the white rhino populations by killing, it also has an indirect effect, as their lifetime reproductive potential decreases. An adult female rhino can have about 6 calves in a lifetime, but with the recent poaching trends, this number drops to 0.7 calves. Correspondingly, when the mother of a calf has been poached, the calf will most likely die from predation, overheating, dehydration or hunger, depending on the calves' age. When taking this into account, together with the adults being poached, the lifetime reproductive potential of a female rhino is reduced to 0.5 calves, which is not high enough to sustain a population (Nhleko et al., 2021).
In addition to the poaching, South Africa experienced a severe drought and a strong El Niño event that lasted from 2015 to 2016 (Baudoin et. al., 2017). This also had an impact on the

decline in the white rhino numbers. Due to this drought the mortality rates increased and the birth rates decreased even further. This caused a disturbance in population dynamics and played a significant role in population decline (Ferreira et al., 2019). Malherbe et. al., (2020) stated that, given the observed and predicted trends in temperatures, it is possible that the type of drought that occurred in 2015/2016 will occur more frequently (Malherbe et. al., 2020). Other studies have shown that due to climate change, Terrestrial Water Storage may decline, especially in the Southern hemisphere. This decline translates in future droughts (Pokhrel et. al., 2021).

From 1992 to 2010, conservation efforts led to an increase in white rhinos numbers with an average of 7.1% population growth. However, due to the increase of poaching, this trend started slowing down in 2010, and numbers started declining again in 2012 and onwards. An important factor of the decline from 2012 and 2017 was a population decrease in the largest population, which resides in Kruger National Park (KNP) in South-Africa. During this period, the KNP population dropped by an estimated 51%, whereas it dropped 26% in other state-run parks and private game reserves. The main cause of this was poaching or translocation to avoid poaching (Emslie et. al., 2019).

In contrast, the populations of white rhinos on private land have been increasing in the last couple of years. Many of these private owners supplementary fed their rhinos during the drought. This resulted in lower mortality rates and higher birth rates compared to the parks that did not do this. The rhinos in these private parks are often well protected by security, making it harder for poachers to get into these reserves (Emslie et. al, 2019; Emslie, 2020). However, the price for a live white rhino dropped significantly around 2016-2017 (Clements et. al., 2020). The security costs are high and the owners get little funding for conservation. Furthermore, without well-structured security measures in place, private owners fear for their own safety as well as that for their family and staff as poachers have killed rangers and owners to get access to the animals (Personal communication with Scheijen, October 14th, 2022; The New York Times, 2022). The high costs, combined with safety issues, has resulted in private owners trying to get rid of their rhinos (Emslie et. al., 2019).

There is a possibility that the South-African government will be enacting a law that will no longer allow the keeping of rhinos in an intensive-managed system (Personal communication with C. Scheijen, August 23, 2021; The Daily Maverick, 2021). If this law comes into effect, then it will be a lot harder for private owners to keep the rhinos healthy as well as safe from poachers.

Though many measures are taken to put a stop to poaching, and the number of rhinos at private reserves is growing, the overall white rhino population is still declining, mainly because of losses in national parks. Haas & Ferreira (2015) have created a model that sought to predict the extinction of the white rhino. In this model, there is no legal horn trade, but legal live rhino trade and legal hunting are included. It predicted that, with the current scenario of small populations and an onslaught of poaching, white rhinos will be extinct by 2036 (Haas & Ferreira, 2016).

One of the private game reserves where the population of white rhinos has been growing, is Rockwood Conservation. Rockwood was founded in 2013 with the goal to protect the rhino and other endemic species. The rhinos in this reserve are in a managed system where there is 24 hours security (Rockwood Conservation, 2019). The rhinos are semi-wild and receive supplementary food (Personal communication with C. Scheijen, October 8, 2021). In 2013, a group of rhinos were translocated from Kruger NP to Rockwood. In contrast with the overall decline of the white rhino in more natural environments, this group from Kruger has tripled over the last 8 years due to the breeding at Rockwood. (Personal communication with C. Scheijen, august 23, 2021; Rockwood Conservation, 2021).

This contrast in population growth shows that there must be differences in population dynamics between the system Rockwood uses, and a more natural system where there is no supplementary feeding and less security. However, it is still unclear what these differences are exactly and which factors play into it. To prevent further population decrease, it is important to understand the differences in systems and their population dynamics.

The aim of this study is to gain a clear picture of the population dynamics of Rockwood and to compare these with systems that are not as managed, such as: Kruger National Park. This study can help generate management goals in the future for Rockwood. Furthermore, other conservationists/reserves can use this research to compare their own population dynamics and management. The outcomes of this study can be used to show the importance that managed systems may have to the conservation of the white rhino.

Following the aforementioned aim of this study, the research question for this paper will be:

How do the white rhino population dynamics differ between Rockwood and other game reserves in South-Africa from 2013 to august 2021?

The following sub questions will help answer the research question:

- Q1: What are the annual birth rates at Rockwood compared to other game reserves?
- Q2: At what age do the female rhinos at Rockwood get their first calf compared to other game reserves?
- Q3: How many months are there between each calving compared to other game reserves?
- Q4: What are the annual mortality rates and their causes at Rockwood compared to other game reserves?
- Q5: How many white rhinos die before they are sexually mature compared to other game reserves?
- Q6: Are there differences in age structure compared to other game reserves?

It is expected that the mortality rate at Rockwood is lower and that the birth rate is higher, due to differences in security (against poaching) and by providing supplementary feed. Moreover, it is expected that there is a shorter inter-calf period and that the females will get their first calf at a younger age. Lastly, it is expected that fewer rhinos die before they are sexually mature and that the population mainly consists of adults.

2. Methods

In this chapter, the methods are explained. Both a literature study and data analyses were conducted. In 2.1, the study area is described, chapter 2.2 contains information about the white rhino, chapter 2.3 describes the data collection, 2.4 explains how the literature review was done and chapter 2.5 describes how the data was analysed.

2.1 Study area

Rockwood is a private game reserve of approximately 12500 hectare, located approximately 180 km west of Kimberley, South Africa. Up until august 2021, Rockwood had 299 rhinos, consisting of 176 females and 123 males (Unpublished data from Rockwood, 2021). The exact location and management of the rhinos are not shared for safety and security reasons. Rockwood's security system has changed 3 times since they were founded. First, security was provided by an outsourced company. Then, Rockwood hired their own rangers who provided 24/7 security in the field. Nowadays, the rangers stay in the field during the day, and at night there are rangers in the field as well as camera security (including infra-red). The camera footage is supervised by rangers from a control room. The rangers in the field move mainly on horseback (Personal communication with Scheijen, October 3rd, 2022).

For the rhinos there are four different breeding camps, and one bachelor camp.
In this system, there is also a big variety of naturally occurring wildlife and game species. The game species are part of the ecosystem and important for ecotourism and hunting (Personal communication with Scheijen, November 22nd, 2021; Furstenburg, 2019).

Each breeding camp has three breeding bulls and the camps are sectioned with fences. Every three months, the rhinos are rotated to a different area within the camps to manage internal parasites and food supply. This is done by using bomas (see Figure 1). These bomas are passive capture and handling facilities designed for megaherbivores, surrounded by fences. They are crossed structures averaging 4 ha, and 1 ha per handling pen. The number of handling pens within a boma is different per camp. 200 meters around the bomas are cleared from vegetation to limit health risks from diseases and parasites, as well as security management (Personal communication with Scheijen, November 22nd, 2021; Furstenburg, 2019).

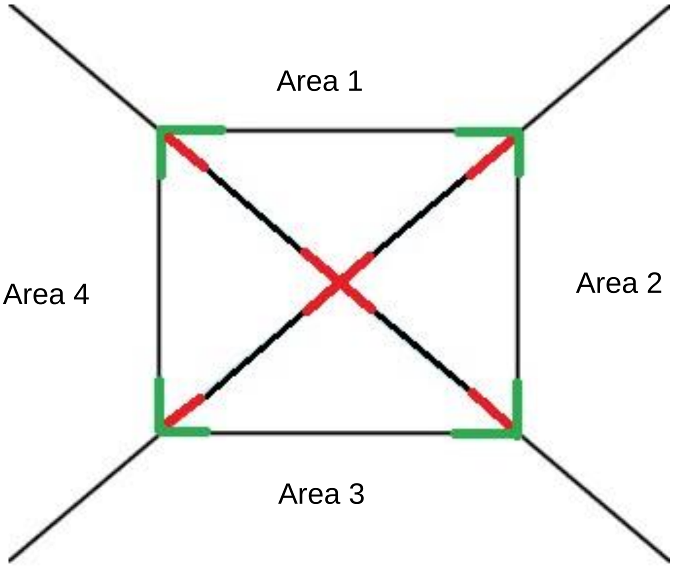

Figure 1: Drawing of a boma used to rotate rhinos to different areas in a camp. The black lines are fences that cannot be opened. The green lines are sliding fences that can open and close. These give the rhinos access from an area to the boma.
The red lines are fences that can also open and close. These give the rhino access to areas within the boma and are normally always open. These fences can close (creating a handling pen) if an individual needs to be separated from the group (in case they need veterinary care for example).

2.2 Study species

The white rhino is the second largest terrestrial mammal after the elephant. White rhinos are dimorphic. Grown males can reach a height of 1.85 metres and 2400kg. Adult females are smaller and can weigh about 1700kg. White rhinos have two horns, the front horn larger than the rear horn. White rhinos are social animals. Observations in the Umfolozi Game Reserve showed that females are accompanied by their offspring or by a few sub-adults, usually sisters. Males often roam alone, except when the females are in heat, this is when the males can also be found with females (Owen-Smith, 1975). These animals can live approximately 40 years in the wild. Females become fertile at the age of 4-5 years, but do not reproduce until the age of 6-7. After about 16 months of gestation the female usually gives birth to one calf, then there is a period of 2-3 years before the females get another calf. On average, males start reproducing at the age of 10-12 years old (WWF, 2020; Rhino review, 2021). The white rhino can be found in short grass areas (figure 2), with thick bushes for cover and water. These animals inhabit a wide range of woodlands if there is enough food and water (Stuart & Stuart, 2007).

Figure 2: Rhinos in their habitat, (n.d.). Pxhere.
https://pxhere.com/en/photo/650370

2.3 Data collection

The data was collected by the staff of Rockwood between the beginning of 2013 and august 2021. The data contains information about each rhino at Rockwood: studbook number, birth date (some are estimates), place of birth (some rhinos are bought from other parks), permit & year (if the rhino was bought), breeding status, sex, date and cause of mortality, and the studbook numbers of the parents. The raw data cannot be shared in this report for the safety of the rhinos.

2.4 Literature study

The available data from Rockwood was compared with data from other game reserves and national parks. The information of these parks was obtained by doing a literature review. This information came from various but reliable sources such as annual reports from SANparks (South-Africa National parks) and peer reviewed articles from either universities or scientific journals. The search engines that were used for the literature review can be found in Table 1.

Table 1:Search engines for searching literature

Search engine	Weblink
Google	https://www.google.nl/
Google Scholar	https://scholar.google.nl/
Sciencedirect	https://www.sciencedirect.com/
Green I	https://www.greeni.nl/iguana/www.main.cls?surl=greeni&theme=greeni
Wiley Library	https://onlinelibrary.wiley.com/
Springer Link	https://link.springer.com/
Koedoe (African protected area conservation and science)	https://koedoe.co.za
Sabinet (African journals)	https://journals.co.za
South-Africa National parks	https://www.sanparks.org/

To find the right literature, certain terms have been selected to be used for the literature review. These terms have been selected to answer the sub questions. Table 2 shows which searching terms were used for the literature review.

Table 2: Terms for searching literature

Searching terms	
Commonly used terms	**Composition of terms**
***Ceratotherium simum* and/or White Rhino**	*Ceratotherium simum:* - Population trends - Population dynamics - Population growth - Birth rates - Mortality rates - Inter-calf interval - Reproduction - Reproductive performance parameters - Reproduction rates - Reproduction parameters - Age structure - South Africa - Management - Poaching - Disease

To make sure that the literature that was found was eligible for the research and to maintain the quality of the report, certain criteria were selected. These criteria can be found in table 3.

Table 3: Selection criteria for found literature

Searching criteria	
Not useable	**Useable**
Scientific reports that are not peer reviewed	Reports from national parks on the population dynamics (these are excluded from the peer-reviewed rule)
Reports that do not contain information on population dynamics	Annual reports from national parks that contain information on population dynamics (these are excluded from the peer-reviewed rule)
Reports that contain the needed info but are not written professionally.	Peer reviewed reports or published in a journal
Reports that are not written in Dutch, English and Afrikaans.	Report is found on one of the selected websites or found on a professional website within this field
	Reports that are written in Afrikaans and can be understood by the writer of this report.

The amount of literature needed to make a decent comparison is still undecided. An orientating search for literature has been done prior to this study. During this quick search, it became clear that there are not many reports on population dynamics in less managed reserves. So, it has been decided that as many useable reports as possible will be used for this study.

2.5 Data analysis

To analyse the data Rockwood has provided, descriptive statistics were used with the following parameters:

The birth rate (BR) is defined by the number of calves born annually, relative to the population, in percentages. In this parameter, males and females are separated. The birth rate is represented as a bar graph.
The age at first calving (AFC) is defined as the number of months between confirmed birth date and first calving date. There was some data available of AFC's outside Rockwood, from females that have been bought, but this data has been removed since the study period is 2013- august 2021. For this parameter, the average AFC was calculated for each year. The age at first calving is represented in a scatter plot.
The inter-calf interval (ICI) is defined by the mean number of months between two subsequent calvings. To calculate this interval, only females who had two or more calves during the study were used (Hitchins & Anderson, 1983: Truter, 2021). To determine the ICI for each cow, the total number of months was divided by the total number of calvings.
Mortality rate (MR) is defined by the percentage of the population that died annually. In this parameter, males and females are separated. Mortality rate is represented in a bar graph.
Mortality cause (MC) is divided in categories, these are: cause unknown, died in a fight, stillborn, sickness and poaching. In this parameter, males and females are combined.

Mortality cause is represented in a pie graph.
The premature death rate (PDR) is defined by the annual number of animals that have died before they were sexually mature (five years). In this parameter, males and females are separated.

Age structure (AS) is divided into three categories: calf (0-2 years), sub-adult (2 to 5 years) and adult (+5 years). The annual frequency of each category is calculated as well. There is no distinction in sex for this parameter.
To give an overall view of the population, the population growth was calculated. This was calculated by the formula used by Monks (1995) and rewritten by Truter (2021): *r = (Pres pop/Prev pop)^(1/N)-1.* In this formula, *r* equals population growth, *Pres pop* means the number of rhinos present for the chosen year, *Prev pop* means the population of the previous year and *N* stand for number of years, starting from 2013. In order to calculate the population size, 3 variables were used: births, the number of rhinos born annually, mortality, the amount of rhinos that died annually and bought, the amount of rhinos that were bought annually. There was no distinction between males and females for this parameter. The population size is represented in a bar graph, the population growth is included as a line graph.

During the literature study, there was a search for similar statistics on the population dynamics and information on the management of other parks. Specifically, if the rhinos get supplementary food, whether there is security to prevent poaching and if the rhinos receive veterinary care. Both the statistics and the management information are described and compared in the results section. Most of the parameters (BR, AFC, ICI, MR, PDR, AS) are compared by either mean, or median, upper quartile and lower quartile. For the MC, the categories and how many rhinos died in this category, is also compared.

3. Results

In this chapter, the results of both the data analysis and the literature research are shown. In paragraph 3.1 the data analysis is shown and explained. This paragraph is divided into three more sub paragraphs: 3.1.1 Birth parameters, where the results of the birth rate, age at first calving and inter-calf-interval are shown and explained. 3.1.2 Mortality parameters, where the results of the mortality rate, mortality cause and premature deathrate are shown and explained. 3.1.3 Herd parameters, where the herd size, growth and age structure are analysed and explained. In paragraph 3.2, the results of the literature study are described. In sub paragraph 3.2.1 the results for the birth and herd parameters . In sub paragraph 3.2.2 the results for the mortality parameters.

3.1 Data analysis

3.1.1 Birth parameters

Figure 4 shows the annual birth rate, relative to the population size each year. In total, 178 rhinos were born at Rockwood from 2013 to august 2021, 78 females and 100 males. The birth rate was highest in 2016, and lowest in 2015. Overall, more males were born each year, except for 2015 and 2017. The minimum birth rate was 7,87% and the maximum birth rate was 18,69%

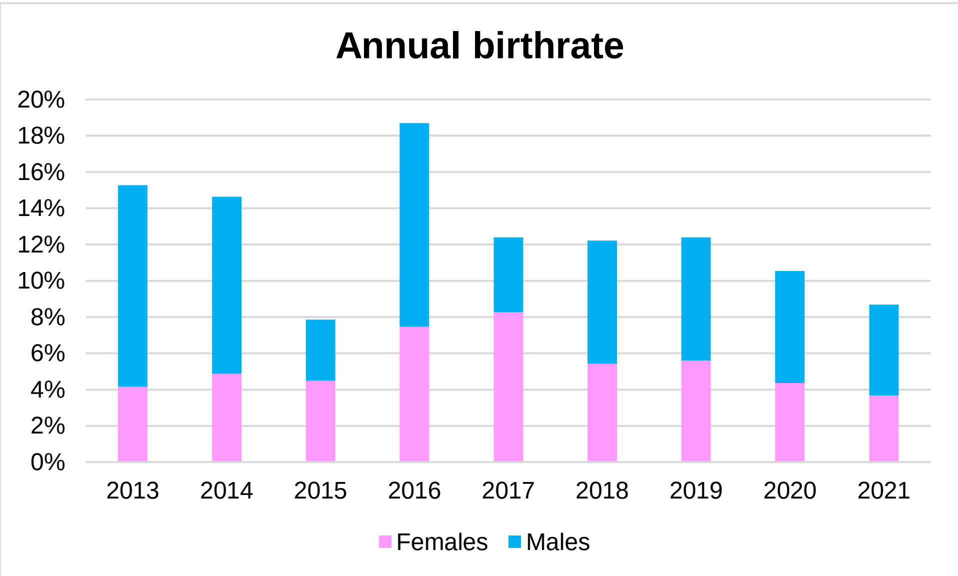

Figure 4: Annual birth rate, relative to the population size of each year. At the y-axis the amount of calves, at the x-axis the years.

Figure 5 represents the annual Age at first calving (AFC). Most of these calvings happened between 2013 and 2017. Data from 57 females were used for this parameter. All of the AFC's were from females that were bought from other owners. Within this database, no female born at Rockwood has had her first calf yet. The average AFC was 124 months (~10 years), the median 131 months, the upper quartile 145 months and the lower quartile 101 months. For most of these females, it is unsure whether this was the first calf or not.

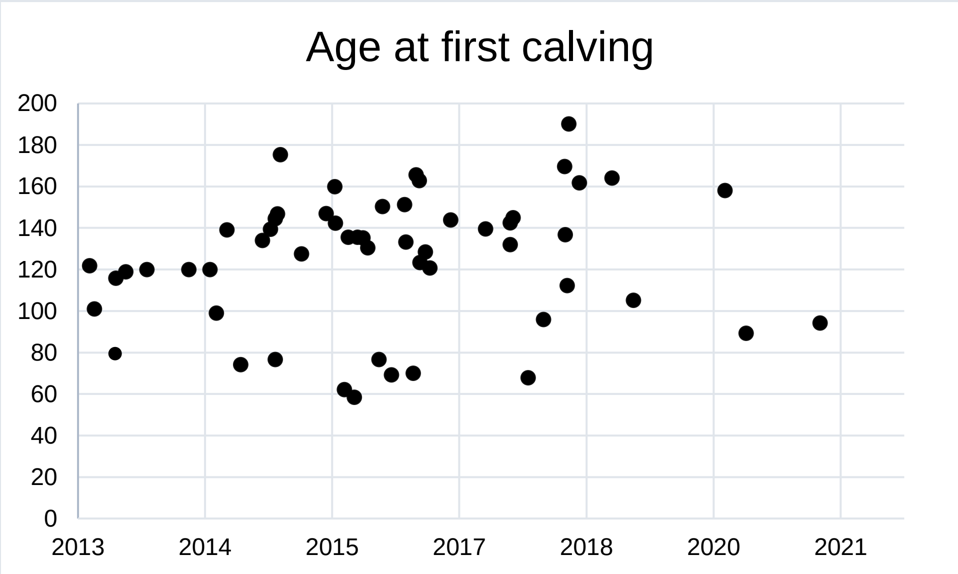

Figure 5: Age at first calving. At the y-axis the amount of months, at the x-axis the year. Each dot represents one single female.

The histogram in Figure 6 represents Inter-calf-interval (ICI). There were 57 females that had had 2 or more calves. A total of 96 calvings were used for calculating this parameter. The maximum number of calvings per female within this dataset was 4. The interval of 23 and 24 months had the highest frequency, followed by 21 and 22 months. These 4 intervals made up about 40% of the used dataset. At an ICI of more than 24 months, the frequency dropped from 12.5% to 5% and dropped further from there on. The mean is 29 months, the median is 24 months, the upper quartile is 27 months and the lower quartile is 21 months.

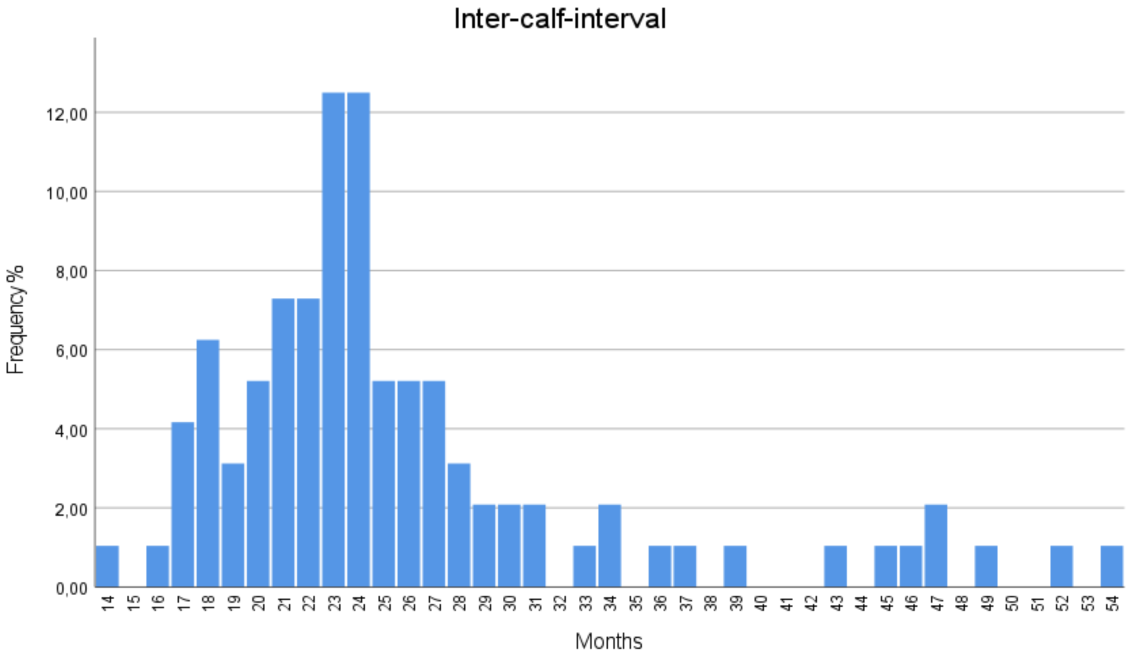

Figure 6: Inter-calf-interval, at the y-axis the frequency, at the x-axis the months.

3.1.2 Mortality parameters

Figure 7 shows the annual mortality rate, relative to the population size of each year. The mortality rates are a lot lower than the birth rates. In total, there were 20 deaths from 2014 to august 2021 with ten females and ten males. Two poaching incidents happened. The first one in 2014 on a female and calf. The mother was still alive when the rangers found the animals, but the mother was paralyzed due to bullets in the spine. The calf had a bullet in the forehead but survived the wound. The second one was a male in 2015.

The mortality rate was highest in 2016 and 2018 with 1,87% and 1,8%. The lowest was in 2021 with 0,67%.

In 2015 and 2021 there were only female deaths, one sick and one stillborn. In 2016 and 2017, only males died, all cause unknown. The most common cause of death is unknown (45%), followed by stillborn (30%), fights (10%), poaching (10%) and last, only one of sickness (5%). The mortality causes are shown in Figure 8.

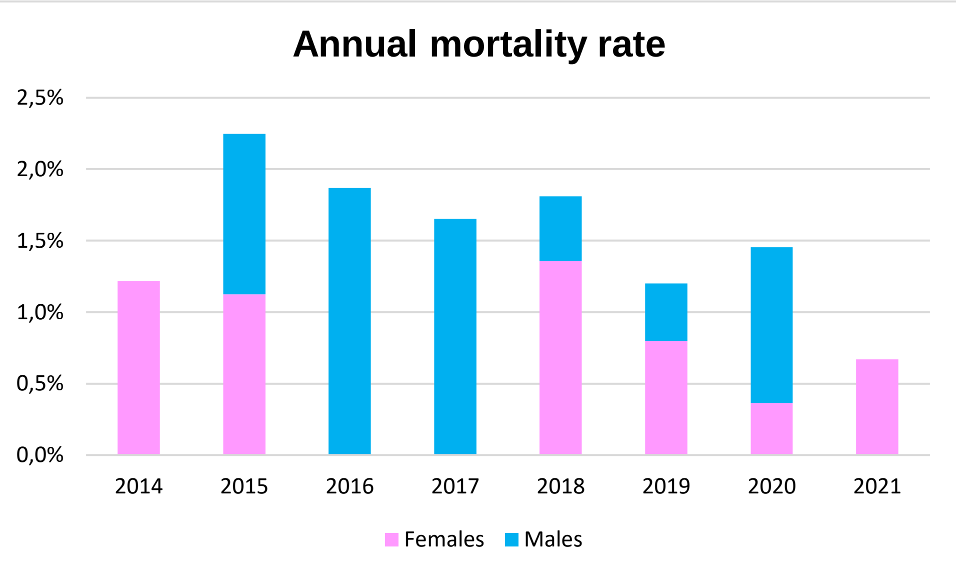

Figure 7: Annual mortality rate relative to the population size of each year. At the y-axis the percentage of rhinos that died, at the x-axis the years.

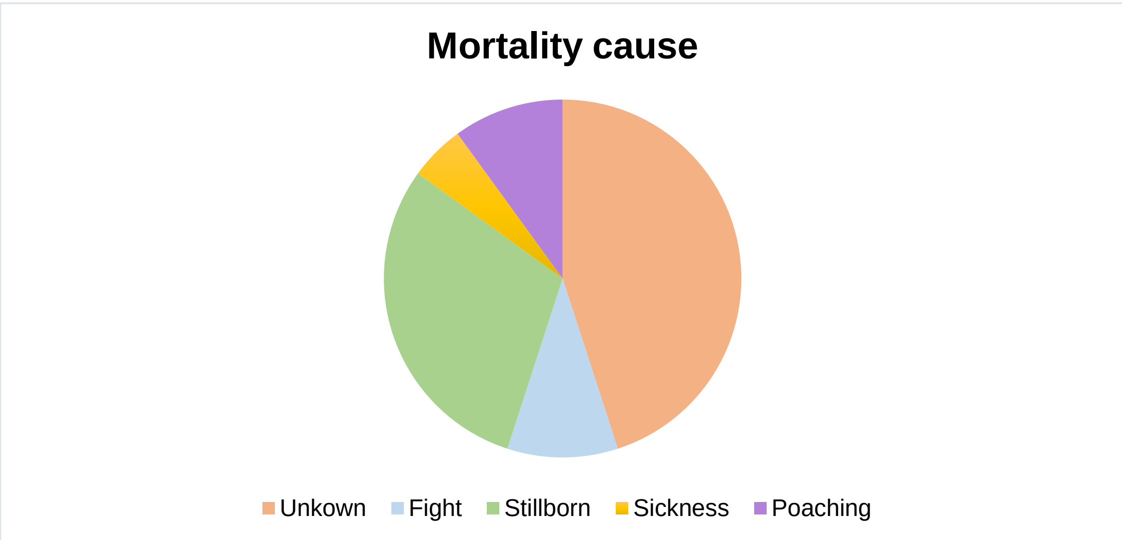

Figure 8: Mortality cause

Out of 20 deaths, 17 were premature and 3 were mature. Of the females, 8 died premature and all the males died premature. The first 2 deaths are the poaching incidents discussed above, in 2021 another mature rhino died, it was a female and the mortality cause is unknown (Table 4).

Table 4: Annual premature death rate

Year	Females	Males	Total number of premature deaths
2015	1	0	1
2016	0	2	2
2017	0	2	2
2018	3	1	4
2019	2	1	3
2020	1	3	4
2021	1	0	1
Total	8	9	17

3.1.3 Herd parameters

Figure 9 shows the population growth over the years, the yellow line (R) shows the percental population growth through birth. The bars show the total population size including bought rhinos. The first rhinos came to Rockwood in 2013, 61 rhinos bought from various places. Most of these rhinos came from Kruger National Park, but some also came from Hluhluwe-Imfolozi game reserve and other ranches or game reserves. In that year, there were also 11 calves born at Rockwood. From there on, there was a steady population growth of at least 7% each year. 2015 had the lowest population growth with 7%. In 2016 and 2018, there was a growth of 20% due to more births than in previous years. The mean population growth is 15%.

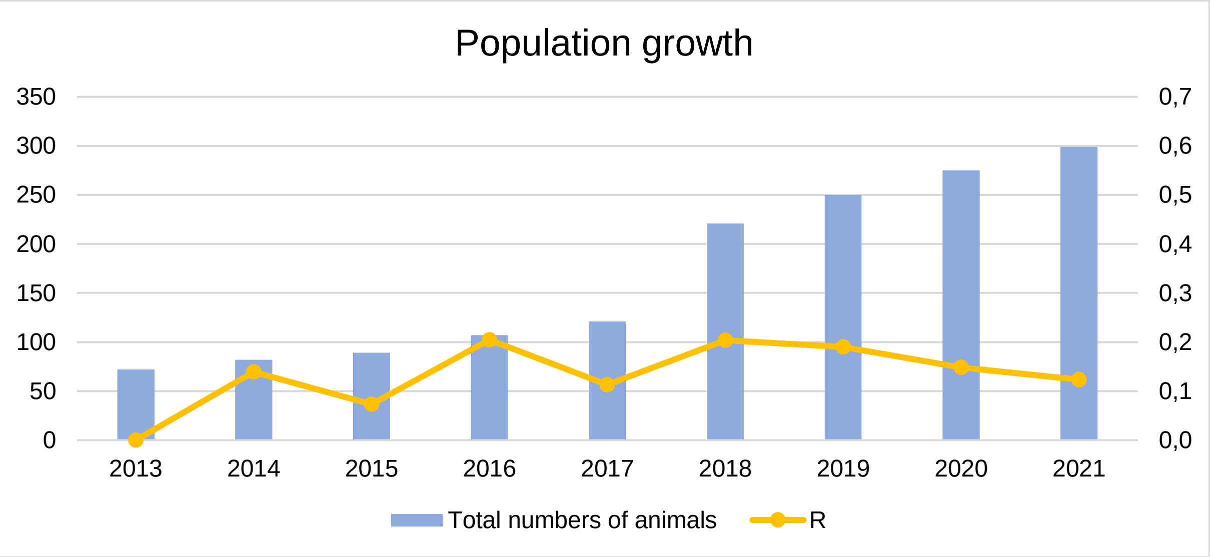

Figure 9: Herd growth and size. The bar graphs representing the herd size and the line graphs representing the herd growth. At the left y-axis, the number of rhinos. At the right y-axis the herd growth (R). At the x-axis, the years.

Table 5 shows the annual age structure of Rockwood's population. Over the years, at least half the population were adults. Proportion calf was always bigger than that of the sub-adults. The proportions remained somewhat the same since the start. Even though there were many rhinos bought in 2018, the age structure did not change much.

Table 5: Age structure, divided into three categories. Calf 0-2 years, sub-adult 3-5 years, adult >5 years.

Year	Calf	Sub-adult	Adult
2013	0,22	0,18	0,60
2014	0,29	0,16	0,55
2015	0,31	0,09	0,60
2016	0,32	0,13	0,55
2017	0,31	0,18	0,51
2018	0,29	0,13	0,58
2019	0,26	0,15	0,58
2020	0,29	0,14	0,57
2021	0,28	0,13	0,60

3.2 Literature study

There were very little studies found on the population dynamics of white rhinos. Also, most of this data was from private parks with management similar to Rockwood. If the data from these private parks is to be excluded, there is little to no information to compare the data with. Therefore, all the available data was used and compared to the results from the data analysis. In this chapter, the birth and herd parameters are combined since all the studies on birth parameters also included herd parameters.

3.2.1 Birth & Herd parameters

To start with, a study by Purisotayo et. al. (2019) was done in a reserve. The only management that was mentioned was security against poaching. In this study the sample size was 55 rhinos, 22 males and 23 females. Here the mean age at calving for females was 6.8 years and the ICI was an average of 3.7 years. The mean percentage of herd growth was 15.9% over 21 years (Purisotayo et. al., 2019).

A study by Penny et. al. (2020) was conducted in a private reserve in the Northwest Province, South Africa, that also had other animals that naturally occur in the area. There was no mention of security against poaching, there is no supplementary food, but the rhinos do have access to artificial mineral licks and water sources. There is limited animal husbandry and veterinary care. According to the paper the population is representative for other white rhino populations in South Africa. In this study, the ICI of rhinos that were horned, and had trimmed horns were compared. The study period lasted from November 1992 to January 2020 with 7 rhinos that gave birth to 31 calves. The mean ICI was 38.4 months, with a standard deviation of 3.6 months (Penny et al., 2020).

A paper by Ververs et, al. (2016) looked at birth parameters at the Buffalo Dream Ranch. The management was very similar to Rockwood's, with supplementary feeding in the winter, breeding camps, veterinary care and large roaming areas. Rockwood's security is based on the security of this reserve, so security is also very similar. The study lasted from 2008 to 2016, with a population size of 1,354 rhinos. The aim of this paper was to study the reproductive performance parameters of the population and obtaining reference values. The median age at first calving was 83.2 months, with an interquartile range of 72.9 - 110.7. The median ICI was 29.2 months, with an interquartile range of 24.6 - 34.8. The average annual population growth was 7%, with a minimum of -9% and a maximum of 15% (Ververs et. al., 2016).

There were no studies on age structure to compare the age structures in this study. However, there were two studies that mentioned a proportion of observed animals that were less than one year of age (calf). In 2018, the estimate for the Kruger park white rhino population was 4116 rhinos, with 10.9% of these animals being calves (Ferreira & Pienaar, 2020). In 2019, the estimate was 3549 rhinos, with 11.8% of the population being calves (le Roux & Ferreira, 2021).

3.2.2 Mortality parameters

Almost all information about mortality that was found was mostly about poaching, there was one more recent paper about bovine tuberculosis. Most papers did not have the exact numbers to compare with. However, SANparks publishes annual reports which include population size and poaching rates which are available on SANParks's website. Moreover, there are also publicly shared scientific reports with some numbers, and data made public by the department of Environment, Forestry and Fisheries of the South-African government.

In 2018, Ferreira et. al, wrote a paper about the effects of poaching on rhinos. The data was from Kruger Park. This paper mentioned that between 2015 and 2016, 127 poached white rhinos were found (do note that not all carcasses can be found in big reserves so mortalities are estimates) with a poaching rate of 7.3%. Between 2014 and 2015, 83 white rhinos were poached, with a poaching rate of 9.3% (Ferreira et al., 2018) In 2018, the proportion of rhinos poached consisted of 7.5% (South African National Parks, 2021).

The South-African government also shared some poaching rates on the website. In 2018, a total of 769 rhinos were poached, of which 422 were in South-African national parks. In 2019, this dropped to 594 rhinos poached in total, of which 328 in national parks (South African government, 2021). In 2020, the number of poached rhinos dropped further due to COVID-19 regulations, with 394 in total and 247 poached rhinos in national parks (South African government, 2021). However, the population in Kruger Park kept declining (Ferreira et. al., 2021). In the first six months of 2021, 249 rhinos were poached. In 2022, the government stated that the poaching moved away from Kruger Park, but towards private reserves. (South African government, 2022).

Beside poaching, bovine tuberculosis is another cause of rhino mortality. Bovine tuberculosis is a chronic infectious disease that can affect many species, like the white rhino. It is caused by Mycobacterium bovis (M. bovis) (Michel et. al., 2006). M.bovis is most often transferred in the following ways: First, through the excretion of sputum, urine or faeces from the infected animal, to the other animal by consumption of contaminated material (such as grass). Secondly, through interspecific encounters. After infection, it can take years before symptoms occur. Though the clinical signs are related to the route of infection and the symptoms differ among species, common symptoms of bovine tuberculosis are: emaciation, respiratory problems such as coughing, swollen lymph nodes, and draining sinuses (Renwrick & Bengis, 2006).
In 2016 and 2017, six white rhinos had died due to this disease in Kruger park (Miller et. al., 2018). There have not been many cases of bovine tuberculosis mentioned in the literature (yet). However, there are concerns that this disease limits the translocation of rhinos to keep bovine tuberculosis from spreading further (Miller et. al., 2018). No other diseases were mentioned as a significant mortality cause in the literature.

4. Discussion

The results in this study were compared with the studies mentioned in chapter 3.2. Some of the parameters could not be compared since these were not found in other papers during the literature study. Consequently, the parameters that are not compared are: birth and mortality rate, and premature death rate. The mortality cause was found to some extent, but nothing similar to what was used in this study.

The mean AFC in this study is a lot higher (~40 months) than the results of the other papers. This is probably due to the fact that no females that were born on Rockwood have had their first calf yet. For many females that were able to reproduce, the actual AFC's are unknown. Therefore, the mean AFC is not as accurate as it was in the other studies. Many of the females that were bought in 2013, were already old enough to have reproduced at the former owners. Thus, the mean AFC was calculated again. However, this time those older females were removed from the dataset, to check if they were the cause of the high mean AFC. This meant that the females that were older than 6 or 7 years old when they came to Rockwood were removed. If the maximum age at arrival is 7 years, the mean AFC changes to 96 months (N=22). If the maximum age at arrival is 6 years, the mean AFC changed to 84.6 months (N=15). Though these values are still higher, they are more similar to the values found in the other papers. Moreover, some of the birth dates of the females that were bought are estimates. So the new AFC's might still not be as accurate. When more of the females that were born at Rockwood are of reproductive age, it would be interesting to see if the mean AFC is then indeed lower, as was expected in the hypothesis.

As for the inter-calf interval, both the mean and median ICI at Rockwood were lower than what was mentioned in the 3 papers that were found. The median was 5 months lower then at the Dream Ranch. The mean was ~12 months lower then at the other two reserves. This means that the number of months between pregnancies of Rockwood's females was lower than it was in the other parks. According to the Guidelines for implementing SADC rhino conservation strategies, the ICI of Rockwood's population indicates a good to excellent fecundity (du Toit, 2006). This suggests that Rockwood has a better management system for reproduction compared to the other parks, though it is still unsure since there was not enough data to compare with. It is also unclear which aspects of the management are better, since the aforementioned studies did not describe much about the management.

The herd growth at Rockwood over the years was a minimum of 7%, maximum of 20% and a mean of 15%. The guidelines for implementing SADC rhino conservation strategies set the threshold for a good to excellent performance of annual growth at a minimum of 7.5% (du Toit, 2006). Moreover, these values were higher than they were in the study from Ververs and colleagues (Dream Ranch), where the minimum was -9%, maximum 15% and the mean 7% (Ververs et. al., 2016). Compared to the other reserve, the mean herd growth at Rockwood was slightly lower: 15.9% compared to 15%, though the population size was way smaller than Rockwood's' (Purisotayo et. al., 2019). One factor that probably influences the big difference between the Rockwood population and the Dream Ranch population is that the ICI is much lower at Rockwood. More calves are born thus the population grows faster. Moreover, it is possible that the population at Rockwood also has a lower mortality rate. Since the mortality rates are not mentioned in the study, this is unknown. It is also not known why the population growth of the population from the paper from Purisotayo and colleagues is higher while the ICI is lower. This might be due to other factors that are unknown, such as supplementary care or mortality.

The age structure was quite stable over the course of this study. Overall the proportion of calves was about 20%, subadults 15% and adults 55%. In the literature, there was only a brief mention of the proportion of calves at Kruger park for 2018 and 2019 (Ferreira & Pienaar, 2020; Roux & Ferreira, 2021). In both years, the proportion of calves in the population was higher at Rockwood. In 2018 it was 18% higher and in 2019 it was 14% higher. The difference in age structure could be explained by the fact that the Rockwood rhino population is reproducing year round, and the rhinos are being monitored. Thus, not only are new calves born year round, but these calves are also very well protected and probably have a higher survival rate.
It would be interesting to further study how age structures differ among different parks/habitats, since the age structure is an important indicator of the population status (Schowalter, 2006).

For mortality, there was no recent paper that stated the mortality rate as was done in this paper. In the literature study, poaching rates from recent years were described and some cases of bovine tuberculosis. Bovine tuberculosis has not been found in any of the rhinos at Rockwood.
Since there was no mortality rate to compare with, Rockwood's poaching rate for 2014 and 2015 was calculated so that the these could be compared with Kruger's poaching rate in those years. The poaching rate in Kruger park between 2014 and 2015 was 9,3% with 83 rhinos poached. Between 2015 and 2016, the poaching rate was 7,3% with 127 rhinos poached. The poaching rate at Rockwood was 1,22% in 2014 and 1,12% in 2015. It is very clear that the number of rhinos poached annually is substantially lower than in Kruger Park. Moreover, even though the poaching is shifting from national parks towards private reserves, Rockwood has not had a new poaching incident.
One thing that was interesting about the mortality at Rockwood is that out of the 20 rhinos that died at Rockwood, 17 died before they matured. Six of these were stillborn. When it comes to giving birth, there are many factors that can negatively affect it. Even if the female and the foetus are healthy, and the pregnancy had no troubles, dystocia and stillbirth are still a risk (Hermes et. al., 2020). Other death causes were unknown, sickness or fights. Most of these premature deaths were calves that were less than 3 months of age. Calves are still very vulnerable during this time. Not only are the calves more susceptible to disease because the immune system is still developing, but these animals are also still very dependent on the mother. If the mother cannot produce enough milk or is not as protective, then survival chances of the calf become slimmer. As the calves get older, these factors form less of a risk. Moreover, at Rockwood, each individual rhino is seen at least twice a day by the rangers. So it a rhino died, the staff would notice it very soon. In other reserves, this might not be the case so less dead rhinos would be found. The rhinos at Rockwood are very well protected so the mature rhinos don't face many risks. If there is more data available from other parks, it would be interesting to investigate whether the premature death rate is similar, and which factors influence this.

The results of this study (even though it is only compared with little literature) show that not only is Rockwood's rhino population growing while the populations in national parks are declining, but it is also growing faster, or almost as fast, as other populations in private parks/reserves.

The lack of comparable literature that is available is probably to avoid more poaching. But it also shows the importance of this study. Though it is already known that private parks have a higher population growth, it is still not known how the birth parameters differ from one another. The white rhino population is still declining and the protection of this species is crucial. In the current situation with poaching still being such a big problem, it would be very risky to move the rhinos from a protected private reserve to wilder habitats where the animals are less protected. If the government were to put a stop to breeding rhinos in private parks/reserves, it is still unsure what the exact consequences of those actions would be. It would be advisable to further investigate what the differences in population dynamics are, before making such a decision. Especially since the long term consequences are unknown.

5. Conclusion

This study was conducted to answer the following question:

How do the white rhino population dynamics differ between Rockwood and other game reserves in South-Africa from 2013 to august 2021?

The following sub questions helped answer the research question:

- Q1: What are the annual birth rates at Rockwood compared to other game reserves?
- Q2: At what age do the female rhinos at Rockwood get their first calf compared to other game reserves?
- Q3: How many months are there between each calving compared to other game reserves?
- Q4: What are the yearly mortality rates and their causes at Rockwood compared to other game reserves?
- Q5: How many white rhinos die before they are sexually mature compared to other game reserves?
- Q6: Are there differences in age structure compared to other game reserves?

The annual birth rate of Rockwood was at minimum 7,87% and at maximum 18,69%. This parameter could not be compared to other reserves since it was not found in the literature. However, it does show that the population is growing well.

The mean age of females that got their first calf was 124 months (~10 years) which was about 40 months higher than in other parks. However, this might not be accurate since all these females came from different owners. When more females that were born at Rockwood get their first calf, this parameter could be calculated again for a more accurate result.

For most of the females, it took 21 to 24 months to have a new calf, with a mean of 29 months. There was little literature to compare with, but the mean number of months between each pregnancy was lower at Rockwood.

The annual mortality rate was highest at 1,87%, and lowest at 0,67%. There was no literature to compare the mortality rate with. The only causes that were found in the literature were poaching rates and one paper about bovine tuberculosis. In that paper was stated that six rhinos at Kruger Park died from this disease. In 2014 and 3015, the poaching rates at Rockwood were substantially lower then at Kruger park. Moreover, Rockwood has not had a poaching incident since 2015. Bovine tuberculosis has not been found in one of the rhinos there.

Out of 20 deaths, 17 rhinos died before they matured. Most of these premature deaths, were calves that were less than 3 months of age. There is no data from other parks to compare these results with, but it would be interesting to investigate if other parks have similar results, and what factors influence this.

The age structure was quite stable over de study period, overall the proportion of calves was about 20%, subadults 15% and adults 55%. In the literature, there was very little to compare with. However, the two papers that mentioned the proportion of calves in the population, had a lower percentage than in this study. In 2018 the proportion of calves at Rockwood was 18% higher and in 2019 it was 14% higher

Thus, the population dynamics of the white rhino population at Rockwood differ from other populations. Most reproductive performance parameters show that Rockwood has a higher population growth than the parks found in this study. However, since there was very little to compare with, and almost none of the literature came from natural reserves such as national parks, it is still inconclusive how exactly Rockwood's population dynamics differ from more natural systems.

Recommendations

This study was conducted to show the importance of a semi-managed system, for conservation of the white rhino. During the study it became clear that there is very little literature available, and not nearly enough to draw a proper conclusion.

On the short term it is highly recommended for other reserves to make information about the management (such as security, by feeding, veterinary care) and information on population dynamics more accessible for other researchers. If safety is an issue, a better solution could be to share this information between reserves and private owners, so that more research can be conducted.

For the long term, it would be very interesting to see how different factors influence the population dynamics exactly, and how these differ between reserves. For example, there already is some information on the ICI and AFC, but not quite enough to make a proper comparison with. The AFC also might be inaccurate and should be calculated again in a couple of years when more females that were born at Rockwood get their first calf. The birth rate and mortality rate were not found in any of the papers, though these parameters give a good indication of why a population is growing or declining. For future studies, it would be valuable to make the calculations for these parameters and see if there are any significant differences between the results. Not only could these results give a better understanding of the importance of managed systems, but comparing these parameters between reserves/parks could also indicate if the management is going well or if adjustments are needed. If more information is shared among rhino owners, they could also help each other grow their populations. For the mortality cause, it would be interesting to find out if the causes are similar in other parks/reserves and which factors play into those causes. Moreover, in this study most rhinos that died were calves. In the discussion is mentioned that calves are more prone to dying because they are still rather fragile, further studies in premature deaths could help with understanding which factors play into these deaths and how to prevent them.

This study can be the start for more studies to gain a better understanding of the importance of semi-managed systems and compare those with more natural systems. Since this comparison cannot be made yet, it is hard to predict the consequences of a law that prohibits private ownership of white rhinos. Because this law is suggested to protect the rhino population, it is advised to first conduct more research on the long term consequences.

6. Literature

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