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To notch or not to notch? – Evaluation of the current rhino notching program in the Greater Kruger Area (ZA) and development of a consistent guideline

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Declaration in lieu of oath

I herewith declare in lieu of oath that this thesis has been composed by myself without any inadmissible help and without the use of sources other than those given due reference in the text and listed in the list of references. I further declare that all persons and institutions that have directly or indirectly helped me with the preparation of the thesis have been acknowledged and that this thesis has not been submitted, wholly or substantially, as an examination document at any other institution.

27.10.2018	A. Hessel
Date	Signature

Abstract

Monitoring of white (*Ceratotherium simum*) and black rhino (*Diceros bicornis*) seems crucial, as populations of these species have been, and are still, severely threatened. Rhino often lack unique marks or patterns, which makes distinction between individuals, especially from a distance, difficult. To overcome this difficulty, various reserves of the Greater Kruger Area (GKA), South Africa, have embarked on ear notching programs. Unfortunately, this program has not been coordinated between the reserves, despite them being part of an open, contiguous, area.

In this thesis, perceived problems within the rhino notching program were tested via a survey with experts from 13 reserves of the GKA. The survey found 59 % of all notched white and 35 % of all notched black rhino in the area are not marked uniquely by ear notches. The main causes for such duplicates were the use of different notch code keys and lack of coordination between reserves.

As there were no data available on the reliability of rhino identification using notches, a field study was performed. The visibility of different ear notch positions, from five distance points in a bush and an open habitat, was tested. The outcomes suggest that ear notching alone does not allow for reliable identification of individual rhino, from even relatively short distances, like 20 m, in both habitat types. Identification success was largely dependent on the distance between observer and object, habitat type, age of observer and the use of binoculars.

Outcomes of the survey, the field study, and decisions, made by responsible authorities of the reserves, were combined to develop a consistent guideline for participating members of the rhino notching program. In addition, a corresponding database was established to support coordination between the reserves. Results suggest that in interconnected reserves, an ear notching program in rhino can only be justified if participating members cooperate closely.

Keywords: rhinoceros · rhino monitoring · rhino management · rhino identification · animal marking method · ear notching · guideline · South Africa

Kurzfassung

Ein umfassendes Monitoring von Breit- und Spitzmaulnashörnern scheint essentiell, da Populationen dieser Arten nach wie vor stark bedroht sind. Nashörnern fehlen jedoch meist individuelle Erkennungsmerkmale, was eine Identifizierung von Einzeltieren erschwert. Um diese Hürde zu überwinden, starteten mehrere Reservate der Greater Kruger Area (GKA) in Südafrika, Markierungsprogramme zur individuellen Erkennung der Tiere anhand von Ohrkerben. Obwohl die Reservate miteinander verbunden sind, fand bislang keine Koordination dieser Programme statt.

In der vorliegenden Arbeit konnten Probleme des Markierungsprogrammes durch eine Umfrage mit Experten von 13 Reservaten der GKA belegt werden. Diese offenbarte, dass 59 % aller Breit- und 35 % aller Spitzmaulnashörner der Region nicht individuell durch Ohrkerben markiert sind. Die Hauptgründe hierfür lagen in der Verwendung unterschiedlicher Kerbmusterschlüssel und fehlender Koordination zwischen den Reservaten.

Da Daten über den Identifizierungserfolg von Nashörnern mittels Ohrkerben bislang fehlten, wurde eine Feldstudie durchgeführt. Die Erkennbarkeit verschiedener Kerbpositionen wurde von jeweils fünf Distanzen, im Offen- und im Buschhabitat, getestet. Die Resultate legen nahe, dass Ohrkerben allein bereits auf 20 m keine verlässliche Identifizierung von Individuen zulassen. Der Identifizierungserfolg war stark abhängig von der Distanz zwischen Beobachter und Objekt, Habitat, Alter des Beobachters und der Verwendung eines Fernglases.

Ergebnisse der Umfrage, der Feldstudie und Beschlüsse zuständiger Entscheidungsträger wurden kombiniert, um einen Leitfaden für das Markierungsprogramm zu entwickeln. Ergänzend wurde eine Datenbank angelegt, welche die Koordination zwischen den Reservaten unterstützen soll. Die erlangten Erkenntnisse legen nahe, dass ein Markierungsprogramm zur individuellen Erkennung von Nashörnern mittels Ohrkerben in verbundenen Reservaten nur gerechtfertigt werden kann, wenn diese eng miteinander kooperieren.

Schlagwörter: Nashorn · Nashorn Monitoring · Nashorn Management · Nashorn Identifikation · Markierungsverfahren · Ohrkerben · Leitfaden • Südafrika

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1. Introduction

Wildlife management tools are needed when managers aim to manipulate animal populations or their habitats. The intentions behind these manipulations can be for either human or a focal species' benefit (Anderson 1999). The data needed to implement and evaluate such manipulations can be provided through monitoring parameters like birth rate, mortality and/or sex ratios within populations (Emslie and Brooks 1999; Walpole 2002). There are mainly two possibilities when monitoring wildlife: the monitoring of populations and the monitoring of individuals. Both have their advantages and disadvantages. Decisions on which to use depends on the needs of the reserve, the conservation status of the target species and the resources available to conduct any monitoring programs (Ringold *et al.* 1996; Gibbs *et al.* 1999; Witmer 2005). Monitoring individuals of a species allows collection of individualized and accurate data if ongoing observations are reliable. It can represent a useful tool e.g. in terms of studying animals' movement across boundaries, feeding habits, breeding success and animal behaviour (Cochran *et al.* 1965; Siniff and Jessen 1969; Turner *et al.* 2000). One important consideration for monitoring individuals is that the animal concerned will need a distinctive feature with which it can be identified and distinguished from other individuals e.g. in form of a natural characteristic such as coat patterns or an artificial mark (Pennycuick and Rudnai 1970; Kelly 2001). Applying artificial marks can be costly and might affect the animal in a negative way (Swenson *et al.* 1999; Caya *et al.* 2004). Furthermore, marks like ear tags, tattoos or brandings might appear unattractive or unacceptable with respect to animal welfare for certain interest groups (Hammerschlag 2014). Additionally, monitoring individuals represents only a sample of a population, if not all animals within a population are individually marked and monitored. In such cases, the question of the sample size is crucial. The number of monitored individuals should be adequate to capture variation within the population and therefore be representative for the whole population (Shah 2011). Finally, success of an individualized monitoring program is highly dependent on regular observations and consistent data collection (Du Toit 2006).

Main methods for monitoring populations have been described by Lancia *et al.* (1994). They might be easier to perform in terms of effort per day and animal. Monitoring populations usually represents a non-invasive and less disruptive way of monitoring wildlife and estimating population densities (Rowcliffe 2008). Disadvantages of this method are that the data collected are not individualized and hence, movements of individuals across boundaries or individual changes in behaviour might not be detected or verifiable. Like with an individual monitoring program, meaningfulness of population monitoring depends on repeated measurements and data acquisition.

Gathering reliable spatial and temporal data of rhino is particularly important, as these species are facing the threat of imminent extinction (Haas and Ferreira 2015). In terms of the ongoing poaching crisis in Southern Africa, using accurate data for predictive modelling could direct conservation measures thereby, increasing the chances of successful protection. Knowing where rhino move to in different seasons, under different conditions, or, for example, what their inter-calving periods and success rates are, could help in managing healthy populations and in giving early warning signs if there are population level problems (Ferreira *et al.* 2011). Unfortunately, there are several challenges when monitoring rhino: individuals can move long distances, even within one day (Joubert and Eloff 1971; Adcock *et al.* 1998); the dropping of fences within and between reserves, changing climatic conditions (droughts/floods etc.), as well as cofounding factors like pressure from poachers could encourage rhino to leave established home ranges (Dunham 1994; Patton *et al.* 2010; Ihwagi 2018). These factors aggravate monitoring in a large and open area, particularly those made up of multiple management areas. Additionally, rhino often lack adequate unique natural marks or patterns for individual identification - especially at distance. This makes the monitoring of individual animals, their movements and assessment of their condition over time, difficult. Thus, it stands to reason that artificial marking of rhino is sensible to allow monitoring on an individual basis. One option for this purpose is ear notching, which has been in use by several reserves in Southern Africa (Hall-Martin 1986; Adcock *et al.* 1998; Ngene *et al.* 2011). More recently, concerns about the efficiency of this marking method arose, as reserves do not coordinate notching across their boundaries.

In this thesis, the ear notching program of the Greater Kruger Area (GKA), South Africa, is examined and evaluated to test the hypotheses that

(H_1) the ear notching program of rhino in the GKA lacks efficiency and consistence.

Information and data on the notching system were gained by conducting a survey with involved rhino experts. This survey should help to answer the questions:

(Q_1) how many rhino already have been notched in the area concerned,
(Q_2) which notch code keys are currently being used,
(Q_3) if there are individuals with identical notches that could be mistaken for one another,
(Q_4) which other problems are associated with ear notching and
(Q_5) how do the experts value preassigned criteria of the rhino notching program.

As ear notches are commonly used for monitoring rhino in African parks and reserves (Hall-Martin 1986; Adcock *et al.* 1998; Ngene *et al.* 2011; Ferreira *et al.* 2017), the second hypothesis tested is that:

(H_2) ear notches represent a reliable tool for monitoring individual rhino from a distance.

There were no data available on the reliability of rhino identification using this method, hence a field study testing the visibility of ear notches from a distance was performed. It should provide information on:

(Q_6) identification rates of individual notch codes,
(Q_7) identification rates of single notch positions,
(Q_8) the maximum distance for identification of marked rhino ears,
(Q_9) how the use of binoculars influences identification rates and
(Q_{10}) what other factors might affect identification.

Results of the survey and field study are used to develop a consistent guideline for a coordinated notching program between reserves of the GKA. In addition, a secure database that allows ongoing monitoring of marked rhinos is established, to help conserving the species more efficiently. Finally, outcomes of the evaluation are discussed and alternatives to, as well as improvement suggestions for the notching of rhino ears given.

1.1 The southern white rhinoceros *(Ceratotherum simum ssp. simum)*

The southern white rhinoceros (*C. simum ssp. simum*) is the third largest land mammal and represents the commonest sub-species of the family Rhinocerotidae worldwide (Emslie *et al.* 2016; IRF 2017). It is native to Southern Africa and wild populations of it are present in Botswana, Kenya, Namibia, South Africa, the Kingdom of Eswatini (formerly Swaziland), Zambia and Zimbabwe (Rookmaaker and Antoine 2012; Emslie *et al.* 2016) (Fig. 2). The southern white rhino almost became extinct at the end of the 19^{th} century. Only a remnant population of less than 100 individuals survived in the area of KwaZulu-Natal, South Africa (Emslie and Brooks 1999; Tomášová 2005; Rookmaaker and Antoine 2012; Child 2012). All of today's southern white rhino genetically originate from this population. The recent estimated overall population is about 20.300 individuals, with more than 90 % of them being distributed in South Africa (Emslie *et al.* 2016; IRF 2017). Although current population trends show an increase, the species is classified as "near threatened" by the IUCN Red List of Threatened Species (2018). The main cause of this status is ongoing poaching of rhino for their horns, which are sold primarily to black markets in Vietnam and China (Milledge 2007; Milliken and Shaw 2012; Duffy *et al.* 2013; Emslie *et al.* 2016; Knight 2016). International trade in rhino horn was banned by the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) in 1977. In 2017, at least 1.112 individuals of the species were poached in Africa, resulting in an average loss of about 3 rhino per day (Knight 2018) (Fig. 1).

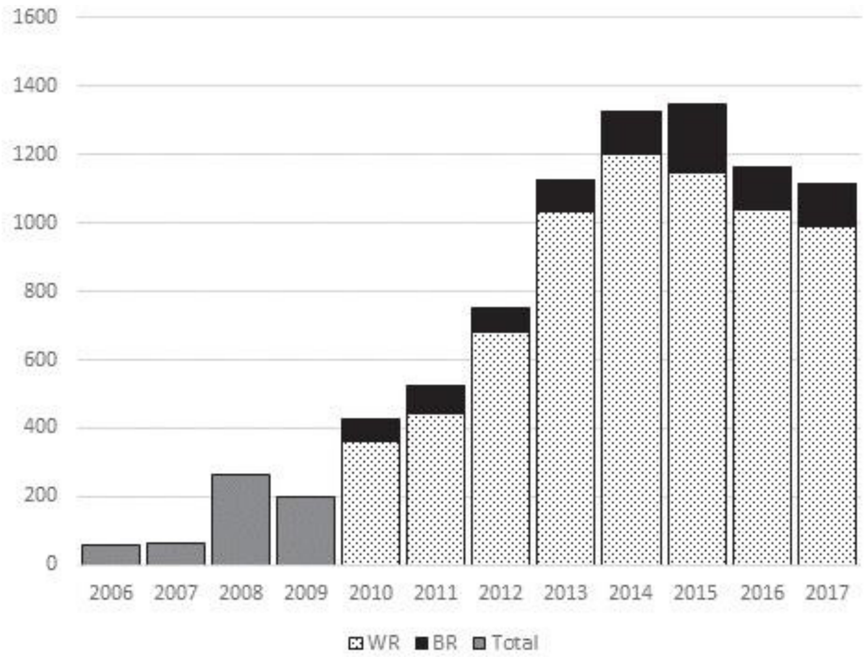


Figure 1 Reported numbers of African rhino (WR = white rhino, BR = black rhino) poached per year in Africa. The bars represent minimum numbers as some carcasses may go undetected. (from: Knight 2018)

White rhino are grazers and therefore prefer open habitats with a good cover of grass and herbs (Groves 1975; Trense 1989; Tomášová 2005; Dinerstein 2011). They are active during night and day, but like many other African mammals, avoid midday heat by seeking shady places or wallows (Owen-Smith 1973; Trense 1989; Tomášová 2005). Adult females weigh between 1.800 to 2.000 kg, whereas adult males can weigh up to 2.700 kg (Tomášová 2005; Dinerstein 2011). Their maximum lifespan is given as 45 up to 50 years (Schenkel 1987; Trense 1989; Tomášová 2005). White rhino can be seen in groups more frequently than black rhino. Although dominant adult bulls are territorial, they often tolerate subordinate bulls in their exclusive range (Joubert and Eloff 1971; Owen-Smith 1972 and 1973; Tomášová 2005). The territory of a dominant male rhino covers several home ranges of female rhino. Size of the home ranges mainly depends on food and water availability and can vary from 10 to 20 km² in female and from 1 to 5 km² in adult males (Owen-Smith 1972; Tomášová 2005; White *et al.* 2007; Dinerstein 2011). Nevertheless, movement within wider annual home range is difficult to predict and individual cases, where rhino travelled distances up to 25 km within one day, have been recorded (Joubert and Eloff 1971; Owen-Smith 1973).

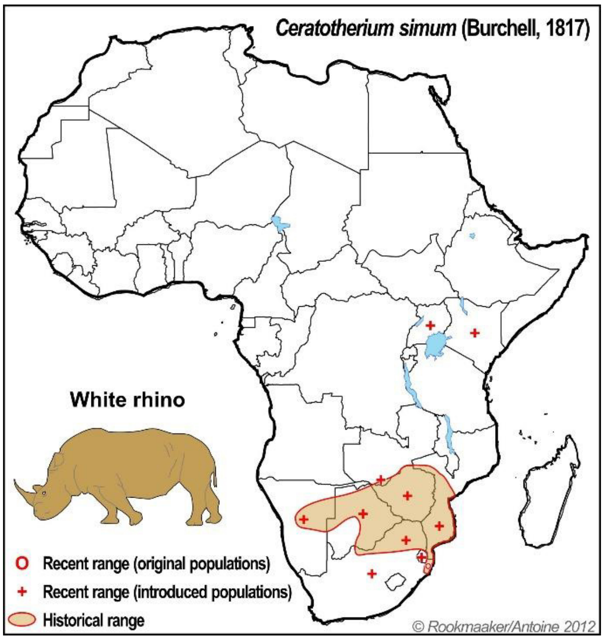


Figure 2 Historical and current distribution of the southern white rhino. The historical range is shown in brown. The only original population remained in the early 20th century in parts of KwaZulu-Natal, South Africa. (from: Rookmaaker and Antoine 2012; updated by Hussek according to Emslie *et al.* 2016)

1.2 The southern-central black rhinoceros *(Diceros bicornis ssp. minor)*

Distribution of populations of the southern-central black rhinoceros (*D. bicornis ssp. minor*) can be found nowadays in Botswana, Malawi, South Africa, the Kingdom of Eswatini (formerly Swaziland), Tanzania, Zambia and Zimbabwe (Rookmaaker and Antoine 2012; Emslie *et al.* 2016; Knight 2018) (Fig. 3). A massive decline in population numbers of this species has been seen since the 1970s (Cumming 1987). Between then and 2015, the estimated amount of black rhino has decreased from about 65.000 to 5.250 (Emslie *et al.* 2016). Only about 2.150 individuals of these belong to the southern-central sub-species *minor*. More than 70 % of all remaining southern-central black rhino occur in South Africa. Since 2000, this sub-species is currently listed as "critically endangered" under the IUCN Red List of Threatened Species. Like the southern white rhino, populations of *D. bicornis ssp. minor* are largely threatened by poaching for their horns (Fig. 1).

Black rhino are browsers and mainly feed on leaves from bushes and shrubs (Schenkel and Schenkel-Hulliger 1969; Joubert and Eloff 1971; Adcock and Amin 2005). Feeding peaks are during dusk and dawn (Joubert and Eloff 1971), whereas hot periods of the day are spent resting or sleeping (Schenkel and Schenkel-Hulliger 1969; Emslie 2012). Female black rhino weigh about 900 kg, while body weight of male individuals can reach up to 1.600 kg. Their normal maximum lifespan is about 40 years (Schenkel 1987; Trense 1989; Adcock and Amin 2005; Patton *et al.* 2007). Home range size can vary greatly, but waterholes should be available within 10 km (Adcock *et al.* 1998; Dinerstein 2011). Like all rhino, they have poor eyesight and depend largely on their sense of hearing and smell. Black rhino are known to react more aggressively when surprised than white rhino (Ritchie 1963; Schenkel 1987; Adcock and Amin 2005).

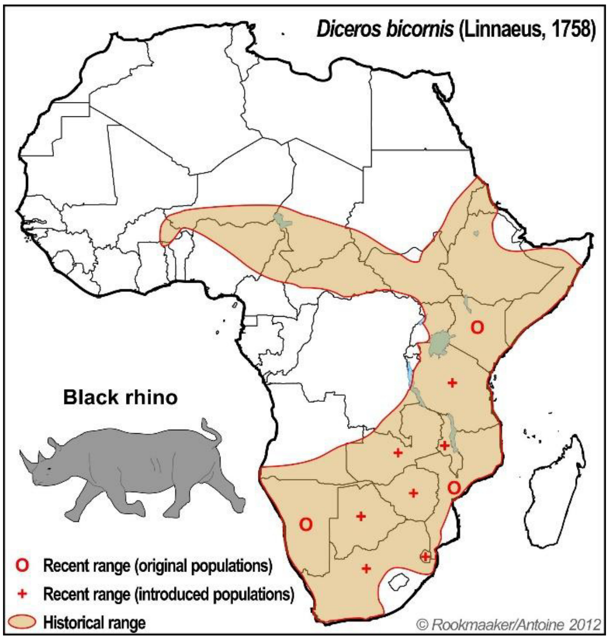


Figure 3 Historical and current distribution of the southern-central black rhino.
The historical range in the period after ad 1500 is shown in brown.
(from: Rookmaaker and Antoine 2012; updated by Hussek according to Emslie *et al.* 2016 and Knight 2018)

1.3 Study area

The study area is the Greater Kruger Area (GKA), located in the north-west of South Africa, bordering Mozambique (Fig. 4a). This area covers the Kruger National Park and several smaller, private game reserves as shown in Fig. 4b. Reserves in the GKA cooperate with each other and other partners, such as the Southern African Wildlife College (SAWC) in some sectors. 13 of these reserves participated in this study, including Balule Nature Reserve, Blue Canyon Conservancy, Kapama Game Reserve, Kempiana Nature Reserve, Klaserie Private Nature Reserve, Kruger National Park, MalaMala Game Reserve, Manyeleti Game Reserve, Sabi Sand Reserve, Selati Game Reserve, Umbabat Private Nature Reserve, Thornybush Game Reserve and Timbavati Private Nature Reserve. These reserves cover a total area of about 23.500 km². Boundary fences between private and national reserves were partially removed over the last few years, allowing game to migrate freely between them. Albeit three reserves of the GKA are permanently separated by public roads and fences (Fig. 4b). They cover an area of about 525 km².

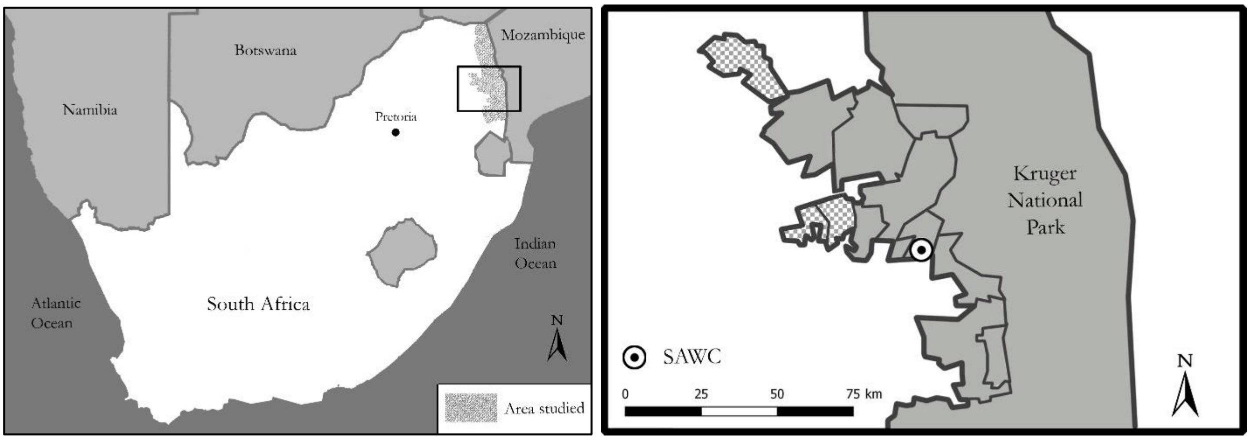


Figure 4 a) *(left)* Location of the Greater Kruger Area in South Africa. The framed area is shown enlarged in b).
b) *(right)* Location of the 13 reserves and the Southern African Wildlife College (SAWC) within the Greater Kruger Area. Reserves that are permanently separated by roads and fences are plaid.

1.4 Ear notching

Ear notching is the marking of an animals' ears by cutting notches or holes into it. The notches represent a numerical code. Ideally, this code allows individual identification of the animal from a distance. Figure 5 shows a commonly used method of coding notches.

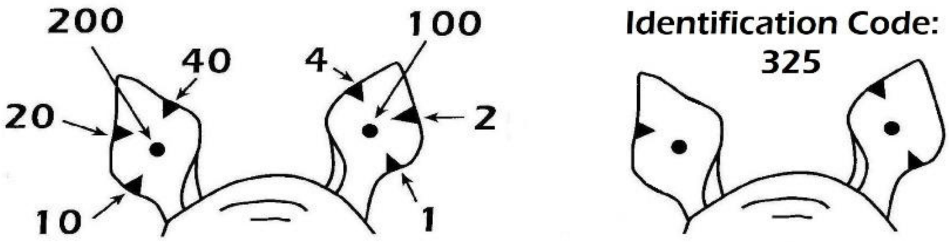


Figure 5 Pattern of an ear notching code key (*left*) and corresponding example for the numeric identification (*right*).

This marking method has been in use in the study area for black and white rhino identification for the last 15 years. Notching is done in winter (mainly July/August) when temperatures are lower than in summer and so there are fewer risks to the immobilised animal. It is often sponsored by private donors who are invited to join the notching. They receive detailed information about the notching process, rhino physiology and conservation. Before the notching, a plane flown by an experienced pilot looks for a suitable rhino from the air. A rhino is considered suitable if it is adult, unmarked and if the terrain surrounding it allows access from air and ground. A skilled veterinarian will then immobilise the rhino from a helicopter with an pressurised dart fired from an specialist dart gun (Fig. 6a). The dart injects medication into the rhino on contact which immobilises it. As soon as the animal is down it is very closely monitored and its ears notched (Fig. 6b,c). To reduce stress for the rhino its eyes are covered for the entire process (Fig. 6b). A catheter is placed into a vein behind the ear, to ensure immediate access in case of an anaesthetic emergency (Fig. 6d). Oxygen supply for the anaesthetised rhino is provided by a nasal tube, as respiration rate of the animal is reduced by immobilisation drugs (Fig. 6b). The vet uses a scalpel to cut circular notches free-handed (Fig. 6d) and a plier to cut triangle-shaped notches (Fig. 6c). Margins of the wounds are clamped and treated with Potassium Permanganate to keep the impact of the procedure as low as possible (Fig. 6e).

Following national legislation, darted and immobilised rhino must be microchipped and DNA-sampled (DEA 2016) (Fig. 6f-h). Furthermore, measures from the base and the inner and outer curves of both horns are taken. After the procedure, which takes about half an hour, the vet administers the antidote to the animal to wake it up (Fig. 6i).

Figure 6 (a-i) Photos showing an ear notching event in a white rhino, South Africa. An adult rhino is darted by a vet out of a helicopter (a). Once the darted rhino is tranquilized, the animal is cooled with water, its eyes are covered and respiration supported with oxygen (b). Triangle-shaped notches are cut into the ears with a plier (c), whereas round notches have to be cut with a scalpel (d). A needle in the vein of an ear allows immediate access to the animals' circulation. Wounds are stapled and treated with disinfecting Potassium Permanganate (e). Collection of DNA samples is legally obligate when treating rhino. The excised patch of skin from a notch, as well as other DNA samples are collected (f and h). Furthermore, microchips have to be implemented into the rhino hump and horns (g and h). Only 20-30 minutes after darting, the notched rhino is up on its feet again (i).

The main benefit of ear notching is the possibility to collect individualized data of an animal. The marking should last a lifetime if the animals' ears stay intact. The notches appear more natural to many tourists than with other marking methods like e.g. coloured ear tags therefore, lodges are less likely to worry about financial losses due to guests staying away from their reserve. Additionally, it was assumed that ear notches in rhino are easily visible in the field (Du Toit 2006). Principally, this marking method can only function well if each rhino is marked with a unique notching code and the program is conducted in close cooperation with all participating reserves.

1.5 Problems of the notching program in the study area

The costs of a notching exercise are high (~ 50.000 ZAR), due to the amount of people and equipment needed. This is aggravated by the fact that the capture, handling and sedation of the rhino can put the animal at risk as rhino are very sensitive to the anaesthetic. There is also a possible risk for the people involved. However, reserves of the GKA started marking rhino without considering or coordinating marking codes of neighbouring reserves. When boundary fences between private, provincial and national reserves were removed, rhino could move freely between properties. Since then, multiple different individuals with identical notch codes or animals with notches that are unrecognized in various areas, were observed. This reduces the value of notching programs as it is no longer possible to reliably identify individuals. Additionally, animals were considered "lost" when they might be on a neighbouring property, which also increased uncertainty about the whereabout of individuals and their potential poaching. Cases in which marked rhino were found about 80 km away from where they originally have been marked, were recorded in the study area before. Crucial estimates on population densities could be aggravated thereby. Furthermore, some reserves already started to run out of codes as the amount of possible code combinations (*pcc*) is limited by the amount of notches used on each ear. There is also uncertainty about the reliability and validity of ear notches being observed and recorded in field. Regarding the amount of resources currently being used to try to protect rhino from poaching (Emslie and Brooks 1999; IRF 2017), plus the risk for human and animal during handling, this situation was far from ideal.

The development of a consistent guideline for participating members of the rhino notching program, as well as the establishment of a centrally managed database were needed to standardize and coordinate the notching program.

2. Aims of the thesis

This thesis should support the sustainable conservation of black and white rhino in the GKA by evaluating the current rhino notching program and finding a way forward. The evaluation should give an overview about the current situation of ear notching in rhino in the study area [**(Q_1)** to **(Q_5)**]. It will also assist in verifying the hypothesis that the current notching program lacks efficiency and consistence **(H_1)**. A guideline should be created to help with the allocation of available notch codes and standardize notching and data collection of notched animals. In this context, the hypotheses that ear notches are an effective tool for monitoring individual rhino from a distance **(H_2)** should be tested by providing answers to questions **(Q_6)** to **(Q_{10})**. A conclusive discussion about the notching program should examine possible alternatives to, or combination options with rhino ear notching.

3. Methods

In a first step, all available data of notched rhino from the reserves involved were collected to gain information about the status quo [**(Q_1)** and **(Q_2)**]. With this, the proportion of different rhino individuals with identical notches was determined **(Q_3)**. Secondly, an evaluation of the notching systems was performed by an expert survey to reveal problems **(Q_4)** and to examine advantages and disadvantages of the different patterns of notch code keys **(Q_5)**. A field study on the visibility of rhino ear notches assisted in this issue. It gave information about the usefulness of ear notches when observing marked rhino from a distance [**(Q_6)** to **(Q_8)**] and revealed weak spots and factors influencing their detectability [**(Q_9)** and **(Q_{10})**]. Results of the survey and the field study were used to work out one standardized notching methodology for rhino in form of a Standard Operating Procedure (SOP). Derived from this guideline, a secure database was established that contains all relevant information about already notched rhino.

3.1 Survey on the status quo

All surveys were conducted as personal interviews. This method allowed for more flexibility and interviewees were given the chance to set personal priorities (Potthoff and Eller 2000). The rhino experts of each reserve were interviewed in an identical manner each time, following points of a pre-formulated survey sheet (Appendix I). Reserves that already participated in notching were asked to provide their rhino notching data.

3.1.1 Participants

Table 1 The table includes all interview partners that participated in the survey about rhino notching on the reserve they work on as well as their position and the date the survey was conducted.

Date of interview	Name	Relevant position	Reserve
11.07.2017	Leonie Hofstra	Field technician and rhino monitor	Balule Nature Reserve
24.07.2017	Dave Powrie	Warden	Sabi Sand Reserve
	Edwin Pierce	Ecologist	
27.07.2017	Tim Parker	Head ranger	Blue Canyon Conservancy
01.08.2017	Tom Coetzee	Warden	Thornybush Game Reserve
01.08.2017	Almero Bosch	Ecologist	Timbavati Private Nature Reserve
03.08.2017	Colin Rowles	Warden	Klaserie Private Nature Reserve
04.08.2017	Mark Shaw	Warden	Umbabat Private Nature Reserve
08.08.2017	Dusty Joubert	General Manager	Selati Game Reserve
16.08.2017	Cathy Dreyer	Black rhino monitoring coordinator	Kruger National Park
	Pauli Viljoen	Research logistics coordinator	
18.08.2017	Wayne Boyd	Director	MalaMala Game Reserve
25.08.2017	Albe Nel	Head of security and APU*	Kapama Game Reserve
28.08.2017	Kevin Robertson	Veterinarian at the SAWC	Kempiana Nature Reserve
29.08.2017	Mark Bourn	Section head	Manyeleti Game Reserve

* Anti Poaching Unit

13 reserves of the GKA agreed to cooperate and assist in this study. The interviewees participating in the survey were the ones responsible for planning and performing the rhino notching on their reserve, as well as for linked data management. They are experts in their area of competence and represent the main decision makers in an ongoing rhino notching program. Table 1 lists the names of the interview partners for each of the 13 reserves as well as their employment title.

3.1.2 Survey sheet (Appendix I)

I developed a survey sheet for interviewing rhino experts in each of the participating reserves. Before starting the survey, interviewees were informed that they were free to decline to answer any questions for any reason. During the survey, interviewees were also given the opportunity to elaborate whenever wanted. This allowed me to get a better understanding of the situation on each of the reserves. Additionally, it promoted mutual trust, which was of importance for gaining approval on notching data collection and further discussions.

The double-paged survey sheet included 14 question blocks, excluding the collection of general information like name of the interviewee and conservation area, if the reserve is open to other reserves or fully fenced, size of the area, and the estimated total amount of black and white rhino within the reserve. One of the most important questions was about the notch code key each reserve uses. The questionnaire included a template of blank rhino ears, in which the rhino experts were asked to draw the notch code key pattern used on their reserve. For added clarity, I included two further, smaller rhino ear templates that could be used to draw in two examples of notching patterns and their numerical translation. The second question was used to get an indication of the extent to which rhino cross boundaries, but at the same time, could reveal possible lack in monitoring efforts. The interviewee was also asked if he/she had knowledge of alternatives to notching. Experts were asked to rate five different criteria when notching rhino, according to their importance. The more points given, the more important the criteria were. Results of this question indicate the main purpose for notching rhino and help to focus when creating a general guideline. I also asked about the relevance of trophy hunting of rhino, which could have considerable economic influence on the decision of whether to notch or not to notch rhino. Furthermore, information was requested about when the notching program started, the numbers of black and white rhino that have been notched so far and how many of them have been poached on each reserve. These facts were collected to compare against the notching data I received. I asked each interviewee about planning and performing notching events and how monitoring of notched and unnotched rhino is performed in the area, including what kind of equipment is used for this purpose. Additionally, the experts were asked about their experiences in notching rhino. They could name problems, offer criticism and give improvement suggestions. Finally, I wanted to know what importance they assign to the notching and monitoring of rhino for their conservation.

3.1.3 Evaluation

Answers from the survey sheet as well as the notching data I received, were structured and evaluated with Microsoft Excel (Microsoft 2016). If reserves submitted notching data as hard copy, information was manually transferred into a new Excel sheet. I only used data of rhino that were still alive at the time of data reception. For the evaluation of doubles, I only considered reserves connected with each other, as identically marked rhino can only be mistaken for one another in this case. To find double marked rhino, I created one universal translation code key (Fig. 7). This translation key matched notch code keys of some reserves (Fig. 13a,b), which therefore did not have to be adapted. Notch codes of the other reserves had to be translated according to the universal translation code key. A complete database for black and white rhino in the GKA was created to find repeated notch patterns and to give an overview of the amount of already notched rhino. Then the database was checked for rhino with identical microchip numbers, to avoid double-entries. If such entries were found, further details of the submitted notching data on this individual were compared. I kept the entry which was more recent or included more details on the rhino and excluded the other one for the final notch database.

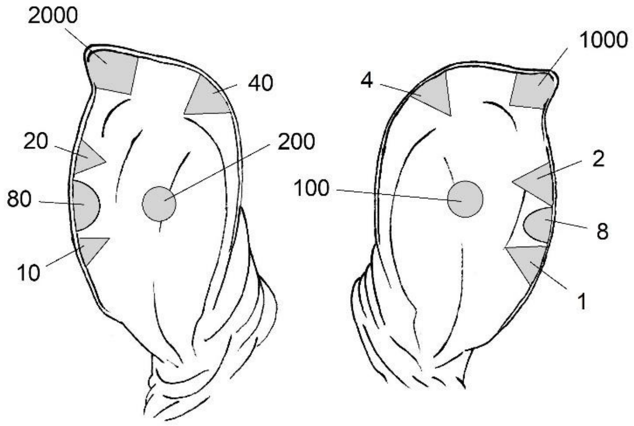


Figure 7 This pattern was used as universal translation code key to find double marked rhino. All numerical notching codes based on patters that did not match the numerical codes shown in this figure, had to be changed accordingly.

For practical issues of an ongoing ear notching program, I also calculated the possible total amount of unique code combinations (*pcc)* when using one to six ear notches on every ear. For this purpose, I used the formula

$$pcc = (2^{nl} \times 2^{nr}) - 1$$

with *nl* being the amount of notches used on the left ear and *nr* being the amount of notches used on the right ear. It was assumed that six is the maximum amount of notches that can be placed on a rhino ear in terms of space and detectability. This assumption was justified by the fact that none of the reserves used more than six notch position in one ear.

3.2 Field study on the visibility of rhino ear notches

3.2.1 Field study area

The field study area was located in the GKA, at the Southern African Wildlife College (SAWC) campus which is part of Kempiana Nature Reserve. It shares borders with Timbavati Private Nature Reserve and Kruger National Park in the Mpumalanga province of South Africa (Fig. 4b). Field studies were conducted between August 22nd and September 4th, 2017, with 107 participants. Participants were mainly college staff, field rangers, students and contractors with different level of wildlife observation experiences. The total number of participants for each variable included in the study is listed in Table 5.

I used five participants to set the basic conditions for the test which included: minimum and maximum distance between participant and rhino dummy, time given to note the notches seen, the format of the survey sheets, and clarifying instructions to participants to allow for a clear procedure (Appendix II). These five participants' observations were excluded from the main evaluation.

A pair of dummy rhino ears (Fig. 9) were located in two different habitat types. One was an open grassland, consisting of patches of bare soil, forbs and grass (Fig. 11b). The second was a bush habitat, including low growing grass, forbs, bushes and trees (Fig. 11c). Visibility of the rhino ears was not obstructed in the open habitat but was obstructed by trees and bushes in the bush habitat. The study was conducted in the dry season when there were fewer leaves on the trees and bushes and so was considered a "best case scenario" for bush habitat view.

Vegetation in the open area consisted mainly of *Urochloa brachyura* with an average height of 40 cm. The same grass species occurred but on average was half as tall in the bush habitat. In the open habitat woody plants were not present or were shorter than the grass. Average height of woody plants in the bush habitat was approximately 2.5 m. Woody vegetation was dominated by several Fabaceae species like *Vachellia exuvialis* and *Senegalia nigrescens*.

The dummy rhino ears were set at five distances, in a straight line, away from the observer, in both habitats (Fig. 8). In the open habitat dummies were set 20, 35, 50, 65 and 80 m away from the observer. Shorter distances were chosen for the bush habitat due to obstructed visibility. Distances were 10, 15, 20, 25 and 30 m. All observations were done during daylight hours and under dry weather conditions.

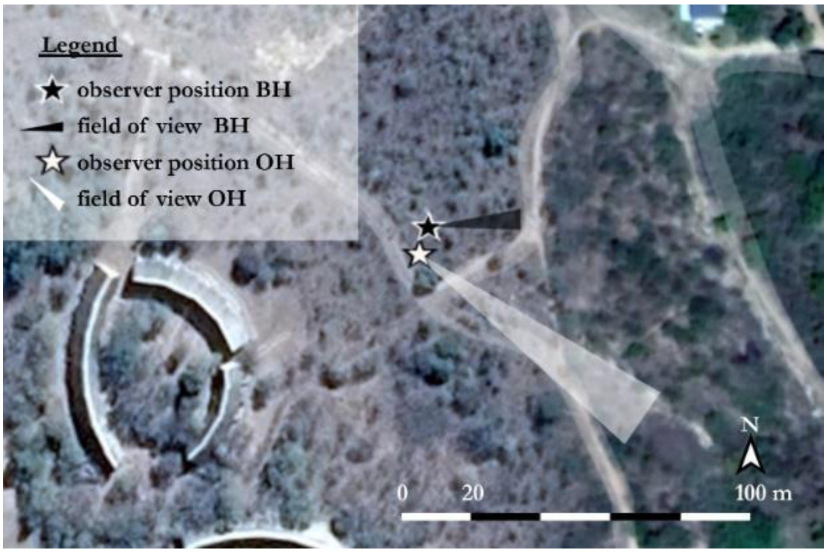


Figure 8 The map shows the area of the field study on the visibility of rhino ear notches. It is located on the Southern African Wildlife College campus. Viewpoints of the participants are marked with a white star in the open habitat (OH) and with a black star in the bush habitat (BH). The view of field is highlighted as funnel-shaped mark in corresponding colors. The length of the funnel is equivalent to the maximum distance that was tested in each of the habitats. (from: DigitalGlobe, Map data © 2018 Google; edited by Hussek)

3.2.2 Dummy rhino ears

I made 20 rhino ears out of A4 paper (160 g/m²). Size and shape closely resemble that of an adult rhino ear (Fig. 9). The ears were folded in a uniform way and fixed with tape on the bottom to hold them in shape. A template was used to guarantee that shape and alignment of the five possible, pre-assigned notch positions, was identically for all the dummy ears (Fig. 10). The hole in the middle of the ear had a diameter of 1.6 cm (congruent to a ZAR 10 cent coin) and the edge lengths of the triangle-shaped notches were 3.6 x 3.6 x 3.1 cm. These sizes were in line with veterinary recommendations, however notches often vary in size. The sizes used represent an optimistic average from comparisons of many photos of notched rhino ears provided by participating reserves. The dummy ears were painted twice with Dulux Acrylic PVA – Deep Base 9 matt paint to achieve a grey "rhino" colour. Each possible notch position represents a number and could be used either on the right or the left ear (Fig. 18).

Figure 9 One of twenty dummy rhino ears. This left ear is notched at positions 6, 8 and 10.

Figure 10 The template used to guarantee that every notch is identically positioned on the dummy rhino ear. The hole notch is congruent with a ZAR 10 cent coin.

3.2.3 Procedure

Participants were briefed about the main aim and procedure of the study (Fig. 11a) and received a data form on which they were asked to mark the code combination they saw (Appendix II). If they were not able to see any notches, they were instructed to leave the form blank. Information about the possible maximum (5) and minimum (0) amount of notches in each ear was given. In addition, participants were asked for information regarding their age, job title, experience in wildlife observations (yes/no) and to rate their eyesight (fair, good, very good). An assistant was used throughout the study to make sure that forms were filled in correctly, that no participant copied answers, and to answer procedural questions that might arise during the process.

The participants were randomly split into five different groups of equal size (A-E). Table 2 shows the pre-assigned notch combinations shown to each group. The different combinations were created to gather information about the visibility of each of the different notch positions at each distance point. Every group consisted of three participants who stood adjacent to each other in a position (left, centre, right) which they kept for observations in both habitats.

Table 2 The table shows the different code combinations (I-V) presented to each of the five groups (A-E). The order of ears differed between groups, habitats and distance points to maximize the amount of data gained for every notch position.

Open habitat:						Notch positions:			Bush habitat:						Notch positions:		
Distance/Group	A	B	C	D	E		right ear	left ear	Distance/Group	A	B	C	D	E		right ear	left ear
20 m	I	III	II	V	IV	I	2,5,	7,9	10 m	IV	II	I	III	V	I	1,3,4,5,	6,8
35 m	II	I	IV	III	V	II	1,3,	6,8	15 m	I	V	III	II	IV	II	1,3,	6,8,10
50 m	III	V	I	IV	II	III	2,4,	6,7,9,10	20 m	II	I	IV	V	III	III	2,5,	7,9,10
65 m	IV	II	V	I	III	IV	1,5,	6,7,8,10	25 m	V	III	II	IV	I	IV	2,4,	7,9
80 m	V	IV	III	II	I	V	1,2,3,5,	6	30 m	III	IV	V	I	II	V	1,2,3,	6,10

A best-case scenario was created in which the rhino is facing the observer directly so that both ears are visible. For each round of observations, I held the dummy ears at a height of 1.20 m (Fig. 11b,c). This height was chosen as rhino usually have their heads down, with limited upward mobility, and so ears are slightly below should height. Shoulder height data of white rhino is 1.5 -1.8 m (Tomášová 2005) and 1.6 m for black rhino (Adcock and Amin 2005). The dummy rhino ears were slowly rotated for 30 seconds, at angles that mimic a rhino moving its ears to listen. This was done in the same manner each time, to allow participants a chance to view the ears and notches from several angles. Participants were allowed to crouch and stretch and take one step sideways if needed (Fig. 11d). This option allowed for more flexibility and realistic viewing, especially in the bush habitat. Within the 30 second timeframe, participants were asked to mark with a "x", or a circle, which notches they thought they saw on the data form. The form showed the five possible notching positions on each ear (Fig. 18) to allow for a more precise evaluation of the results. After the 30 seconds, the dummy ears were shown at the next distance and the procedure repeated until observations at all five distances were completed.

The entire procedure was then repeated in the second habitat. Ear combinations differed between first and second habitat to increase the amount of data about the visibility of each notch position from every distance point.

(a) (b) (c) (d)

Figure 11 (a-d) Impressions from the field study on the visibility of rhino ear notches. All participants received detailed information about the aim and procedure of the study (a). Dummy rhino ears were presented in an open habitat type (b), with unobstructed view, and in a bush habitat type (c), where branches and scrub could impair vision on the dummy ears. Participants were allowed to crouch and stretch (d) to simulate a more realistic monitoring situation, especially in the bush habitat.

From August 29th, 2017 onwards, I included binoculars (MINOX 8x42) for the maximum distance in both habitats to test if their use improved accuracy. Participants had to look at all the distances without binoculars first and then repeat the last distance with binoculars. 20 seconds to adjust the focus of the binoculars at the set distance were given. For this purpose, I lifted a hand to the position where the dummy ears would be.

3.2.4 Evaluation

All data were structured with Microsoft Excel 2016 and evaluated with R 2.3-0 (R Core Team 2016) and R Studio 3.4.3 (RStudio Team 2016). Generalized Linear Models (GLM) with Age, Experience, Eyesight, Job.Activity, Start.Time and Weather defined as independent variables, and totally correctly identified notch codes as dependent variable were created for the closest point in both habitats. This was considered a best-case scenario. As correlations between one or more dependent variables could influence results of the GLM, I tested if any of the factors correlated with one another by calculating the Variance Inflation Factor (VIF) for the independent variables, defined as $VIF_j = 1/(1-R_j^2)$ with R^2 being the coefficient of determination (Fox 1991). A VIF < 10 indicates that it is very likely that no correlation exists between any of the variables (Miles 2005).

Variable Start.Time correlated with the altitude of the sun (AM: Solar altitude from east-north-east to north, PM: Solar altitude from north-north-west to west-north-west) and was included to test if resulting shades or sunbeams influenced results. At 13:05 solar altitude was north at the location of the field study, so all observations starting until this time were included in the AM group, all observation starting afterwards in the PM group to simplify the GLM. Variable Age was grouped into participants under 40 years and those older or equal 40 years and converted into a factor (Newman *et al.* 2003). A Fisher´s exact test via contingency table was used to test for significant differences between the two age classes. I chose this test as it is better suited for small sample sizes than Pearson´s chi-squared test which in turn was used to compare the amount of totally correct answers in the bush and the open habitat (Lamprecht 1992).

As correct identification of each rhino is dependent on every single notch being seen correctly, answers were only classified as totally correct, if all notches present on the ears were correctly recorded by the participant. Due to the binary dependant variable (correct/wrong), the family of the GLM was set as binomial with a logit link function. A stepwise model selection was performed to find the most parsimonious model by using Akaike´s Information Criterion (AIC) to differentiate between models.
A conditional inference tree (ctree) was used to determine if the data can be divided into groups based on the independent variables. I used OH1_totally.correct as response variable and the other six variables as inputs for the ctree (package "party") (Hothorn *et al.* 2006).

Mann-Whitney-U-Tests were used to check for significant differences between viewing distances and the amount of correctly identified notches in each of the habitat types. To find the most visible notch positions, I used Pearson´s chi-squared test to test for significant differences between the amount of correctly and incorrectly identified notches on each position of the dummy ear. The confidence level for significance was selected at 95 % in all analyses.

3.3 Creation of a guideline and shared database

Close cooperation with all participating reserves throughout the whole process of developing a consistent guideline was of main interest. For this reason, several meetings of the Greater Kruger Environmental Foundation (GKEPF) members were used as platform for discussions, presentations and votes on ear notching in rhino. In a first step, I wanted to know if reserves of the GKA are performing, or intent to start monitoring of rhino on their property (Fig. 12). Linked to this question, the reserves should decide for themselves what their aim of monitoring rhino would be and thus, which techniques might be useful for this purpose. They should also think about the amount and kind of rhino that need to be monitored in order to reach their ambition. Finally, methods and ways to ensure continuous data collection and monitoring of rhino should be reconsidered. By doing so, reserves should become more aware about the process and ambitions of possible rhino monitoring programs.

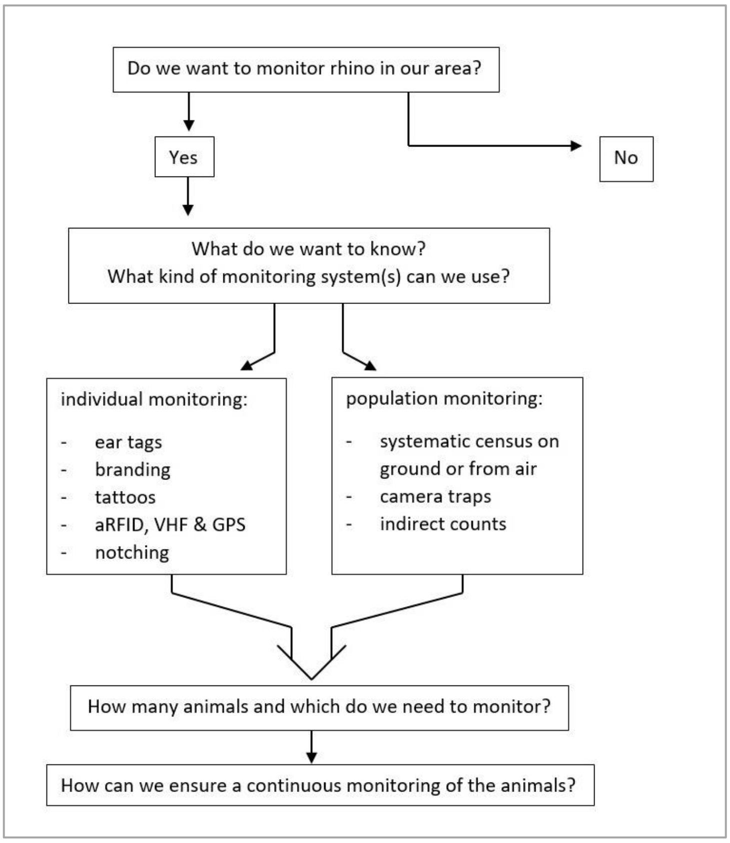


Figure 12 A simple decision diagram created to help with the decision-making process according to the notching and monitoring of rhino in the Greater Kruger Area.

Results from the evaluation and from votes during GKEPF meetings, legal obligations as well as personal experiences and information from the commonly used "Trainee´s Guide for Monitoring African Rhino" (Adcock and Emslie 2007) were incorporated for the creation of a guideline. For uniformity reasons within the GKEPF administration, the layout and design of this guideline was determined as Standard Operating Procedure (SOP) document. Development of the shared database was guided by legal obligations as well as by results from the evaluation of the notching data I received from participating reserves. A draft for future recordkeeping of notched rhino was created in a password-protected Microsoft Excel table.

4. Results

Some of the data I received from the participating reserves of the GKA must be seen as sensitive information in terms of security issues related to rhino poaching. Therefore, results are presented in a summarized and anonymous form, rather than in relation to each individual reserve. This procedure was a consensual prerequisite for cooperation with the reserves.

4.1 Results of the survey

The survey on rhino notching was carried out during July and August 2017. Therefore, the results presented in the following only include notching data until then. No statements are made about rhino that were marked after the interviews with the rhino experts.

Evaluation of the survey showed that regular ear notching of rhino in the study area started in 2003, but in many cases, notching events have not been carried out annually. Seven of the reserves started with the notching in, or after, 2010.

4.1.1 Amount of already notched rhino

Of the 13 reserves that participated in the survey, eleven stated to already use ear notching in rhino on their area. The other two were thinking about starting rhino notching as well. Eight reserves only notched white rhino, as no black rhino are present in their area. The area covered by the 13 reserves contains approximately 7500 white and 350 black rhino. The total amount of notched rhino was 736, comprising 685 white and 51 black rhino. This means that about 9.1 % of all present white and about 14.6 % of all present black rhino in the GKA are notched already. Three reserves were not open to other reserves, as roads and fences separate them (Fig 4b). The amount of notched rhino within the remaining ten reserves that are potentially connected was 592 white and 40 black rhino. The statements I received on the amount of poached notched rhino were quite vague in some cases, as poaching statistics are part of internal security management. The data obtained can estimate the extent of confirmed poached notched rhino with about 70 white and 13 black individuals.

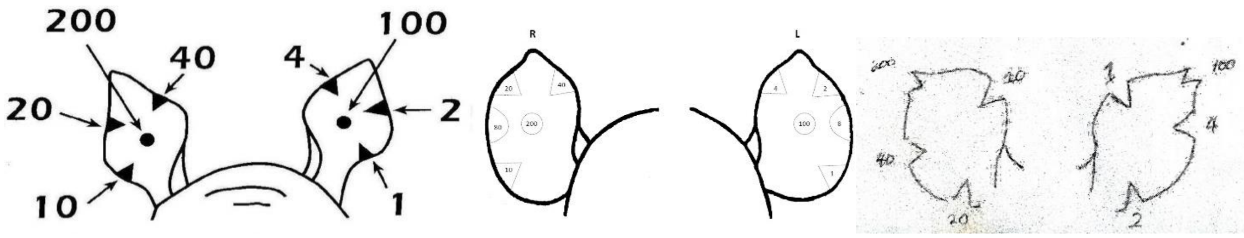
4.1.2 Notch code keys

Evaluation of the survey proved that different patterns of notch code keys are being used by the reserves in the GKA. This includes different notch positions on the rhino ear, shapes of the notches themselves as well as different code keys for translating the notches into a numerical code.

The most commonly used key pattern is shown in Figure 13a. This pattern was applied by four of the eleven reserves that stated they perform ear notching in rhino. It uses three triangle-shaped notches on the edge and a circular hole in the middle of each ear. The resulting four possible notch positions on both ears offer 255 *pcc*.

Two reserves used the same key pattern but included another semi-circular notch in the middle of the outer curve of the ears (Fig. 13b). As this pattern allows five notches on each of the ears, the amount of *pcc* increases to 1023.

Another two reserves used a key pattern with four triangle-shaped notch positions on the edge of both ears (Fig. 13c). Unlike most of the other reserves, they also used the tips of the rhino ears as possible notch position. The remaining two reserves performed notching without a numerical translation code key. They used different shapes of notches like triangles, small and bigger circles as well as squares.



(a) (b) (c)

Figure 13 (a-c) Different rhino ear notch key patterns used by reserves of the Greater Kruger Area. The notches differ in shape, position on the ears as well as their numerical code translation. The most commonly used key pattern is shown in (a) followed by (b) and (c).

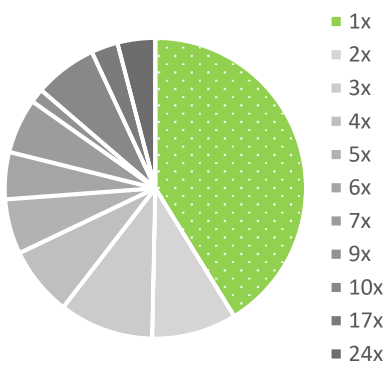
4.1.3 Duplicates

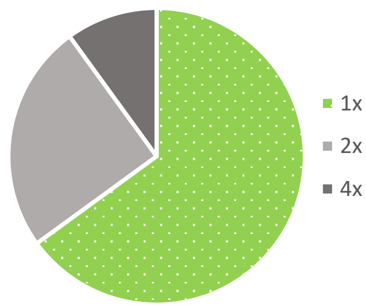
Ten of the 13 reserves were connected with each other, with two of them stating that they have not carried out any rhino notching events so far. The remaining eight reserves covered 151 codes for white and 21 codes for black rhino that had to be adapted manually according to the universal translation code key (Fig. 7).

The evaluation has shown that a total of 348 from 592 notched white rhino are not individually marked. For black rhino the amount of doubles was 14 out of 40. Details of the evaluation are presented in table 3. These results reveal that 59 % of all notched white rhino and 35 % of all notched black rhino in the connected reserves of the GKA are not individually marked and could be mistaken for one another in terms of their ear notches. The extend of multiples in notched white rhino was up to 24 and in black rhino up to four individuals wearing the same notches.

Table 3 The amount of multiple identically marked black and white rhino are presented. 348 white and 14 black rhino did not receive individual ear notches in the study area and hence could be mistaken for one another.

White rhino		**Black rhino**	
Multiples	Count	Multiples	Count
1x	244	1x	26
2x	27	2x	5
3x	20	4x	1
4x	11		
5x	7		
6x	5		
7x	5		
9x	1		
10x	4		
17x	1		
24x	1		
∑	592	∑	40



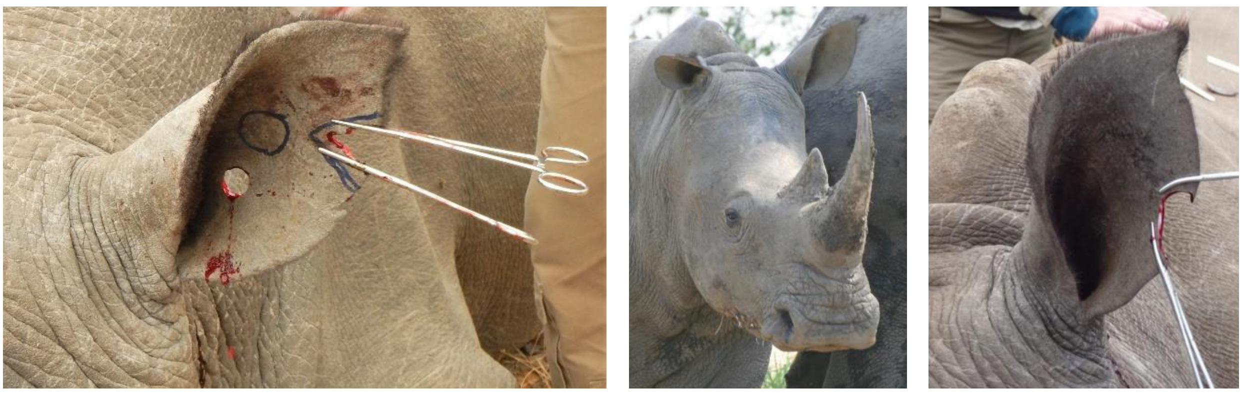


Double marked rhino did not only appear between reserves due to different notch code key patterns or insufficient coordination, but also within reserves. Results showed that doubles, triples and quadruples, resulting in a total amount of 41 % of all notched rhino being not marked individually, appeared on one and the same reserve.

4.1.4 Problems

Ten reserves named problems with the notching or aspects of it that they would like to have improved. Their criticism partly overlapped with results of my evaluation.

First, a considerable amount of marked rhino in the area are not marked with unique notches. This can result in the risk of confusion of individuals and therefore weaken the original benefit of a notching program. Six of the ten reserves open to each other answered that they have seen rhino with unknown notch combinations in their area before. The evaluation revealed that doubles did not only appear between, but also within reserves. Different notch code key patterns are being used, which makes clear identification of individuals that move across boundaries, difficult. This problem is compounded by the fact that coordination and cooperation between the reserves, in terms of information flow about notched animals, largely lacks. Furthermore, even if a reserve used a special notch code key pattern, the actual notch positions on the real rhino ear could show variation according to size and position in some cases as veterinarians differ. Moreover, the positions of the notches cut also have to take into account veins running through the ears (Fig. 14a). This makes a clear identification even more difficult. Some photos showed rhino with already torn or malformed ears (Fig. 14b). The circular notch in the middle of the ear can cause similar injuries, as branches are likely to get stuck in it. Additionally, the circular and semi-circular notch some reserves use are more difficult for the vet to cut than a triangle. The resulting shape of the notch might not be perfect in those cases (Fig. 14c). Trying to avoid these notch positions would imply a limitation in possible code combinations. As the estimated total amount of rhino in the area is 7850, not even a notching system with six possible notch positions would offer enough codes to mark all rhino uniquely (Table 4).



(a) (b) (c)

Figure 14 (a-c) Deviations of the exact notch position on a rhino ear can occur e.g. due to veins which the vet will avoid cutting (a) or malformed ears, that does not allow for an application of notches (b). Free-handed cutting of semi-circular notches with a scalpel is more challenging than notching with a plier and might result in an imperfect notch shape (c).
(Figures (b) and (c) from: Balule Nature Reserve 2017)

Table 4 The table shows the corresponding maximum amount of possible code combinations (pcc) that could be achieved with 2 to 12 notches on both ears of an animal.

Amount of notches on both ears (left + right)	Amount of possible code combinations $pcc = (2^{n^l} \times 2^{n^r}) - 1$
2	3
4	15
6	63
8	255
10	1023
12	4095

This fact leads to the next problem: the overall aim of notching rhino is not clearly defined in several cases, including the number of individuals that finally should be notched. All participants of the survey stated that notching and monitoring of rhino is important or very important for the conservation of this species. Only one reserve made use of a specially designated rhino monitor. This person is skilled in tracking rhino and studying their behaviour and performs daily counts of rhino by observation or camera trapping. Three reserves said that their Anti Poaching Units (APUs) undertake regular monitoring of notched and unnotched rhino, including the one with the rhino monitor. APUs should protect animals from poachers. Their training is often of a more military nature, than behavioural biology. Commercial units like game drivers, field guides or rangers were used for regular counts of rhino in six reserves. Intervals for those regular counts ranged from daily to every three months. Four interviewees stated that they use no regular counts, but opportunistic sightings by tourists, guides or patrols. Camera traps for monitoring of rhino were used by three of the 13 reserves. Tracks and dung middens of rhino were recorded by five reserves. Nearly all reserves used the Intelligence Software Application *Cmore* to share information about patrols and observations (https://cmore.csir.co.za/). Aerial counts were performed in eleven reserves, some as annual census, other as patrols throughout the year. Annual aerial counts are often used for an estimation of game in general, and do not only focus on rhino. Most of the reserves monitoring staff used GPS devices, while only about half of them reported using binoculars when observing rhino. This was explained as binoculars representing unessential weight for the patrols, which often have to stay in the bush for several days or even weeks, to carry. Space in the backpack is limited and preferably filled with more essential things like food, water or clothes rather than with binoculars. This listing illustrates the diversity of monitoring measures of rhino within the GKA and their different levels of intensity. It can be concluded that there is no consistent monitoring concept for rhino in the study area.

Another factor that was mentioned as a weak point were the costs of notching and who is going to pay for it. Several people, including a vet, vehicles, a helicopter, a plane and anaesthetics are needed to carry out such an event. As ear notching represents an invasive method which implies stress for the animal, it can only be performed under cool weather conditions and when the animal is in good condition. Those factors limit the possible application of notching in temporal and monetary terms and require high flexibility of all participants.

The visibility of notches was also mentioned. One reserve noted that notches might not always be visible in a bushy habitat. Three interviewees mentioned that they have experienced confusion amongst staff about which ear is defined as "left" and which as "right" ear. This causes unreliable data coming back from observations.

A possible negative impact on photo-/ecotourism was mentioned by three reserves, although all of them relativized this statement by saying that the impact is strongly dependent on how well the notching program is explained to tourists.

Six of 13 reserves had knowledge about alternative methods of marking rhino. These were mainly Global Positioning Systems (GPS) or Very High Frequency (VHF) transmitters, ear tags or the use of natural marks like horn size or scars.

4.1.5 Expert opinions on notching

Totalled up, rhino experts stated that "visibility of the notch pattern from distance" is the most important out of the five given criteria, with almost 50 % of the maximum score (Fig. 15). Calculated individually, eight reserves gave most of the 100 points to this criterium. Two experts allocated most of the points to "acceptance of notches by hunters, tourists and others", although they belonged to the twelve reserves stating that trophy hunting of rhino for their area is unimportant. One expert distributed the 100 points equally to the two mentioned criteria. The criteria "use of the most common notching method" was most important for the remaining two reserves. Seven experts allocated zero points to the criteria "intensity of the operation in the rhino". The averaged results for the ten connected reserves give the same picture as results for all 13 reserves. These outcomes represented the starting basis for my field study on the visibility of rhino ear notches.

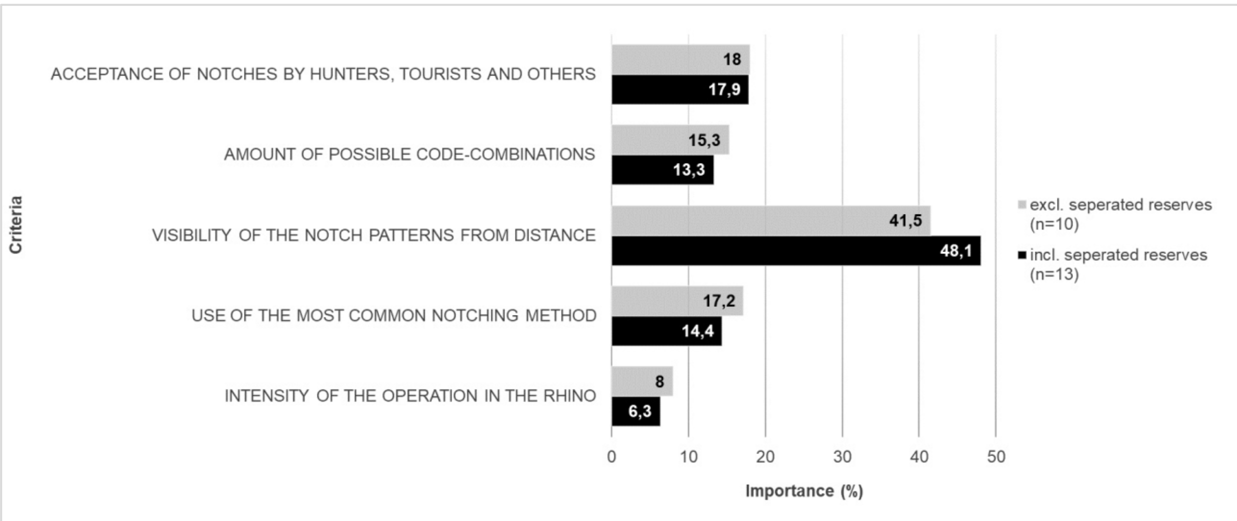


Figure 15 Expert opinions on ear notching in rhino in the Greater Kruger Area. Experts of 13 reserves were asked to rate five different criteria according to their personal relevance. The resulting relative importance (%) is shown for all (black bars) as well as only for reserves that are directly connected with each other (grey bars).

4.2 Results of the field study

Table 5 shows a summary of the field study data analysed. Total numbers between open and bush habitat differed slightly, because of two entries in the open habitat that were excluded due to a misunderstanding of the task during the first iteration.

Table 5 The recorded variables are listed with appropriate abbreviation used for the GLM, how they were translated for evaluation and an explanation. The two columns on the right show the total number of participants for each of the variables in the open (OH) and in the bush habitat (BH).

Variables	Abbreviation	Translation	Explanation of Variable	Total OH	Total BH
Age	1	18-39 yrs.	Age of participant	79	81
	2	40-69 yrs.		21	21
Experience	Yes	has experience	Personal assessment of	64	66
	No	no experience	participant´s experience of observing wildlife	36	36
Eyesight	Fair		Personal assessment of	13	13
	Good		quality of participants vision	56	56
	Very good			31	33
Job.Activity	Student	Student	Main occupation or activity	38	39
	Worker	Kitchen staff, Housekeeper, Building contractor…	of participant	31	32
	Academic	Clerk, Field ranger, Academic supervisor…		31	31
OH1_totally.correct	y	yes	Amount of totally correctly	23	
	n	no	identified notch codes at 20 m in the open habitat	77	
BH1_totally.correct	y	yes	Amount of totally correctly		26
	n	no	identified notch codes at 10 m in the bush habitat		76
Start.Time	AM	Start time until 13.05	Time the exercise started	52	52
	PM	Start time after 13.05		48	50
Weather	Sunny		Weather status while exercise	83	85
	Cloudy		was carried out	17	17
∑ Participants				100	102

4.2.1 Identification rates of individual notch codes

The amount of totally correctly identified notch codes at the closest point was 23 out of 100 in the open, and 26 out of 102 in the bush habitat type. Correct identification rate from the closest distance was approximately 25 % in both habitat types. Identification rate continuously decreased with increasing distance and reached zero at the maximum distance (Fig. 16). At 20 m, a distance used in both habitats, identification rates were highly significantly more accurate in the open than in the bush habitat ($\chi^2 = 12.034$, df = 1, $p < 0.001$).

4.2.2 Identification rates of individual notch positions

The amount of correctly identified notches showed that the visibility of rhino ear notches is better in an open than in a bush habitat (Fig.17). Again, identification rates decreased with increasing distance between the dummy rhino ears and the participant. The decline in the open habitat showed a strong linear relationship with distance ($R^2 = 0.98$). This significant relationship was present, but weaker in the bush habitat

(R^2= 0.61). Here, the amount of correctly identified notches decreased by about 50 % from the first point (10 m) to the second (15 m).

The proportion of correctly and incorrectly identified notch positions is shown in table 6. Positions 2 and 8 on the upper outer curve of the rhino ears were the ones most visible in both habitats, followed by notch positions 5 and 10 plus 3 and 7. Notch positions 1 and 9 on the lower outer curve of the rhino ear showed the worst results in both habitat types (Fig. 18).

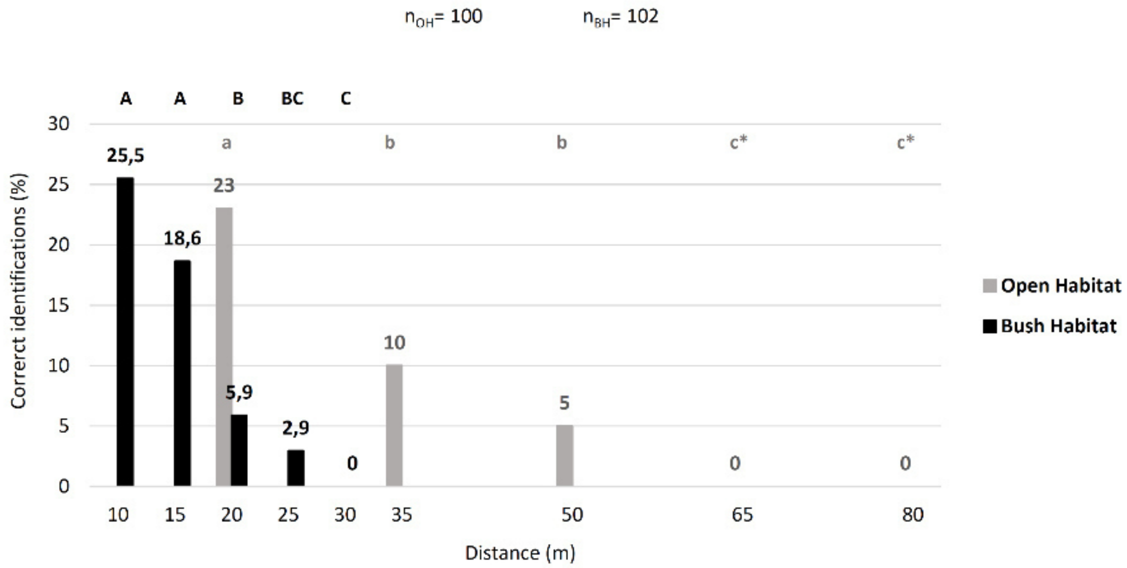


Figure 16 The amount of totally correctly identified rhino ear notch codes in relation to distance (in %) for two habitat types are displayed. Identification rates decrease with distance. Results of Mann-Whitney-U-Tests are included as letters above bars. Bars with same letters do not differ significantly. *Results of distances 65 m and 80 m could not be compared to each other as no correct identification was recorded in both cases.

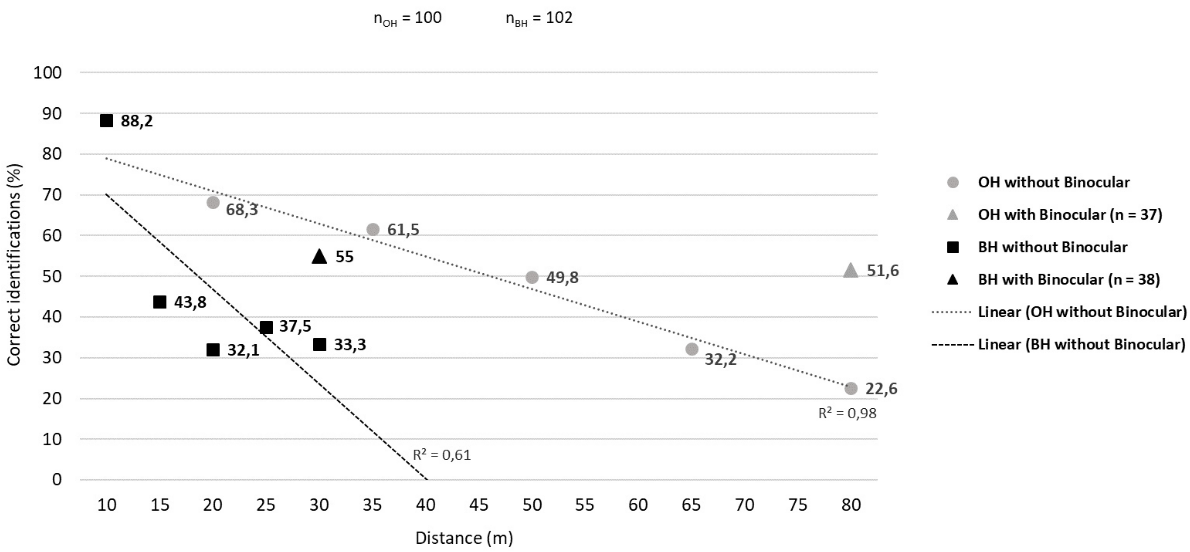


Figure 17 The mean percentage of correctly identified notch positions in relation to distance. Regression lines reveal a clear relationship between distance and identification rates. The result of using binoculars is marked as triangle at the maximum distances in the open (OH) and bush (BH) habitat and shows a considerable increase in the detectability of rhino ear notches.

Table 6 Number of correctly identified vs. total number of rhino ear notch positions in open (OH) and bush (BH) habitat with or without the use of binoculars. The grey boxes give the percentage of their identification rates – lighter colours mean higher accuracy identification level than darker colours.

	OH						BH					
	with binocular			without binocular			with binocular			without binocular		
Notches	correct	total	%	correct	total	%	correct	total	%	correct	total	%
1&9	115	536	21	111	499	22	55	548	10	51	510	10
2&8	364	538	68	333	501	66	191	548	35	170	510	33
3&7	294	537	55	276	500	55	127	552	23	115	514	22
4&6	188	503	37	174	468	37	120	584	21	114	543	21
5&10	292	532	55	268	500	54	163	548	30	153	510	30

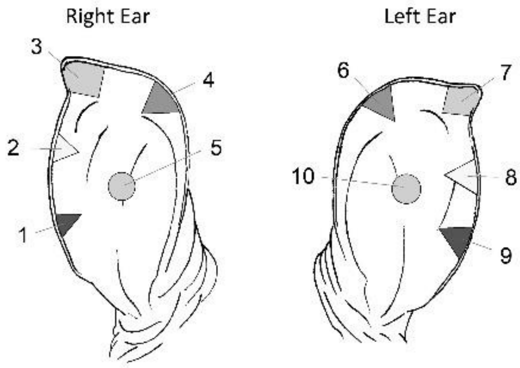


Figure 18 Notch code key for the field study. Each notch position represents a number which can be used on the left or the right ear (e.g. the hole in the middle represents number 5 on the right ear or number 10 on the left ear). The results of testing their individual visibility are included as shades of grey – the lighter the colour, the better visibility.

4.2.3 Maximum distance for identification

Results suggested that the maximum distance for possible correct notch code identification in an open habitat ranges between 50 and 65 m and between 25 and 30 m in a bush habitat. At 65 and 30 m respectively, the correct identification rate reached zero. Mann-Whitney-U-Tests revealed that distribution significantly differed between some of the distance points ($p < 0.05$) as shown in figure 16.

4.2.4 Impact of the use of binoculars

The use of binoculars noticeably improved the amount of correctly identified notch positions. This improvement effect was stronger for the open than for the bush habitat (Fig. 17). Nevertheless, their use could not improve notch code identifications at the maximum distances in both habitats. Difficulties in proper handling and use of the binoculars could be observed in some participants.

4.2.5 Other influencing factors

The linear correlation between distance and identification rate suggests the assumption that distance is the main influencing factor when identifying rhino ear notches. Further factors influencing the results in both habitat types could be revealed by using GLM for the closest distance. VIF for all variables in both habitats were < 2, indicating that no correlation, which could impair evaluation, existed between any of the independent variables (Miles 2005).

For the open habitat, variable age significantly influenced the amount of totally correct answers ($p < 0.05$, GLM). Participants 40 or older did significantly less well than younger participants (AIC- Coefficients for $Age_{\geq 40yrs}$= -2.46; p_{OH} < 0.05, Fisher´s exact test). Results showed no significant effect of eyesight and experience on identification quality. Eyesight was not correlated with age (p_{OH}= 0.573, Fisher´s exact test). The ctree created explained variation of the response variable totally.correct (Fig. 19). Age only influenced correct notch code identification if participants were in the group of academics or students, as no participant of the group of workers gave a completely correct solution. Chances of accurate identification were about 40 % if the participant was in either the group of academics or students and younger than 40 years old.

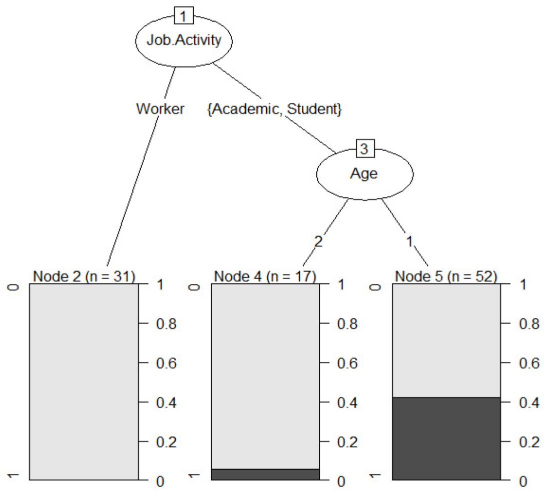


Figure 19 Conditional inference tree for the open habitat data (n=100). Ranked nodes reveal differences between recorded variables within the sample of participants. *Age* is divided into participants < 40 years (node 1) and participants > 40 years (node 2). This variable represents the main influencing factor for correct identification of rhino ear notches. The dark bars indicate the chance of correct identification by every group.

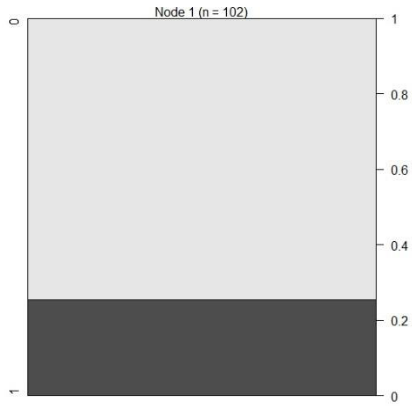


Figure 20 Conditional inference tree for the bush habitat data (n=102). Chances of accurate identification of rhino ear notches at 10 m distance were about 25 %.

For the bush habitat, participants stating they have experience in wildlife observation showed more accurate identification results than those with none ($p < 0.05$, GLM). Like in the open habitat, participants 40 or older achieved worse results than the ones younger than 40 years (AIC- Coefficients for $Age_{\geq 40yrs}$= -1.108). Fisher´s exact test showed that there was no correlation between eyesight and age (p_{BH}= 0.45). No additional key factors influencing accuracy of results could be revealed via ctree (Fig. 20). It only states that the chances of accurate identification at 10 m distance in the bush habitat were about 25 %.

4.3 Guideline and shared database (Appendix III)

As reserves wanted to continue with the notching, the SOP lists a detailed description of performing the ear notching of white and black rhino. Furthermore, it includes a template for the notching itself as well as for ongoing observations of notched rhino, which could easily be used by patrols and rhino monitors.

The responsible authorities decided to differentiate between the notching of black and white rhino in the future. As population numbers for white rhino (n ≈ 7500) are much higher than those of black rhino (n ≈ 350), the reserves agreed to stop individual notching of white rhino. Instead, they decided to use a "Reserve ID" for the marking of white rhino. This decision was reasoned by the fact, that there are not enough notch codes available to mark every white rhino individually (Table 4). It was suggested that already marked white rhino could still be used for gaining knowledge about individual spatial and temporal movement and behavioural patterns e.g. under changing climate conditions. The reserves were welcomed to continue with an individual monitoring of white rhino where possible and wanted, but only in form of bookwork (i.e. as a rhino is microchipped and DNA-sampled it will receive a unique identifier on the paper work) and not as mark on the rhino itself.

Outcomes of the survey and results from the field study were combined to decide which numbers should be allocated to the 13 reserves and how the corresponding notch code key pattern should look (Fig. 21a). As observed rhino might stand sideways rather than front on the observer, I decided to use at least one notch on each ear. Notch positions that proved to have a higher visibility (Fig. 18) were preferred, although the hole in the middle of the ear as well as the notch at the tip of the ear were excluded, due to their negative impact on the structure of the ear (De Beer, pers. com. 2018). No more than three notch position were used, in order to keep the intensity of the operation as low as possible.

For the black rhino, reserves decided to maintain an individual notching program, as the amount of individuals of this species is considerably fewer than 1023. Hence, a notching system with five notch positions on each ear will allow enough notch combinations to mark every black rhino individually in the GKA and even show a surplus of codes if population numbers should increase. To exhaust all possibilities of combinations given with ten notches, I extended the notch code key pattern by a decimal potency (Fig. 21b). Codes 1-2965 were allocated to the reserves, relative to the number of black rhino in their area and their expended effort in notching. I included a generous buffer in case black rhino numbers should rise and also left codes ranging from 3000-3565 available, in case a reserve should exhaust their allocated codes. Those codes could also be allocated to new reserves, willing to join the rhino notching system. Black and white rhino with duplicate notch codes, of which there were over 360 individuals, should be remarked, if captured, to make their markings unique and improve individual identification.

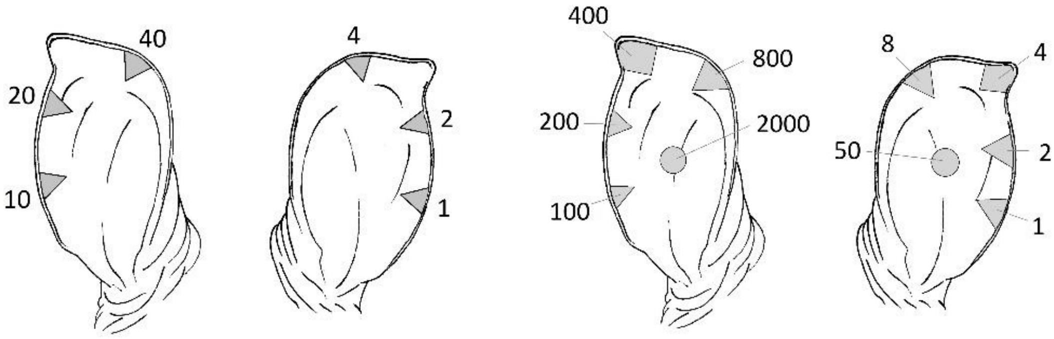


Figure 21 (a) *(left)* New reserve key pattern for the ear notching of white rhino.
(b) *(right)* New individual key pattern for the ear notching of black rhino.

Table 7 Information included in each of the two shared databases. Detailed information about each term can be found in the Standard Operating Procedure (Appendix III).

Notching rhino		**Observing rhino**
Notching Code		Reserve ID
DNA Sample Kit Number		Date
Microchip Numbers	Anterior Horn	Time
	Posterior Horn	Latitude
	Left Hump	Longitude
	Right Hump	Species
	Left Axilla	Notched
	Right Axilla	Notching Code
Anterior Horn Measures	Base	Sex
	Outer Curve	Age class
	Inner Curve	Condition
Posterior Horn Measures	Base	Observer
	Outer Curve	Distance (m)
	Inner Curve	Binocular Magnification
Species		Comments
Sex		
Date of Birth		
Age		
Condition		
Reserve ID		
Notching Date		
Notching Time		
Coordinates	Latitude	
	Longitude	
Veterinary		
Date of Natural Death		
Date of Poaching		
Sold		
Calf into Foster Care		
Comments		

The database was divided into two files: one for the notching of rhino and one for rhino observations (Table 7). The information required in the two files partly differed, as some parameters like e.g. microchip numbers are highly important when notching, but not when observing a rhino, as it will not be possible for observers to read out the microchip on a moving animal or from a distance. Relevant parameters selected for the database correspond to the instructions given by the SOP. The files were password-protected and should be centrally held and updated by the Command Centre of GKEPF, to assure highest technical and safety standards. Reserves were asked to forward information on notched and observed rhino to GKEPF in regular intervals.

5. Discussion

Outcomes of this thesis reveal, that existing concerns about a lack of coordination within the rhino notching program are justified and thus confirm the first hypothesis **(H_1)**. Evaluation of survey data showed that about 14.6 % (51) of the black rhino and about 9.1 % (685) of the white rhino population in the GKA have been notched **(Q_1)**. But neither a consistent implementation of the notching does exist, nor do all participating reserves have a concept for suitable continuous monitoring of notched animals. The use of at least three different notch code key patterns within the 13 reserves proves this assumption **(Q_2)**. This situation has resulted in a seriously high amount of duplicates in notched white (59 %) and black rhino (35 %) **(Q_3)**. These individuals could possibly be mistaken for one another when crossing reserve boundaries. Such incidents seem likely to happen, as more than half of all connected reserves stated they have seen unknown notched rhino on their property before **(Q_4)**. Therefore, regular communication between the reserves is needed to allow for a comprehensive and complete monitoring of marked individuals. A universal numerical code key and notch pattern as described in the SOP (Appendix III) seems beneficial for this case.

Additionally, it should be kept in mind that South Africa is home to the largest proportion of African rhino therefore, often involved in rhino translocation programs (Player 1967; Buys 1987; Fyumagwa and Nyahongo 2010). For a nationwide coordination of such programs, a consistent marking system in rhino would be beneficial for all participating reserves. If reserves do not participate in translocation programs and are fully fenced, coordination of ear notch codes with neighbouring reserves might not be relevant in terms of double marked individuals, because there is no actual danger of confusion. Nevertheless, results revealed, that doubles, triples and quadruples even appeared within one reserve **(Q_3)**. This situation can only work, if the reserve has established a well-coordinated, regular monitoring system.

Within a notching program, "visibility of the ear notches" proved to be the most important factor for rhino experts **(Q_5)** which emphasizes the need for conducting a field study on the visibility of rhino ear notches. Results suggests that this method is not as reliable as previously thought and its usefulness for monitoring individuals from a distance should seriously be questioned **(H_2)**.

A notch coding system for individual animal identification is effective only if all notches can be reliably identified. For this reason, the statistical evaluation of influencing factors via GLM concentrated on the amount of totally correctly identified notch codes only. The dummy rhino ears used in the two habitat types might not perfectly represent a real observation of a notched rhino, but I attempted to create a best-case scenario. Even in these best-case setups the identification rate was only below 25 % at a distance of 20 m [(**Q_6**); Fig. 16]. In real situations the animal might move, stand sideways obscuring at least one ear, or the observer might not be able to get this close. Furthermore, for much of the year and in more heavily vegetated areas, the view will be far more obstructed than in either of my field study habitats. For this reason, a distance of 10 m, in a bushy habitat, might even be an optimistic value for accurate rhino identification. For black rhino, this could be particularly dangerous for the observer, as they are known to react aggressively if surprised (Ritchie 1963; Schenkel 1987; Adcock and Amin 2005).

Differences in the visibility of single notch positions were found [(**Q_7**); Table 6], indicating which positions should be preferred for the Reserve ID in white rhino. Nevertheless, when considering the suitability, or visibility, of different notch positions, attention must be given to the potential for structural problems for the rhino´s ears (**Q_4**). Instances of rhino ears becoming torn or floppy when notched in the middle or on the tip have been reported (De Beer, pers. com. 2018). Especially black rhino, which prefer bushy habitats, run the risk of ripping their ears, if a branch gets stuck in the circular notch in the middle of the ear. Resulting wounds could become infected and therefore affect animal welfare. Such negative consequences on individuals of an already endangered species, would not be acceptable, as impact on monitored wildlife should be minimized (Wilson and McMahon 2006). Cutting circular and semi-circular notches is more invasive, as they are more difficult to cut and bleed more than a triangle-shaped notch. Besides, they have to be cut big enough, to avoid closing after a few years, and they can appear ´filled´ or covered by mud when wallowing (Ritchie 1963; Owen-Smith 1973; Trense 1989; Tomášová 2005). Considering the high costs and efforts of a notching event, as well as the risk for the darted rhino, such an insufficient result would be hard to justify ethically. For these reasons, the notch positions on tip and in the middle of the ear were excluded for the Reserve ID, although they showed the second best visibility (Fig. 18, positions 3 and 7 plus 5 and 10).

Due to their poor vision, rhino are mainly dependent on their sense of smelling and hearing (Schenkel 1987; Adcock and Amin 2005). A possible negative impact of the notches on the hearing ability has not been tested so far. Albeit, cases of rhino with natural ear notches and individuals that lost parts of their ears, have been documented in the study area (Fig. 14b). Such injuries are known to happen mainly to calves, being attacked by hyaenas or lions (Hall-Martin 1986; Schenkel 1987; Adcock and Amin 2005). In these cases, an application of artificial notches might not be possible and appropriate for identification (**Q_4**). However, natural malformations, tears or notches already represent a distinctive feature and could be used as such.
Since there is a legal obligation to collect DNA and microchip rhino when handled, one option would be to notch the animals' ears only at positions showing the highest visibility (Fig. 18, positions 2 and 8) to mark the animal as sampled. The excised patch of skin would serve as DNA sample at the same time (DEA 2016). Private donors could still participate at such events, allowing fund raising and awareness campaigns to continue.

The GLM revealed that the age of the observer was a major influencing factor on how accurately notches were identified (**Q_{10}**). People younger than 40 might be expected to have better eyesight than those over 40 years (EDPRG 2004). That eyesight was not correlated with age, and had no significant effect on identification quality, can be explained by this parameter being a subjective estimate by participants rather than an objective measure. Participants might misjudge their quality of vision and level of experience in wildlife observations. This finding can be useful for reserve management. If reserves want to employ rhino monitors, mandatory eye examinations and proof of relevant experience should be used in addition to personal statements. The practical execution of the field study highlighted the need of proper supervision and training of relevant staff. This item was also mentioned by some rhino experts stating that they have noticed confusion amongst staff when recording observations of notched animals **(Q_4)**.

An inference of the quality of an observation, or identification, can be made when considering the distance between rhino and observer (linear regression model R^2_{OH}= 0.98, R^2_{BH}= 0.61). Though vegetation density was not objectively measured in the study, results show clear differences between open and bush habitat types. The visibility of the notches was better in the open, unobstructed habitat than in the bush habitat. Additionally, the effect of distance on the quality of observations was stronger in the bush habitat as vegetation accumulates with distance and thus impairs vision drastically. At least from 30 m in a bush habitat and from 65 m in an open habitat, no reliable identification of an individual rhino could be made based on ear notches alone **(Q_8)**. As a consequence, observers in field could either try to get closer to the animal or make use of binoculars. These parameters were also included in the new observation sheet (Appendix III) and can help in rating the reliability of an observation result.

At least in an open habitat, the level of identification can be improved using binoculars at longer distances **(Q_9)**. As binoculars are rated as needless weight for some field patrols **(Q_4)**, the use of specialized rhino monitors, equipped with binoculars and suitable forms for observations, could be beneficial. Similar recommendations for a comprehensive monitoring of rhino can be found in Du Toit (2006), who suggested 1 monitor to every 20 rhino. Although, an optimal monitoring strategy will also depend on the detection probability of a species and the budget available (Joseph *et al.* 2006).

For vast open areas with several different management regimes, no specific monitoring, and a large rhino population, ear notching faces a further restriction as the amount of available code combinations is limited **(Q_4)**. Additional, smaller ear notch positions, or different notch-shapes, to increase the code system, cannot be recommended due to the highly limited visibility of the current ear notches and the damage to the ear. An allocation of the same codes to male and female rhino cannot be recommended as well, as distinction between female and male rhino can be challenging, even for rhino experts.

What is most important when deciding to monitor wildlife is the overall aim e.g. gaining general knowledge about a species biology or more specialised aims, like combating poaching (Ringold *et al.* 1996; Gibbs *et al.* 1999; Anderson *et al.* 2002; Crookes and Blignaut 2016). This aim was not clearly defined in most cases, which was also reflected by a missing long-term strategy of monitoring notched rhino **(Q_4)**.

There is an unquestionable need for action to prevent further African rhino subspecies, like *C. simum ssp. simum* and *D. bicornis ssp. minor* from imminent extinction (Emslie 2011; Haas and Ferreira 2015; Emslie *et al.* 2016). Gaining reliable data on rhino behaviour and ecology is essential in order to make predictions and to evaluate set management strategies (Emslie and Brooks 1999; Emslie *et al.* 2016). It is also needed to assess possible impacts of rhino on their remaining habitats (Cromsigt and Te Beest 2014). Marking of rhino that are not distinguishable from a distance, due to a lack of obvious distinctive features, represents a promising approach to be able to collect individualized data. By notching the ears and microchipping rhino in the GKA, it could be proved that these animals are capable of moving up to 80 km. Changing availability of water or food resources (Dunham 1994; White *et al.* 2007), poaching pressure (Ihwagi *et al.* 2018), as well as the dropping of fences between and within reserves might cause such movements.

Based on the findings of this thesis, notching of rhino ears alone is of limited use for individual identification. Rhino monitors that regularly keep track of individual rhino, either from ground and/or air (Walpole 2002; Ngene *et al.* 2011; Mulero-Pázmány *et al.* 2014) or with assistance of RFID, GPS or VHF transmitters (Plotz *et al.* 2017), could help in collecting individualized data. Advantages, disadvantages and improvement suggestions of these methods have been described by Brown *et al.* (2012) and Ellwood *et al.* (2017). Traditional GPS tags can under- or overestimate movement of animals, depending on the intervals at which data is transmitted. The set interval and data resolution also influence battery life of the tag, resulting in a trade-off between the level of information gained and the period of time data can be collected. A combination with an accelerometer can serve well in this case (Brown *et al.* 2012). Radiotracking of animal via VHF offers high data security, as the animal needs to be located manually in field, but hence is very labour intensive and bears the risk of disturbing wildlife. RFID can work without a battery on the animal, however they require base-stations that detect animals wearing tags (Ellwood *et al.* 2017). Such a system would be too expensive for coverage of the study area but might be useful at highly frequented locations such as waterholes.

Alternatively, or additionally, computer-assisted photo-identification could include the use of the ear notches and might improve identification results (Kelly 2001; Hillman *et al.* 2003; Stahl *et al.* 2008). A combination of distinctive, natural marks, like size and shape of the horns (Sandfort 2015), eye wrinkle patterns (Patton and Campbell 2011), natural ear notches, scars and tail size seems to represent a useful multivariate identification approach for rhino and has been described as such before (Patton *et al.* 2007; Stein *et al.* 2010). Similar identification features have been successfully used to determine population size and demographics of black rhino in Kenya (Patton and Jones 2007; Patton *et al.* 2007). A spoor recognition system represents another non-invasive approach for monitoring rhino (Jewell *et al.* 2001; Law *et al.* 2013). The usefulness of further artificial marking methods, like brandings, ear tags or tattoos (McGregor and Jones 2016; Kasanen *et al.* 2011) would require field testing in rhino.

As a general rule, none of these marking methods will work, if no ongoing monitoring system is established. Although the survey showed that some reserves already have experience with alternative monitoring technologies, the fact that less than half of the 13 reserves stated knowledge of alternative marking methods, allows scrutiny of the seriousness of the interests in monitoring individual rhino. Depending on their main aim of monitoring, these reserves might rather use population-based monitoring measures. Ferreira *et al.* (2017) listed different population survey techniques and their situation suitability with according literature. They recommended annual aerial counts and mark-recapture techniques for estimation of rhino populations in the Kruger National Park. These recommendations should be applicable for bordering reserves as well. A similar approach was used by Kruger *et al.* (2008) who performed distance analyses via aerial line-transects for assessment of large herbivores in the Kruger National Park.

Managing wildlife has been described as being 90 % about managing people (Fazio and Gilbert 1986), and hence the developed guideline for an ongoing rhino notching program in the GKA should be seen as trade-off between obtained knowledge through the survey and field study and decisions made by the reserves. Despite the sobering results of the field study, responsible authorities wanted to continue with the notching. However, reserves were highly motivated in cooperation and decided to stop individual notching of white rhino. This reserve notch can serve as additional distinctive feature of a rhino and can show from a distance that the rhino has been microchipped and DNA-sampled.

The decision to continue with an individual marking of black rhino seems sensible, as this species is more vulnerable (Emslie *et al.* 2016) and thus should be subject to a more detailed monitoring program. As notches proved to be rather unsuitable for an individual identification under given conditions, a monitoring of black rhino is recommended to make use of other technologies and specialised rhino monitors as well.

Ear notches will not directly protect a rhino from being poached and their usefulness for identification of carcasses is very limited due to scavengers eating the ears. Nevertheless, the shared database, created for notched rhino within the reserves, can improve and speed up the investigation process if a poached rhino carcass is detected, as DNA analyses take some weeks. It will also allow for identification of notched rhino that move across reserve boundaries. The developed databases and SOP can assist in structuring the rhino notching program in the GKA and emphasise the profit of cooperation and coordination. The research work invested for this thesis has also forced reserves to look at their protocols and aims with rhino monitoring, which can have ongoing positive impacts.

6. Conclusion

Considering the enormous efforts in notching and the insufficient identification results of rhino marked this way, the previous implementation of ear notching black and white rhino in the GKA must be questioned.
Ear notches can be beneficial as additional distinctive feature in species with individuals that are hard to distinguish from one another. Whereas their actual usefulness for identifying individuals is very limited, especially at distance and in areas with an obstructed view. Carefully considered aims about the kind of data that should be collected and appropriate monitoring measures therefor, need to be defined as a preliminary point. If a rhino is notched, the re-use of the marks should be guaranteed, in order to ensure long-term acceptance by public. Specialized rhino monitors, capable of tracking and identifying individuals by regular and ongoing observations, could be employed for this purpose. Further research and testing of other marking and monitoring methods in rhino in the study area are recommended.
In regions where animals can migrate freely between different reserves and parks, cooperation is needed to coordinate strategies and actions. The developed guideline offers suitable forms for observation and notching of rhino for this purpose. Combined with corresponding databases, they allow for consistency within the rhino notching program and simplify queries and investigation processes.

7. Annotation

Based on the results of this thesis, responsible authorities of nearly all GKEPF reserves dropped ear notching as an individual monitoring technique for white rhino in 2018. Double marked individuals of black and white rhino are given unique codes when captured. The notching database is already in use for rhino in the Mpumalanga region. The SOP is in the process of being officialised within the new GLTFCA (Greater Limpopo Transfrontier Conservation Area) structures which are currently being organised.

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10. Appendices

Date: ……………………

Interviewee: ……………………………………………………………………………………

Interviewer: …………………………………………………………

Conservation area: ………………………………………………………………………… Open to other reserves (y/n): ………………….

Size of area: ……………………………….

Estimated total amount of black rhino *(Diceros bicornis)*: ………………………..

white rhino *(Ceratotherium simum)*: ………………

1.) Notching combination in use:

Code-Key

RIGHT

LEFT

Example 1: ………………..

RIGHT LEFT

Example 2: ………………….

RIGHT LEFT

2.) Have you ever seen rhino with unknown notching combinations in your area?

o yes o no o unsure

3.) Which other/different rhino marking methods have you observed or heard of?

-
-
-
-

4.) Please allocate a total of <u>100 points</u> to following criteria.
Give more points to those items that you think are most important:

☐ intensity of the operation in the rhino *(quantity and size of notches)*

☐ use of the most common notching method *(number of animals that are currently notched this way / effort to re-mark the remaining animals)*

☐ visibility of the notch patterns from distance

☐ amount of possible code-combinations

☐ acceptance of notches by hunters, tourists and others

5.) Do you notch both (black and white) rhino?

o both o only black o only white

6.) How many of each have been notched to date?

black rhino: ……………… white rhino: ………………

7.) For how long has rhino notching been carried out in the area? ……………………………………………………

8.) Approximately how many notched rhino have been poached since then?

black rhino: ……………… white rhino: ………………

9.) How important is trophy hunting of rhino for your area?

o very important o important o less important o unimportant o not specified

10.) How is a rhino notching event planned? List the main steps:

I.)	VI.)
II.)	VII.)
III.)	VII.)
IV.)	IX.)
V.)	X.)

11.) How is monitoring of notched/unnotched rhino done in the area?

- regular counts by: ……………………………………………………………
  intervals: ……………………………………………………………………….
- opportunistic sightings
- cameras
- droppings/middens
- tracks
-

12.) What equipment is used for rhino monitoring:

- binoculars: ……
- hand held cameras: ……………………………………………………………………………………………………
- camera traps: ………
- trained staff: ………
- GSP device: ……
- other: ………

13.) Experiences with notching:

Problems/criticism:

(Improvement) suggestions:

14.) How relevant is notching and monitoring of rhino for the conservation of this species?

o very important o important o less important o unimportant o don’t know

Because:

Group: A B C D E Date:
Side: left middle right *(from the persons perspective)* Time:

Testing the visibility of ear notches in field

Participant details

Sex (f/m): …………

Age: ………………

Job/Activity: ………………………………………………………………….

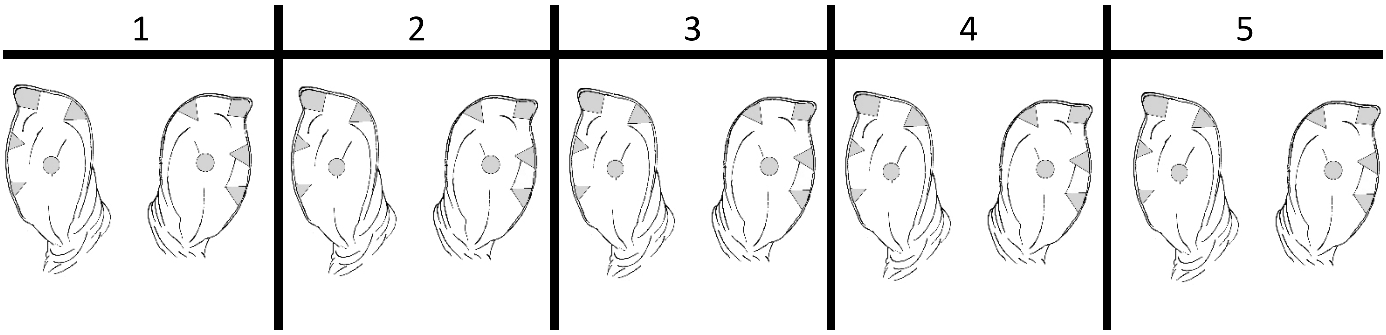
Height: ………………………

Experience in wildlife observation: ○ none ○ some ○ plenty

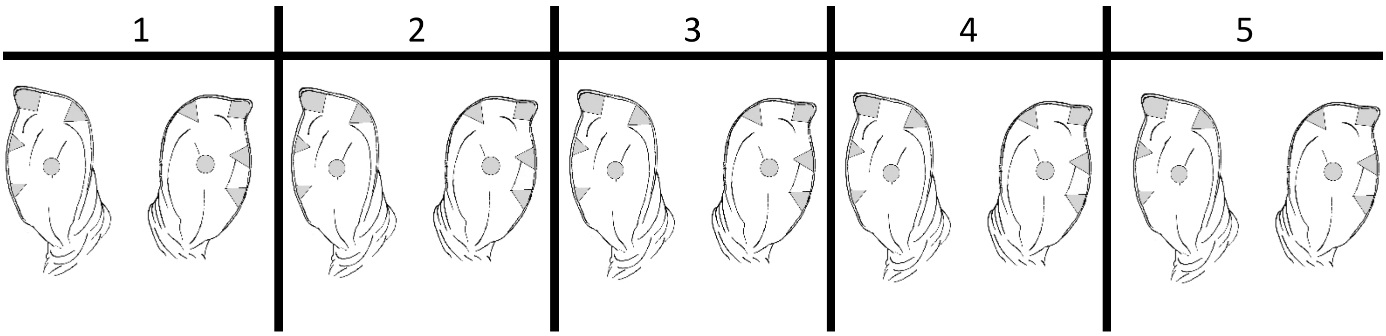
Personal rate of eyesight: ○ poor ○ fair ○ good ○ very good

Test

First Habitat (bush):



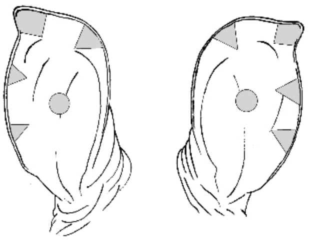
Second Habitat (open):



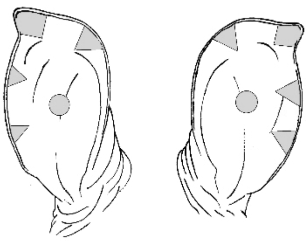
Thank you very much for your participation and support!!!

Test with Binoculars (MINOX 8x42)

First Habitat (bush):



Second Habitat (open):



COMMAND CENTRE
SOUTHERN AFRICAN WILDLIFE COLLEGE
SPRINGVALLEY
27.09.2017

SOP xx
RHINO EAR NOTCHING AND OBSERVATION

References	10,11,17, 34,35:	National Rhino Norms and Standards as per Government Gazette Vol. 607, 12. January 2016, No. 39589 As amended or in process of amendment.
	14,15, 20-30:	Adcock, K., Emslie, R.H., 2007. Monitoring African rhino: trainee's guide. Pietermaritzburg, IUCN SSC African Rhino Specialist Group, pp. 1-24

INTRODUCTION

Rhino ear notching is part of a broader management function in which the ear notching is used as a tool to identify animals, or areas of origin, for management purposes. As the GKEPF area is part of the ecological management of the greater Kruger area, the rhino population must be managed as one meta-population.

Ear notching is one aspect of a multi-facetted approach to rhino protection. Ear notching facilitates management, and/or the investigative process once a poaching incident has taken place.
It is also a part of the process to individually mark rhino along with other methods such as micro chipping, DNA sampling and photography.

Because of the size of the white rhino population throughout the GKEPF area and the possibility of an influx of large numbers into the area it is difficult to individually mark all white rhino.
The black rhino population is much smaller and appears to move over shorter distances and so individually marking black rhino is likely to be more practical.
Hence a distinction must be made between white and black rhino marking.

Rhino notching system

Due to the unique set up of the GKEPF area, encompassing a large number of differently managed reserves with unfenced boundaries and a large population of white rhino, a problem developed with the existing notching system. No practical ear notching system has the breadth of numbers to accommodate the entire white rhino population within the GKEPF area. Therefore, it has become necessary to adapt the notching system from one that identifies individual animals to a system identifying each reserve. For this purpose, a new, multiple marking system has been developed in which individual reserves have an ear notch identification number. This number is henceforth referred to as “Reserve ID”. This ID is detailed in ANNEXURE A.

BLACK RHINO (*Diceros bicornis)*

The status quo on the marking or ear notching of Black rhino remains the same.

Individual animals must be ear notched, micro chipped and DNA sampled with an individual identification number. The marking system to be used is the system proposed in **Fig. 3**, page 3 of this document.

An allocation of numbers per reserve is attached hereto as ANNEXURE B.
Duplicate numbers must be rectified as and when the opportunity presents itself.

WHITE RHINO (*Ceratotherium simum*)

1. If a rhino is newly notched, or a rhino with existing notches is seen, data should be recorded by assigned personnel and the data submitted to the ComCen in regular intervals.

   The field data collection can be done by any qualified representatives of the reserve.
   The data submission to the central database must be limited to a maximum of 2 members per reserve to ensure data quality and consistency.

2. The data collected when rhino are notched or observed should include all information requested as per standardised data sheets (pages 3-5 of this SOP) for all reserves. This data will be transferred into an Excel sheet by each reserve.

3. The data collected should be administered by the ComCen as a centrally held database. This will help to simplify carcass investigations, research and allow to keep track of notched rhino.

4. The intervals in which the data is submitted to the ComCen follows individual agreements between the ComCen authorities and the warden of each reserve. Essentially the intervals should be as short as possible (e.g. weekly or every two weeks) to allow for a current and up to date database.

5. The data can be submitted electronically via mail or personally on an USB flash drive.

AIM

To standardise and coordinate data collection for notched rhino

GREATER KRUGER ENVIRONMENTAL PROTECTION FOUNDATION

DATA COLLECTED WHEN **NOTCHING** A RHINO

6. Reserve ID. Specifies which reserve is performing the notching event (ANNEXURE A).
7. Date. The date on which the notching event was carried out.
8. Time. The time the notching was done.
9. Coordinates. Latitude and Longitude of the location where the rhino was notched. Decimal degrees must be used as GKEPF standard.
10. Veterinarian. Name of the performing Veterinarian who must be registered with the relevant Conservation Department.
11. DNA Sample Kit No. When live rhino are darted (…) DNA samples of the horns and blood must be collected by using the DNA kits as provided by the Veterinary Genetics Laboratory and send to their main office at Onderstepoort. The number of the Sample kit is noted.
12. Species. Tick if animal is a (**W**) White Rhino or (**B**) Black Rhino.
13. Sex. Tick if animal is a (**F**) Female or (**M**) Male.
14. Age or Date of Birth. Estimate when animal was born. Use of experienced persons can help being as accurate as possible. Tick the picture with the appropriate age class.

A < 3 months	**B** 3 months-1 year	**C** 1-2 yrs	**D** 2-3 ½ yrs	**E** 3 ½-7 yrs	**F** >7 yrs

    If it is a young calf with known date of birth it should be recorded.

15. Condition. Classified into five categories. Tick the one most applicable.
    1 = **very thin**, 2 = **thin**, 3 = **average**, 4 = **well covered**, 5 = **fat**.
16. Horn Measures. Note the measures from both horns (in centimetres) in the dedicated boxes. If a horn is too small to measure write "**t.s.**" into the respective boxes (**Fig.1**).
    a.) Base measures the circumference of the horn base.
    b.) Outer Curve measures the outer horn length from base to tip.
    c.) Inner Curve measures the inner horn length from base to tip.
17. Microchip Numbers. In the first instance Microchips must be inserted either in the front of the animals left shoulder (from the animal´s perspective) or in the hump as well as in each of the horns. If required, one more chip can be inserted behind the left ear and two extra chips can also be inserted in the axilla of the front legs. The labels with the 10-digit of each microchip should be stuck into the blank field right to the description of the chip-position.
18. Notching Code. Note the numeric that is represented by the given ear notches (**Fig.2** and **Fig.3**). The notching of rhino ears serves as a mark to help distinguish individuals, and to make it clear from a distance that the rhino has been chipped. The notching pattern should be filled into sketch on the data sheet.

    Additionally, each reserve can allocate an internal number to each individual animal. This number can be documented on the notching form but is no longer marked on the ears. This will assist with individualization and monitoring of animals marked.

19. Comments. Annotations regarding the animal or the procedure.

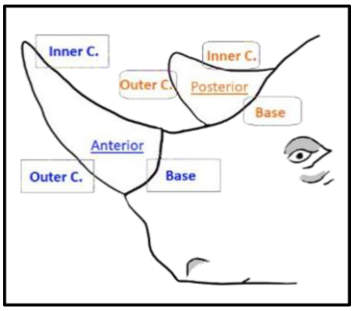


Fig.1: Horn Measure Description

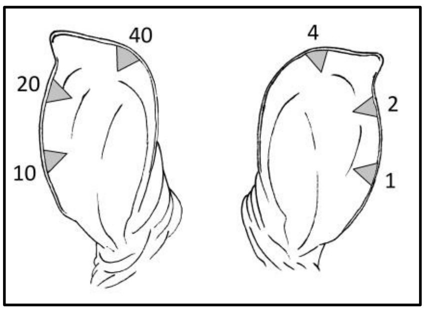


Fig.2: Reserve-Pattern for White Rhino

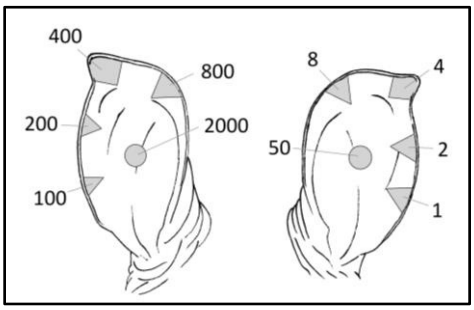


Fig.3: Individual Pattern for Black Rhino

DATA COLLECTED WHEN **OBSERVING** A RHINO

20. Reserve ID. ID Code of the reserve on which the animal was observed (ANNEXURE A).

21. Observer. Name of the person that observed the rhino.

22. Date. The date on which the rhino was observed.

23. Time. The time at which the rhino was observed.

24. Latitude and Longitude. Coordinates of the observation. Decimal degrees must be used as GKEPF standard. If the coordinates are not available, a proper and accurate area description can be acceptable.

25. Species. Tick if observed animal is (**W**) White Rhino, (**B**) Black Rhino or not identifiable (**?**).
For every individual rhino, a new observation sheet should be used to avoid confusion. If a group of rhino is observed, the date, time and coordinates will clarify that a single observation included more than one rhino.

26. Ageclass. Tick the approximate age of the observed rhino.
Classified into three categories:
1 = **juvenile** (≤ 2 yrs.), 2 = **subadult** (2-7 yrs.), 3 = **adult** (> 7yrs.).

27. Sex. Tick if animal is a (**F**) Female, (**M**) Male or if sex cannot be identified (**?**).

28. Notched. Tick if rhino is notched (**yes**), not notched (**no**) or if no statement is possible (**?**).

29. Notch Code. Mark the observed ear notches in the sketch with a cross.

30. Condition. Classified into six categories. Tick the one most applicable.
0 = **unknown**, 1 = **very thin**, 2 = **thin**, 3 = **average**, 4 = **well covered**, 5 = **fat**.

31. Distance (m). Approximate distance between observer and rhino (in metres).

32. Binocular Magnification. Specify if a binocular was used for the observation and if so, which magnification was used. Possible options to tick are: **none**, **6x**, **7x**, **8x**, **9x**, **10x**, **11x**, **12x**.

33. Comments. Annotations regarding the appearance or behaviour of the observed animal.

OTHER EVENTS
Additionally, it needs to be reported to ComCen if any of the following events occur:

34. Natural Death. All natural deaths must be reported as soon as practicable to the relevant Conservation Department. Authorization must be obtained to secure the horns if still on scene. Legal process must be followed with the horn registration. Recovered microchips may not be reused in another animal. If the dead animal can be identified, the details must be updated on the ComCen database and removed to a separate data sheet.

35. Poached. All poaching incidents must be immediately reported on the relevant GKEPF electronic reporting system and to the relevant investigative authorities. All data of prior marking or chipping must be made available to the responsible investigating team.

36. Sold. Submit the date of sale as well as the name and location of the purchaser (reserve or person, region or province). Current bans by the Department of Veterinary Services must be considered.

37. Calf into Foster Care. Note (**y**) or no (**n**) and forward the information. Calves of less than two and a half years of age found wandering alone should be removed to Foster Care. Such a calf has to be DNA sampled and micro chipped. Arrangements on ownership of the calf will determine if ear notching should take place.

38. Other relevant issues

    1) Wounded rhino
    If any rhino must be specifically marked for purposes of treatment, an individual number can be notched in the ears with a number sequence agreed to by the ComCen members. This number can be obtained by re-using numbers from rhino that died of natural causes, were hunted or sold as live animals. No number may be used from rhino poached.

    2) Long term monitoring of specific rhino must be done with the use of an electronic device suitable for the circumstances and/or personnel specially trained for and commissioned with this duty.

    3) Marking or tracking of individual rhino for Scientific research must be approved and coordinated by ComCen members.

    4) Existing duplicate numbers must be rectified as and when the opportunity presents itself.

39. It is also accepted by GKEPF that reserves can have paying spectators at the capture operation under the management and supervision of the reserve representative.

THE FOLLOWING TWO PAGES SERVE AS A STANDARDISED TEMPLATE AND CAN BE REPRODUCED FOR THE USE OF RHINO NOTCHING AND RHINO OBSERVATIONS.

Rhino Notching Data Sheet

Reserve ID: ……………… **Date**: …………………….

Latitude: …………………………………. **Longitude**: ……………………………………. **Time**: …………………….

Veterinarian: ………………………………………………………… **DNA Sample Kit No.**: ……………………………………………

Species: ☐ White Rhino ☐ Black Rhino

Sex: ☐ Female ☐ Male

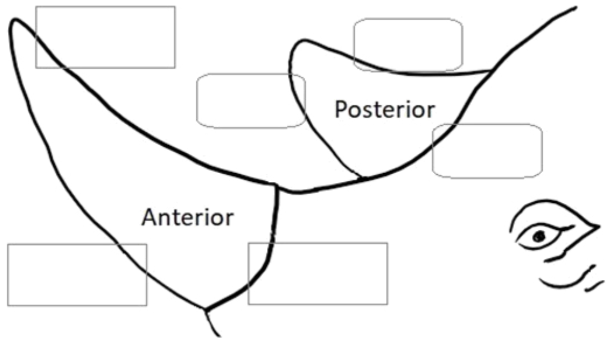
Age:

A	B	C	D	E	F
< 3 months	3 months – 1 year	1 – 2 yrs	2 – 3 ½ yrs	> 3 ½ yrs – 7 yrs	> 7 yrs

Date of Birth: ……………………………….

Condition: ☐ very thin ☐ thin ☐ average ☐ well covered ☐ fat

Horn measures (cm):



Comments:

……………………………………………………………………

……………………………………………………………………

……………………………………………………………………

……………………………………………………………………

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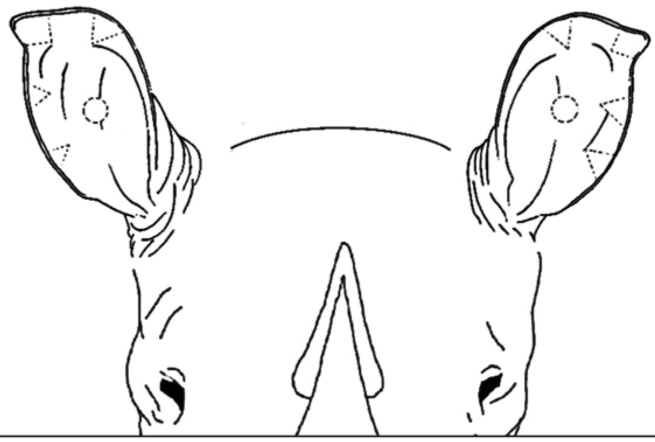
Microchips:

Anterior Horn		Posterior Horn	
Left Shoulder		Right Shoulder	

Notching Code:

Number: …………………

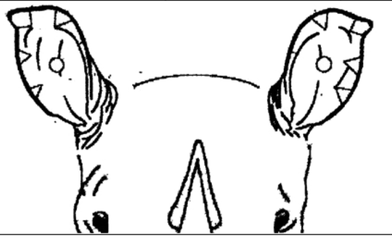
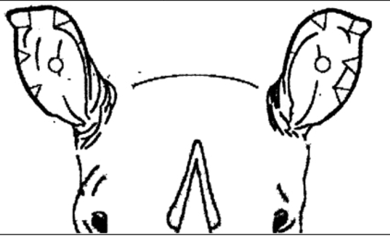
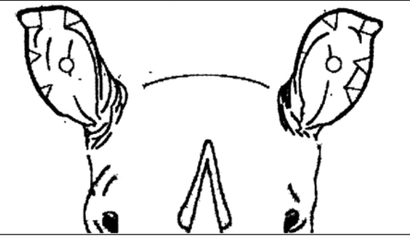
Internal Number:



Rhino Observation Data Sheet

Reserve ID: .... Observer: .... Date: ....
Latitude: .... Longitude: .... Time: ....

Species: ☐ White Rhino ☐ Black Rhino ☐ ?

Ageclass:	juvenile (≤ 2 yrs.)			subadult (> 2-7 yrs.)			adult (> 7 yrs.)		
Sex:	F	M	?	F	M	?	F	M	?
Notched:	yes	no	?	yes	no	?	yes	no	?
Notch Code:									
Condition:	☐ unknown	☐ very thin ☐ thin ☐ average ☐ fat		☐ unknown	☐ very thin ☐ thin ☐ average ☐ fat		☐ unknown	☐ very thin ☐ thin ☐ average ☐ fat	

Distance (m): ....

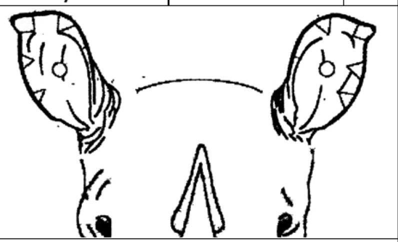
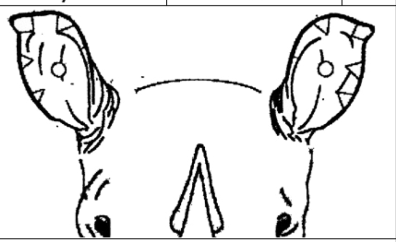
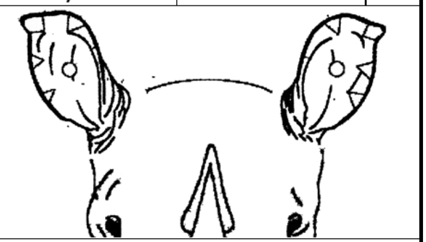
Binocular Magnification: ☐ none
☐ 6x ☐ 7x ☐ 8x ☐ 9x ☐ 10x ☐ 11x ☐ 12x

Comments: ....
....
....

Rhino Observation Data Sheet

Reserve ID: .... Observer: .... Date: ....
Latitude: .... Longitude: .... Time: ....

Species: ☐ White Rhino ☐ Black Rhino ☐ ?

Ageclass:	juvenile (≤ 2 yrs.)			subadult (> 2-7 yrs.)			adult (> 7 yrs.)		
Sex:	F	M	?	F	M	?	F	M	?
Notched:	yes	no	?	yes	no	?	yes	no	?
Notch Code:									
Condition:	☐ unknown	☐ very thin ☐ thin ☐ average ☐ fat		☐ unknown	☐ very thin ☐ thin ☐ average ☐ fat		☐ unknown	☐ very thin ☐ thin ☐ average ☐ fat	

Distance (m): ....

Binocular Magnification: ☐ none
☐ 6x ☐ 7x ☐ 8x ☐ 9x ☐ 10x ☐ 11x ☐ 12x

Comments: ....
....
....

ANNEXURE A

Reserve ID´s:

Reserve Name	Notch Code
Kruger National Park	12
Selati	14
Blue Cnayon	16
Klaserie	21
Manyelethi	22
Timbavati	24
Balule	26
Kapama	42
Thornybush	44
Kempiana	46
Umbabat	62
Sabi Sand	64
Mala Mala	66

ANNEXURE B

Allocation of Notching Codes for Black Rhino:

Reserve Name	Code Range	Total Amount of Notches Available
Kruger National Park	1 -1515	495
Selati	1550 – 2065	48
Balule	2100 – 2315	80
Klaserie	2350 – 2415	32
Umbabat	2450 – 2465	16
Timbavati	2500 – 2565	32
Blue Canyon	2600 – 2615	16
Kapama	2650 – 2665	16
Thornybush	2700 – 2715	16
Kempiana	2750 -2815	32
Manyeleti	2850 – 2865	16
Sabi Sand	2900 – 2915	16
Mala Mala	2950 – 2965	16
-	3000 – 3565	192

Allocation in Detail:

Code	Reserve	Code	Reserve	Code	Reserve	Code	Reserve	Code	Reserve	Code	Reserve
1	KNP	513	KNP	1059	KNP	2005	Selati	2551	Timbavati	3063	
2	KNP	514	KNP	1060	KNP	2006	Selati	2552	Timbavati	3064	
3	KNP	515	KNP	1061	KNP	2007	Selati	2553	Timbavati	3065	
4	KNP	550	KNP	1062	KNP	2008	Selati	2554	Timbavati	3100	
5	KNP	551	KNP	1063	KNP	2009	Selati	2555	Timbavati	3101	
6	KNP	552	KNP	1064	KNP	2010	Selati	2556	Timbavati	3102	
7	KNP	553	KNP	1065	KNP	2011	Selati	2557	Timbavati	3103	
8	KNP	554	KNP	1100	KNP	2012	Selati	2558	Timbavati	3104	
9	KNP	555	KNP	1101	KNP	2013	Selati	2559	Timbavati	3105	
10	KNP	556	KNP	1102	KNP	2014	Selati	2560	Timbavati	3106	
11	KNP	557	KNP	1103	KNP	2015	Selati	2561	Timbavati	3107	
12	KNP	558	KNP	1104	KNP	2050	Selati	2562	Timbavati	3108	
13	KNP	559	KNP	1105	KNP	2051	Selati	2563	Timbavati	3109	
14	KNP	560	KNP	1106	KNP	2052	Selati	2564	Timbavati	3110	
15	KNP	561	KNP	1107	KNP	2053	Selati	2565	Timbavati	3111	
50	KNP	562	KNP	1108	KNP	2054	Selati	2600	Blue Canyon	3112	
51	KNP	563	KNP	1109	KNP	2055	Selati	2601	Blue Canyon	3113	
52	KNP	564	KNP	1110	KNP	2056	Selati	2602	Blue Canyon	3114	
53	KNP	565	KNP	1111	KNP	2057	Selati	2603	Blue Canyon	3115	
54	KNP	600	KNP	1112	KNP	2058	Selati	2604	Blue Canyon	3150	
55	KNP	601	KNP	1113	KNP	2059	Selati	2605	Blue Canyon	3151	
56	KNP	602	KNP	1114	KNP	2060	Selati	2606	Blue Canyon	3152	
57	KNP	603	KNP	1115	KNP	2061	Selati	2607	Blue Canyon	3153	
58	KNP	604	KNP	1150	KNP	2062	Selati	2608	Blue Canyon	3154	
59	KNP	605	KNP	1151	KNP	2063	Selati	2609	Blue Canyon	3155	
60	KNP	606	KNP	1152	KNP	2064	Selati	2610	Blue Canyon	3156	
61	KNP	607	KNP	1153	KNP	2065	Selati	2611	Blue Canyon	3157	
62	KNP	608	KNP	1154	KNP	2100	Balule	2612	Blue Canyon	3158	
63	KNP	609	KNP	1155	KNP	2101	Balule	2613	Blue Canyon	3159	
64	KNP	610	KNP	1156	KNP	2102	Balule	2614	Blue Canyon	3160	
65	KNP	611	KNP	1157	KNP	2103	Balule	2615	Blue Canyon	3161	
100	KNP	612	KNP	1158	KNP	2104	Balule	2650	Kapama	3162	
101	KNP	613	KNP	1159	KNP	2105	Balule	2651	Kapama	3163	
102	KNP	614	KNP	1160	KNP	2106	Balule	2652	Kapama	3164	
103	KNP	615	KNP	1161	KNP	2107	Balule	2653	Kapama	3165	
104	KNP	650	KNP	1162	KNP	2108	Balule	2654	Kapama	3200	
105	KNP	651	KNP	1163	KNP	2109	Balule	2655	Kapama	3201	
106	KNP	652	KNP	1164	KNP	2110	Balule	2656	Kapama	3202	
107	KNP	653	KNP	1165	KNP	2111	Balule	2657	Kapama	3203	
108	KNP	654	KNP	1200	KNP	2112	Balule	2658	Kapama	3204	
109	KNP	655	KNP	1201	KNP	2113	Balule	2659	Kapama	3205	
110	KNP	656	KNP	1202	KNP	2114	Balule	2660	Kapama	3206	
111	KNP	657	KNP	1203	KNP	2115	Balule	2661	Kapama	3207	
112	KNP	658	KNP	1204	KNP	2150	Balule	2662	Kapama	3208	
113	KNP	659	KNP	1205	KNP	2151	Balule	2663	Kapama	3209	
114	KNP	660	KNP	1206	KNP	2152	Balule	2664	Kapama	3210	
115	KNP	661	KNP	1207	KNP	2153	Balule	2665	Kapama	3211	
150	KNP	662	KNP	1208	KNP	2154	Balule	2700	Thornybush	3212	
151	KNP	663	KNP	1209	KNP	2155	Balule	2701	Thornybush	3213	
152	KNP	664	KNP	1210	KNP	2156	Balule	2702	Thornybush	3214	
153	KNP	665	KNP	1211	KNP	2157	Balule	2703	Thornybush	3215	
154	KNP	700	KNP	1212	KNP	2158	Balule	2704	Thornybush	3250	
155	KNP	701	KNP	1213	KNP	2159	Balule	2705	Thornybush	3251	
156	KNP	702	KNP	1214	KNP	2160	Balule	2706	Thornybush	3252	
157	KNP	703	KNP	1215	KNP	2161	Balule	2707	Thornybush	3253	
158	KNP	704	KNP	1250	KNP	2162	Balule	2708	Thornybush	3254	
159	KNP	705	KNP	1251	KNP	2163	Balule	2709	Thornybush	3255	
160	KNP	706	KNP	1252	KNP	2164	Balule	2710	Thornybush	3256	
161	KNP	707	KNP	1253	KNP	2165	Balule	2711	Thornybush	3257	
162	KNP	708	KNP	1254	KNP	2200	Balule	2712	Thornybush	3258	
163	KNP	709	KNP	1255	KNP	2201	Balule	2713	Thornybush	3259	
164	KNP	710	KNP	1256	KNP	2202	Balule	2714	Thornybush	3260	
165	KNP	711	KNP	1257	KNP	2203	Balule	2715	Thornybush	3261	
200	KNP	712	KNP	1258	KNP	2204	Balule	2750	Kempiana	3262	
201	KNP	713	KNP	1259	KNP	2205	Balule	2751	Kempiana	3263	
202	KNP	714	KNP	1260	KNP	2206	Balule	2752	Kempiana	3264	
203	KNP	715	KNP	1261	KNP	2207	Balule	2753	Kempiana	3265	

204	KNP	750	KNP	1262	KNP	2208	Balule	2754	Kempiana	3300	
205	KNP	751	KNP	1263	KNP	2209	Balule	2755	Kempiana	3301	
206	KNP	752	KNP	1264	KNP	2210	Balule	2756	Kempiana	3302	
207	KNP	753	KNP	1265	KNP	2211	Balule	2757	Kempiana	3303	
208	KNP	754	KNP	1300	KNP	2212	Balule	2758	Kempiana	3304	
209	KNP	755	KNP	1301	KNP	2213	Balule	2759	Kempiana	3305	
210	KNP	756	KNP	1302	KNP	2214	Balule	2760	Kempiana	3306	
211	KNP	757	KNP	1303	KNP	2215	Balule	2761	Kempiana	3307	
212	KNP	758	KNP	1304	KNP	2250	Balule	2762	Kempiana	3308	
213	KNP	759	KNP	1305	KNP	2251	Balule	2763	Kempiana	3309	
214	KNP	760	KNP	1306	KNP	2252	Balule	2764	Kempiana	3310	
215	KNP	761	KNP	1307	KNP	2253	Balule	2765	Kempiana	3311	
250	KNP	762	KNP	1308	KNP	2254	Balule	2800	Kempiana	3312	
251	KNP	763	KNP	1309	KNP	2255	Balule	2801	Kempiana	3313	
252	KNP	764	KNP	1310	KNP	2256	Balule	2802	Kempiana	3314	
253	KNP	765	KNP	1311	KNP	2257	Balule	2803	Kempiana	3315	
254	KNP	800	KNP	1312	KNP	2258	Balule	2804	Kempiana	3350	
255	KNP	801	KNP	1313	KNP	2259	Balule	2805	Kempiana	3351	
256	KNP	802	KNP	1314	KNP	2260	Balule	2806	Kempiana	3352	
257	KNP	803	KNP	1315	KNP	2261	Balule	2807	Kempiana	3353	
258	KNP	804	KNP	1350	KNP	2262	Balule	2808	Kempiana	3354	
259	KNP	805	KNP	1351	KNP	2263	Balule	2809	Kempiana	3355	
260	KNP	806	KNP	1352	KNP	2264	Balule	2810	Kempiana	3356	
261	KNP	807	KNP	1353	KNP	2265	Balule	2811	Kempiana	3357	
262	KNP	808	KNP	1354	KNP	2300	Balule	2812	Kempiana	3358	
263	KNP	809	KNP	1355	KNP	2301	Balule	2813	Kempiana	3359	
264	KNP	810	KNP	1356	KNP	2302	Balule	2814	Kempiana	3360	
265	KNP	811	KNP	1357	KNP	2303	Balule	2815	Kempiana	3361	
300	KNP	812	KNP	1358	KNP	2304	Balule	2850	Manyeleti	3362	
301	KNP	813	KNP	1359	KNP	2305	Balule	2851	Manyeleti	3363	
302	KNP	814	KNP	1360	KNP	2306	Balule	2852	Manyeleti	3364	
303	KNP	815	KNP	1361	KNP	2307	Balule	2853	Manyeleti	3365	
304	KNP	850	KNP	1362	KNP	2308	Balule	2854	Manyeleti	3400	
305	KNP	851	KNP	1363	KNP	2309	Balule	2855	Manyeleti	3401	
306	KNP	852	KNP	1364	KNP	2310	Balule	2856	Manyeleti	3402	
307	KNP	853	KNP	1365	KNP	2311	Balule	2857	Manyeleti	3403	
308	KNP	854	KNP	1400	KNP	2312	Balule	2858	Manyeleti	3404	
309	KNP	855	KNP	1401	KNP	2313	Balule	2859	Manyeleti	3405	
310	KNP	856	KNP	1402	KNP	2314	Balule	2860	Manyeleti	3406	
311	KNP	857	KNP	1403	KNP	2315	Balule	2861	Manyeleti	3407	
312	KNP	858	KNP	1404	KNP	2350	Klaserie	2862	Manyeleti	3408	
313	KNP	859	KNP	1405	KNP	2351	Klaserie	2863	Manyeleti	3409	
314	KNP	860	KNP	1406	KNP	2352	Klaserie	2864	Manyeleti	3410	
315	KNP	861	KNP	1407	KNP	2353	Klaserie	2865	Manyeleti	3411	
350	KNP	862	KNP	1408	KNP	2354	Klaserie	2900	SSW	3412	
351	KNP	863	KNP	1409	KNP	2355	Klaserie	2901	SSW	3413	
352	KNP	864	KNP	1410	KNP	2356	Klaserie	2902	SSW	3414	
353	KNP	865	KNP	1411	KNP	2357	Klaserie	2903	SSW	3415	
354	KNP	900	KNP	1412	KNP	2358	Klaserie	2904	SSW	3450	
355	KNP	901	KNP	1413	KNP	2359	Klaserie	2905	SSW	3451	
356	KNP	902	KNP	1414	KNP	2360	Klaserie	2906	SSW	3452	
357	KNP	903	KNP	1415	KNP	2361	Klaserie	2907	SSW	3453	
358	KNP	904	KNP	1450	KNP	2362	Klaserie	2908	SSW	3454	
359	KNP	905	KNP	1451	KNP	2363	Klaserie	2909	SSW	3455	
360	KNP	906	KNP	1452	KNP	2364	Klaserie	2910	SSW	3456	
361	KNP	907	KNP	1453	KNP	2365	Klaserie	2911	SSW	3457	
362	KNP	908	KNP	1454	KNP	2400	Klaserie	2912	SSW	3458	
363	KNP	909	KNP	1455	KNP	2401	Klaserie	2913	SSW	3459	
364	KNP	910	KNP	1456	KNP	2402	Klaserie	2914	SSW	3460	
365	KNP	911	KNP	1457	KNP	2403	Klaserie	2915	SSW	3461	
400	KNP	912	KNP	1458	KNP	2404	Klaserie	2950	Mala Mala	3462	
401	KNP	913	KNP	1459	KNP	2405	Klaserie	2951	Mala Mala	3463	
402	KNP	914	KNP	1460	KNP	2406	Klaserie	2952	Mala Mala	3464	
403	KNP	915	KNP	1461	KNP	2407	Klaserie	2953	Mala Mala	3465	
404	KNP	950	KNP	1462	KNP	2408	Klaserie	2954	Mala Mala	3500	
405	KNP	951	KNP	1463	KNP	2409	Klaserie	2955	Mala Mala	3501	
406	KNP	952	KNP	1464	KNP	2410	Klaserie	2956	Mala Mala	3502	
407	KNP	953	KNP	1465	KNP	2411	Klaserie	2957	Mala Mala	3503	
408	KNP	954	KNP	1500	KNP	2412	Klaserie	2958	Mala Mala	3504	
409	KNP	955	KNP	1501	KNP	2413	Klaserie	2959	Mala Mala	3505	
410	KNP	956	KNP	1502	KNP	2414	Klaserie	2960	Mala Mala	3506	

411	KNP	957	KNP	1503	KNP	2415	Klaserie	2961	Mala Mala	3507	
412	KNP	958	KNP	1504	KNP	2450	Umbabat	2962	Mala Mala	3508	
413	KNP	959	KNP	1505	KNP	2451	Umbabat	2963	Mala Mala	3509	
414	KNP	960	KNP	1506	KNP	2452	Umbabat	2964	Mala Mala	3510	
415	KNP	961	KNP	1507	KNP	2453	Umbabat	2965	Mala Mala	3511	
450	KNP	962	KNP	1508	KNP	2454	Umbabat	3000		3512	
451	KNP	963	KNP	1509	KNP	2455	Umbabat	3001		3513	
452	KNP	964	KNP	1510	KNP	2456	Umbabat	3002		3514	
453	KNP	965	KNP	1511	KNP	2457	Umbabat	3003		3515	
454	KNP	1000	KNP	1512	KNP	2458	Umbabat	3004		3550	
455	KNP	1001	KNP	1513	KNP	2459	Umbabat	3005		3551	
456	KNP	1002	KNP	1514	KNP	2460	Umbabat	3006		3552	
457	KNP	1003	KNP	1515	KNP	2461	Umbabat	3007		3553	
458	KNP	1004	KNP	1550	Selati	2462	Umbabat	3008		3554	
459	KNP	1005	KNP	1551	Selati	2463	Umbabat	3009		3555	
460	KNP	1006	KNP	1552	Selati	2464	Umbabat	3010		3556	
461	KNP	1007	KNP	1553	Selati	2465	Umbabat	3011		3557	
462	KNP	1008	KNP	1554	Selati	2500	Timbavati	3012		3558	
463	KNP	1009	KNP	1555	Selati	2501	Timbavati	3013		3559	
464	KNP	1010	KNP	1556	Selati	2502	Timbavati	3014		3560	
465	KNP	1011	KNP	1557	Selati	2503	Timbavati	3015		3561	
500	KNP	1012	KNP	1558	Selati	2504	Timbavati	3050		3562	
501	KNP	1013	KNP	1559	Selati	2505	Timbavati	3051		3563	
502	KNP	1014	KNP	1560	Selati	2506	Timbavati	3052		3564	
503	KNP	1015	KNP	1561	Selati	2507	Timbavati	3053		3565	
504	KNP	1050	KNP	1562	Selati	2508	Timbavati	3054			
505	KNP	1051	KNP	1563	Selati	2509	Timbavati	3055			
506	KNP	1052	KNP	1564	Selati	2510	Timbavati	3056			
507	KNP	1053	KNP	1565	Selati	2511	Timbavati	3057			
508	KNP	1054	KNP	2000	Selati	2512	Timbavati	3058			
509	KNP	1055	KNP	2001	Selati	2513	Timbavati	3059			
510	KNP	1056	KNP	2002	Selati	2514	Timbavati	3060			
511	KNP	1057	KNP	2003	Selati	2515	Timbavati	3061			
512	KNP	1058	KNP	2004	Selati	2550	Timbavati	3062			