Are ear notches an effective tool for monitoring individual rhinos?

Agnes Hussek[1], Cleo Graf[2] and Klaus Hackländer[1]*

[1]Institute of Wildlife Biology and Game Management, University of Natural Resources and Life Sciences, Gregor-Mendel-Strasse 33, 1180 Vienna, Austria
[2]Southern African Wildlife College, Springvalley Farm 200KU, Kempiana Nature Reserve, Orpen Road, 1380, South Africa
*corresponding author: A.Hussek@hotmail.com

Abstract

Notching of rhino ears is a common method for distinguishing free-ranging individuals, as the species often lacks unique marks or patterns. However, there are no data available on the reliability of rhino identification using this method. We conducted a field study with 107 participants at the Southern African Wildlife College to test the visibility of different ear notch positions from five distance points in bush and open habitats. Results show that correct identification rates at 20 m between observer and rhino were only 6 % in the bush and 23 % in the open habitat. Without the use of binoculars, no correct identification was seen at 30 m distance in the bush and at 65 m in the open habitat. The notching positions we tested differed in terms of accuracy of detection. This allowed us to draw conclusions about which positions should be favoured to optimise identification. Relationships between recorded observer skills, environmental factors, the use of binoculars, and rate of successful identification of ear notches were tested by using generalized linear models. The outcomes of this study suggest that ear notching alone does not allow for reliable identification of rhino individuals from even relatively short distances. We recommend that other artificial marking methods and natural distinguishing marks should be investigated further and could be combined with modern tracking technologies.

Résumé

Le marquage par l'entaille des oreilles des rhinocéros est une méthode communément utilisée pour distinguer les individus à l'état libre. Cependant, il n'y a aucune donnée disponible en ce qui concerne la fiabilité de cette méthode pour identifier les rhinocéros. Nous avons mené une étude sur le terrain comprenant 107 participants au Southern African Wildlife College pour tester la visibilité des différentes positions d'entailles aux oreilles à cinq distances différentes en zones arbustives et ouvertes. Les résultats indiquent que les taux d'identification à une distance de 20m entre l'observateur et le rhinocéros étaient de seulement 6% dans les zones arbustives et de 23% dans les zones ouvertes. Sans l'usage de jumelles, aucune identification positive n'a pu se faire au delà de 30m de distance dans les zones arbustives et au delà de 65m dans les zones ouvertes. La position des entailles influence la précision d'identification. Ceci nous a permis d'arriver à des conclusions en ce qui concerne les positions idéales pour optimiser l'identification. La corrélations entre les compétences des observateurs, les facteurs environnementaux, l'usage de jumelles, et le taux d'itentification positive des entailles aux oreilles ont été analysés en utilisants des modèles linéaires généralisés. Les résultats de cette étude suggèrent que le marquage par l'entaille aux oreilles à lui seul ne permet pas l'identification fiable des individus même à relativement faible distance. Nous recommandons que la recherche d'autres méthodes de marquage artificiel et l'usage de marques distinctives naturelles soient poussés plus loin et puissent être associés à d'autres technologies modernes de repérage.

Introduction

The southern white rhinoceros (*Ceratotherium simum simum*) and the southern-central black rhinoceros (*Diceros bicornis minor*) are two of the most threatened African mammal subspecies. There are various reasons for their declining numbers but poaching for their horns is the main threat (Milledge 2007; Emslie et al. 2013). Great effort is being made and much money spent to stop the decline of these species (Emslie et al. 2016).

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 birth rate, mortality or sex ratios within populations (Walpole 2002).

Gathering reliable spatial and temporal data of rhinos is particularly important, as these species are facing the very real threat of imminent extinction (Haas and Ferreira 2015). In the context of the ongoing poaching crisis in southern Africa, using accurate data for predictive modelling could direct protective measures, thereby increasing the chances of successful protection.

Unfortunately, there are several challenges when monitoring rhinos: individuals are capable of travelling distances up to 25 km within one day and movement within home range is highly unpredictable (Joubert and Eloff 1971). This makes monitoring in the large and open areas typical of many reserves or parks difficult and necessitates cooperation between neighbouring areas. Rhinos often lack adequate unique natural marks or patterns for individual identification, especially at distance. Thus, artificial marking of rhinos seems a sensible measure to allow monitoring of individual animals.

Ear notching represents one option for this purpose. It has been in use for black and white rhino identification in several reserves in the Greater Kruger Area (GKA), South Africa, for the last 20 years. This area includes the Kruger National Park and several smaller, private game reserves (see Fig. 1a & 1b). Notching events are often sponsored by private donors who receive detailed information about the notching process, rhino physiology and conservation. Following national legislation, a darted and sedated rhino must be microchipped and have their DNA sampled when being marked by cutting notches or holes into its ears (DEA 2016). The notches represent a numerical code. Ideally, this code allows individual identification of the animal from a distance, which reduces stress for the rhino and danger to the observer compared to when observers attempt to get very close to the animal.

The marking method can only function well if each rhino is marked with a unique notching code. However, reserves of the Greater Kruger Area started marking rhinos without considering or coordinating marking codes of neighbouring reserves. When boundary fences between private, provincial and national reserves were partially removed, rhinos could move freely between properties and different individuals with identical notch codes were observed. This has reduced the value of notching programmes as it is no longer possible to reliably identify individuals.

Wardens and ecologists from 13 reserves contributed to a comprehensive survey of marked rhinos to get an overview of the current situation with regard to notching within the GKA. As part of the survey, participants were asked to rate several criteria that might influence their decision to use ear notching. *Visibility of the notch patterns from distance* was found to be the most influential factor (Hussek 2018). This finding led to the work described in this study. One aim was to evaluate how accurately individual rhinos can be identified from their ear notches. To this end, we measured how correctly notch patterns were identified in different scenarios. Additionally, we aimed to find out which notch positions were most easily identifiable. From these results we hoped to establish whether or not ear notching is a suitable tool for rhino monitoring.

Materials and methods

Study area and experimental setup

The study was conducted at the Southern African Wildlife College (SAWC) campus which is located in Kempiana Nature Reserve within the Greater Kruger Area, Mpumalanga, South Africa (Fig. 1.(b)).

Observations were conducted in two different habitat

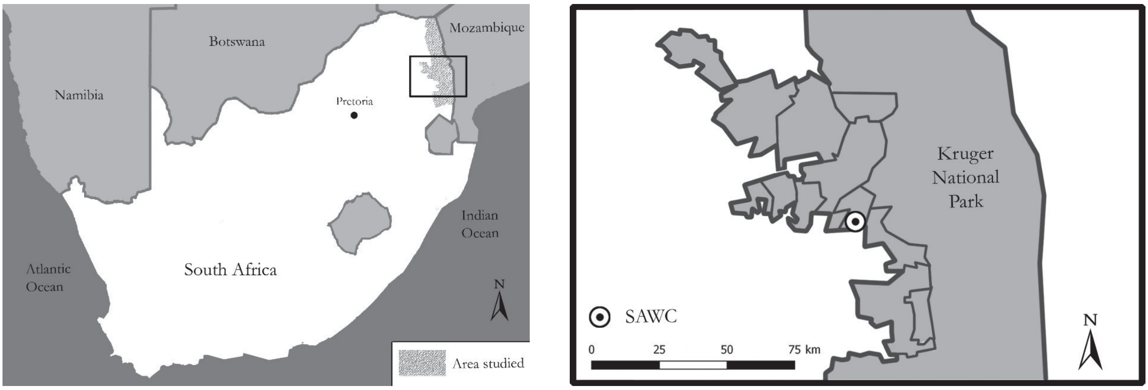

Figure 1a. (left) Location the Greater Kruger Area ('area studied') in South Africa. Figure 1b. (right) Enlargement of boxed area in (a) showing the location of the Southern African Wildlife College (SAWC). The bold line shows the boundary of the Greater Kruger Area; thin lines show the boundaries of the Kruger National Park and private game reserves on the western side of the Park.

types: (1) an open grassland, consisting of patches of bare soil, forbs and grass and (2) a bush habitat, including low growing grass, forbs, bushes and trees. Visibility of dummy rhino ears (Fig. 2) 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 the grass species *Urochloa brachyura*, with an average height of 40 cm. The same grass species occurred in the bush habitat but was only half as tall on average. In open habitat, woody plants were not present or were shorter than the grass. Average height of woody plants in bush habitat was approximately 2.5 m. Woody vegetation was dominated by several Fabaceae species, including *Vachellia exuvialis* and *Senegalia nigrescens*.

The dummy rhino ears were set in a straight line at five distances away from the observer, in both habitats. 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 made during daylight hours and under dry weather conditions.

Dummy rhino ears

A total of 20 rhino ears were made out of A4 paper (160 g/m²). Size and shape closely resemble that of an adult rhino ear (Fig. 2). 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. 3). The hole in the middle of the ear had a diameter of 1.6 cm (the size of a South African 10 cent coin) and the edge lengths of the triangle-shaped notches were 3.6 × 3.6 × 3.1 cm. Notches often vary in size and the sizes used represent an optimistic average based on comparisons of many photos of notched rhino ears provided by participating reserves. Furthermore, they are in line with veterinary recommendations. 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 (see Fig. 6 on page 62).

Procedure

Field studies were conducted between 22 August and 4 September 2017, with 107 participants. Participants were made up of college staff, field rangers, students and contractors with different level of wildlife observation experiences. The total numbers of participants for each variable included in the study are listed in Table 2.

We used five participants in a test run to set the basic conditions for the main test which included: minimum and maximum distance between participant and rhino dummy and time given to note the notches seen. The test run was also used to improve the format

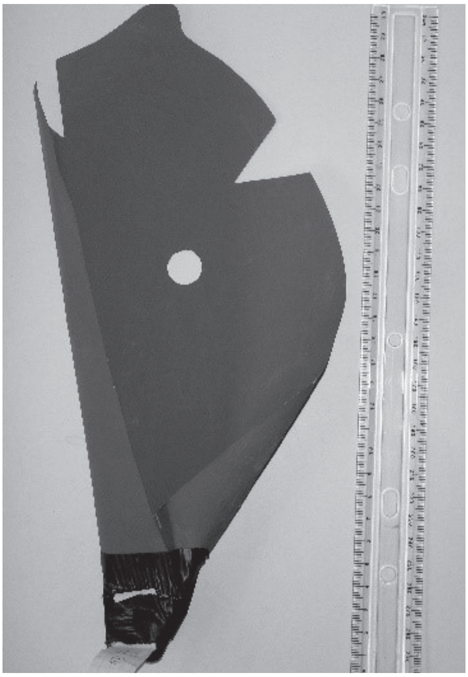

Figure 2. One of twenty dummy rhino ears. This left ear is notched at positions 6, 8 and 10.

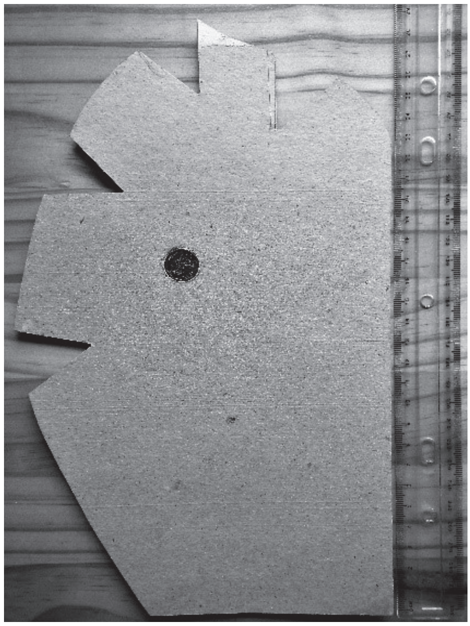

Figure 3. The template used to guarantee that every notch is identically positioned on the dummy rhino ear. The centre hole is the size of a South African 10 cent coin.

of the survey sheets and to clarify instructions to participants. These five participants' observations were excluded from the main evaluation.

Participants were briefed about the main aim and procedure of the study and received a data form on which they were asked to mark the code combination they saw. 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) number 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 1 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.

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, the same researcher held the dummy ears at a height of 1.20 m. This height was chosen as rhinos usually have their heads down, with limited upward mobility, and so ears are slightly below shoulder height. Data on shoulder height indicates it is 1.5–1.8 m for white rhinos (Tomášová 2005) and 1.6 m for black rhinos (Adcock et al. 2005). The dummy rhino ears were slowly rotated for 30 sec, 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. A 30-sec observation period was chosen, as this was considered representative of the length of time an observer may have when approaching a free ranging rhino and because we noted during the test run that this time period allowed the observers to check the data sheet against their observations multiple times and that after 30 sec they didn't add any new notches.

Participants were allowed to crouch and stretch and take one step sideways if needed. This option allowed for more flexibility and realistic viewing, especially in the bush habitat. Within the 30-sec timeframe, participants were asked to mark the notches they thought they saw with an X or a circle on the data form. The form showed the five possible notching positions on each ear (Fig. 6 below) to allow for a more precise evaluation of the results. After the 30 sec, 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.

From 29 August 2017 onwards, we included binoculars (8 × 42) 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. They were allowed 20 sec to adjust the focus of the binoculars at the given distance. For this purpose, the researcher lifted a hand to the position where the dummy ears would be.

Analysis

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). We wanted to know which of the factors recorded are most likely to influence the accuracy of results in both habitat types. Generalized linear models (GLMs) were created with *Age*, *Experience*, *Eyesight*, *Job.Activity*, *Start.Time* and *Weather* defined as independent variables. This was only done for the closest distance point in both habitats (10 m in bush and 20 m in open habitat) as this was considered a best-case scenario.

Job.Activity was included as participants had varying levels of experience and exposure to wildlife observations. We included housekeeping and building staff to test if those with little or no wildlife observation experience did any better or worse than experienced field staff.

Start.Time correlated with the altitude of the sun and was included to test if resulting shade 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 observations starting afterwards in the PM group to simplify the GLM. Similarly, *Weather* was selected to see if shadow created by cloud or bright sunlight affected notch identification. Age was converted into a 2 level factor, <40 yr and >40 yr, following Newman et al. (2003) as we did not have the full range of possible ages in the workforce.

A Fisher's exact test via contingency table was used to test for significant differences between the two age classes. We chose this test as it is better suited for small sample sizes than Pearson´s chi-squared test (Lamprecht 1992).

As correlations between one or more dependent variables could influence results of the GLM, we tested if any of the factors correlated with one another by calculating the variance inflation factor (VIF) for the independent variables, defined as $VIF_j = 1/(1 – R_j^2)$

Table 1.(a) The different code combinations (I–V) used in open and bush habitats and (b) the order in which these were presented to each of the five observer groups (A–E). The order that the dummy ears were shown differed between groups, habitats and distance points in order to maximize the amount of data gained for every notch position.

(a) Notch positions: code combinations I–V

Open habitat			Bush habitat		
Codes	Right ear	Left ear	Codes	Right ear	Left ear
I	2,5	7,9	I	1,3,4,5	6,8
II	1,3	6,8	II	1,3	6,8,10
III	2,4	6,7,9,10	III	2,5	7,9,10
IV	1,5	6,7,8,10	IV	2,4	7,9
V	1,2,3,5	6	V	1,2,3	6,10

(b) Code combinations presented to participants A–E

Open habitat						Bush habitat					
Distance (m)	A	B	C	D	E	Distance (m)	A	B	C	D	E
20	I	III	II	V	IV	10	IV	II	I	III	V
35	II	I	IV	III	V	15	I	V	III	II	IV
50	III	V	I	IV	II	20	II	I	IV	V	III
65	IV	II	V	I	III	25	V	III	II	IV	I
80	V	IV	III	II	I	30	III	IV	V	I	II

with R_j^2 being the coefficient of determination of the linear model for variable x_j based on all other explanatory variables (Fox 1991). A value of VIF < 10 indicates that it is very likely that no correlation exists between any of the variables (Miles 2005).

The dependent variable used the number of notch patterns that were completely correctly identified. 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 GLMs 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 our data can be divided into groups based on the independent variables. We 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, we used Pearson's chi-squared test to test for significant differences between the number of correctly and incorrectly identified notches on each position of the dummy ear. The confidence level for significance was set at 95 % in all analyses.

Results

Main outcomes

Table 2 shows a summary of the field study data analysed. Total numbers between open and bush habitat differ slightly, due to the exclusion of two entries in the open habitat due to a misunderstanding of the task during the first iteration.

The number of totally correctly identified notch codes at the closest point was 26 out of 102 in the bush habitat, and 23 out of 100 in the open habitat. Identification rate continuously decreased with increasing distance and reached zero at the maximum distance in both habitats (Fig. 4). The decline in the open habitat shows 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) (Fig. 5). At 20 m, a distance used in both habitats, identification rates were highly significantly more accurate in the open than in the bush habitat ($x^2 = 12.034$, df = 1, $p < 0.001$).

Results suggest 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 bush habitat. At 65 and 30 m respectively, the correct identification rate reaches zero. Mann-Whitney *U* tests revealed that distribution significantly differed between some of the distance points ($p < 0.05$) as shown in Fig. 4.

The proportion of correctly identified notches shows that the visibility of rhino ear notches was higher in open than in bush habitat. The use of binoculars for the maximum distances noticeably improved the amount of correct results. This improvement effect was stronger for the open than for the bush habitat (Fig. 5). The proportion of correctly and incorrectly identified notch positions is shown in Table 3. 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 and 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. 6).

VIF values for all variables in both habitats were < 2, indicating that no correlation, which could impair evaluation, exists between any of the independent variables (Miles 2005).

Open habitat

The variable Age significantly influenced the proportion of totally correct answers ($p < 0.05$, GLM). Participants 40 years old or older did significantly less well than younger participants (coefficient for *Age*≥40 = –2.46; $p_{OH} < 0.05$, Fisher's exact test). Results showed no significant effect of *Eyesight* and *Experience* on identification quality (Table 4). *Eyesight* was not correlated with *Age* ($p_{OH} = 0.573$, Fisher's exact test).

GLM models including variables *Age* and *Job.*

Table 2. Variables used for the GLMs, and numbers of participants in each category in the open (OH) and in the bush habitat (BH). Note that the total number of participants in the BH (102) was higher than in the OH (100) as explained in the text.

Variables		**Categories**		**No. of participants**	
Variables	**Explanation**	**Abbreviation**	**Translation**	**OH**	**BH**
Age	Age of participant	1	18-39 yr	79	81
		2	40-69 yr	21	21
Experience	Personal assessment of participant's experience of observing wildlife	Yes	Has experience	64	66
		No	No experience	36	36
Eyesight	Personal assessment of quality of participant's vision	Fair		13	13
		Good		56	56
		Very good		31	33
Job.Activity	Main occupation or activity of participant	Student	Student	38	39
		Worker	Kitchen staff, housekeeper, building contractor...	31	32
		Academic	Clerk, field ranger, academic supervisor...	31	31
OH1_ totally.correct	Amount of totally correctly identified notch codes at 20 m in the open habitat	y	Yes	23	
		n	No	77	
BH1_ totally.correct	Amount of totally correctly identified notch codes at 10 m in the bush habitat	y	Yes		26
		n	No		76
Start.Time	Time the exercise started	AM	Start time until 13.05	52	52
		PM	Start time after 13.05	48	50
Weather	Weather status while exercise was carried out	Sunny		83	85
		Cloudy		17	17

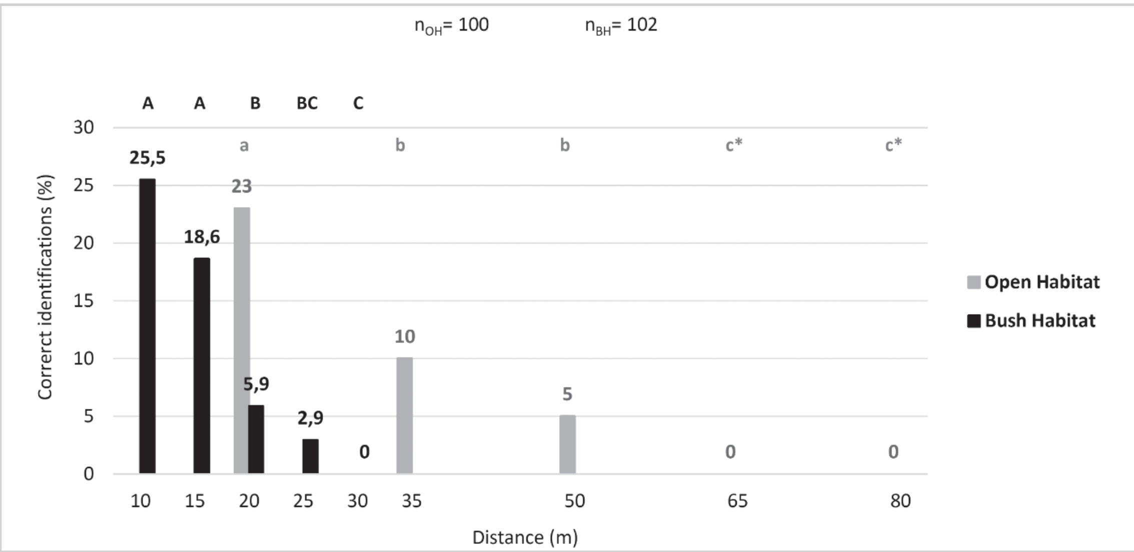

Figure 4. The proportion (%) of totally correctly identified rhino ear notch codes in relation to distance for open and bush habitats. Letters above bars (black upper case: bush; grey lower case: open) indicate the results of Mann-Whitney U tests; bars with same letters do not differ significantly from each other.
*Results of distances 65 m and 80 m could not be compared to each other as no correct identification was recorded in both cases.

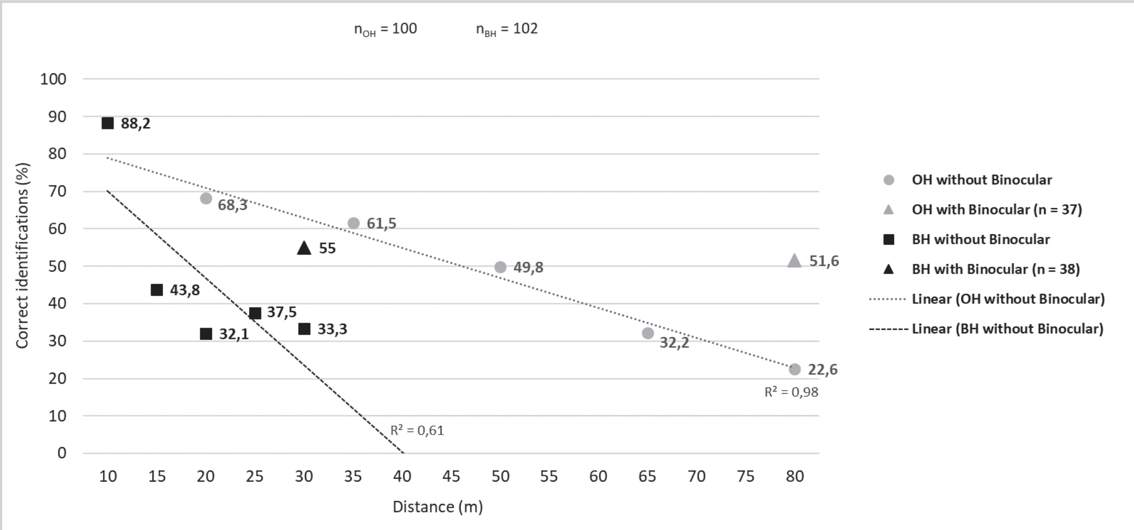

Figure 5. Mean percentages of correctly identified notch positions in relation to distance. Regression lines reveal a clear relationship between distance and identification rates. The result of using binoculars is marked as triangle at the maximum distances in open (OH) and bush (BH) habitat and shows a considerable increase in the detectability of rhino ear notches.

Activity showed the highest model fit in both habitats (Table 4).

The ctree created explains variation of the response variable *Totally.correct* (Fig. 7). Age only influenced correct notch code identification if participants were in the category 'academics' or 'students', as no participant of the group 'workers' gave a completely correct solution. Chances of accurate identification were about 40 % if the participant was in either the category 'academics' or 'students' and younger than 40 years old.

Bush habitat

Participants stating they have experience in wildlife observation showed more accurate identification results than those with none (p_{BH} < 0.05, GLM). Participants stating to have no experience were mainly from the category 'worker'. As was the case with open habitat identification, participants 40 years old or older achieved worse results than those under 40 (coefficient for *Age*≥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 were found using ctree.

Discussion

Although rhino ear notches are commonly used for identification in numerous African wildlife reserves (Hall-Martin 1986; Ngene et al. 2011) results of our study suggest that they are of limited use for rhino identification from a distance, especially without specific training and the opportunity to build up experience.

A notch coding system for individual animal

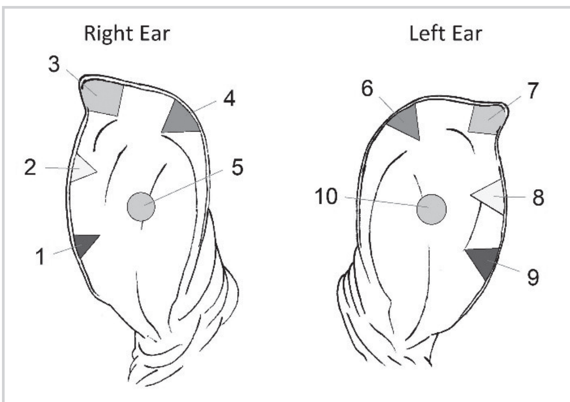

Figure 6. Notch code key for the field study. Each notch position represents a number which can be used on the left or the right ear (e.g. the hole in the middle represents number 5 on the right ear or 10 on the left ear). The results of testing their individual visibility are included as shades of grey: the lighter the colour, the better visibility.

Table 3. Number of correctly identified vs. total number of rhino ear notch positions in open (OH) and bush habitat (BH) with or without the use of binoculars. The grey boxes give the percentage of their identification rates; lighter colours indicate higher accuracy identification levels.

	OH						BH					
Notches	With binocular			Without binocular			With binocular			Without binocular		
	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

Table 4. Stepwise model selection of the generalized linear models (GLM) for open habitat (OH) and bush habitat (BH). The lower the Akaike's information criterion (AIC) value, the better the model fit. Delta AIC (ΔAIC) compares each model with the best model. Lower ΔAIC values suggest more substantial evidence for the model Akaike weight (ωAIC) represent the ratio of ΔAIC for each model relative to the whole set of models. It indicates the relative goodness of fit of the models, where higher equals better (Mazerolle 2004).

GLM models for the OH	AIC	Δ AIC	ωAIC	GLM models for the BH	AIC	Δ AIC	ωAIC
Age + Experience + Eyesight + Job. Activity + Start.Time + Weather	92.75	6.29	0.02	*Age + Experience + Eyesight + Job. Activity + Start.Time + Weather*	122.78	8.27	0.01
Age + Experience + Job.Activity + Start.Time + Weather	90.38	3.92	0.07	*Age + Experience + Job.Activity + Start.Time + Weather*	119.96	5.45	0.04
Age + Experience + Job.Activity + Start.Time	88.75	2.29	0.15	*Age + Experience + Start.Time + Weather*	117.84	3.33	0.11
Age + Job.Activity + Start.Time	87.59	1.13	0.27	*Age + Experience + Start.Time*	115.86	1.35	0.29
Age + Job.Activity	86.46	0	0.48	*Age + Experience*	114.51	0	0.56

identification is effective only if all notches can be identified. For this reason, our statistical evaluation of influencing factors concentrated on the proportion 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 we attempted to create a best-case scenario. Even in these best-case setups the outcomes reveal serious limitations of this marking method as a means of individual identification, with an identification rate below 25 % at a distance of 20 m (Fig. 4). 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 our study habitats. In addition, our study did not include observations made at times of the day when shadows may make seeing notches harder.

The age of the observer was a major influencing factor on how accurately notches were identified (Fig. 7). People younger than 40 might be expected to have better eyesight than those over 40 years old (EDPRG 2004). That eyesight was not correlated with age, and had no significant effect on identification quality, might be explained by the fact that this parameter was a subjective estimate by participants rather than an objective measure. Participants may have misjudged their quality of vision and level of experience in wildlife observations. This finding could be useful for Protected Area (PA) management. Should PAs want to employ rhino monitors, mandatory eye examinations and proof of relevant experience should be required, rather than personal statements, for at least one member of any rhino observation or monitoring team.

Though vegetation density was not objectively measured in our 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 a bush habitat (linear regression model, $R^2_{OH} = 0.98$, $R^2_{BH} = 0.61$). Furthermore, the effect of distance on the quality of observations is stronger in the bush habitat as vegetation accumulates with

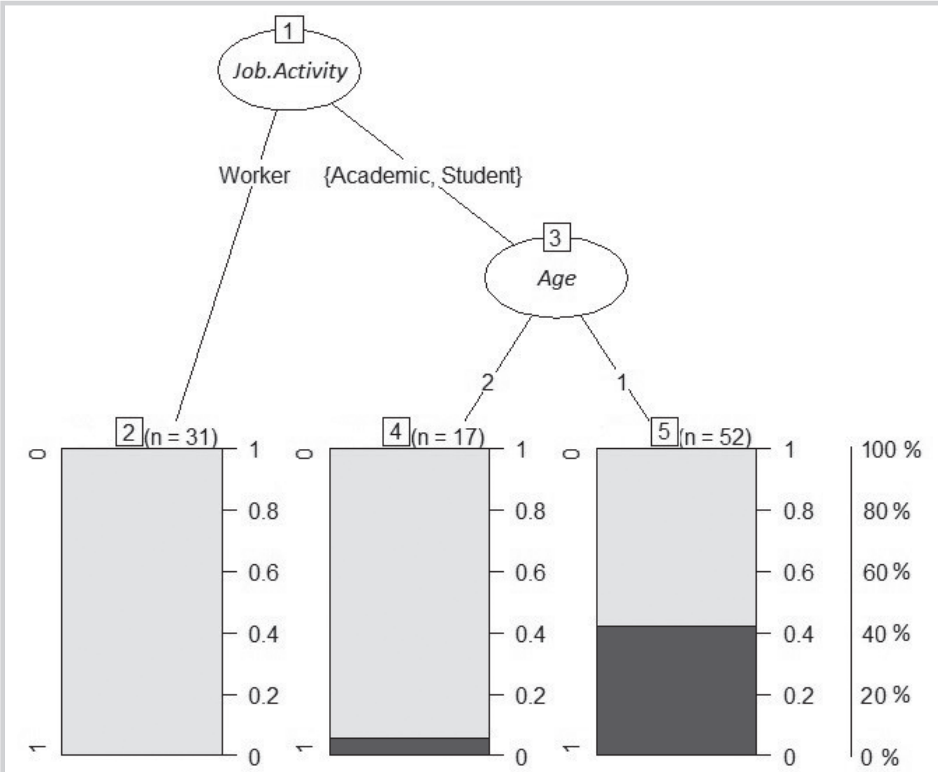

Figure 7. Conditional inference tree (ctree) for the open habitat data (n=100). Ranked nodes reveal differences between recorded variables within our sample of participants. Node 1 shows that variable '*Job.Activity*' influences results. Participants from the category 'workers' gave no correct solution (Node 2). Results of 'students' or 'academics' were dependent on the age of the participant (Node 3). *Age* is divided into participants >40 years (Node 4) and participants <40 years (Node 5). 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.

distance and thus impairs vision drastically. The level of identification can be improved using binoculars at tested distances in an open habitat. Using experienced wildlife observers seemed to be particularly beneficial in bush habitats.

When considering the suitability or visibility of different notch positions, attention should be given to the potential for ear notching to cause structural damage to the rhino's ears. Instances of rhino ears becoming torn or floppy when notched in the middle or on tip have been reported (J. De Beer, Manager of the Investigation Unit of the Province of Mpumalanga's Nature Conservation Department, pers. comm. 2018). This has the potential to affect the ear function and therefore rhino welfare.

In vast open areas with several different management regimes, no permanent monitoring programme, and a large rhino population, a further limitation of ear notching is that the number of available code combinations is limited. Even the use of six possible notch position in every ear would only allow a total amount of 4095 unique codes, which may not be sufficient overall (Emslie et al. 2016). The use of additional, smaller ear notch positions, or different notch shapes, to increase the number of available combinations cannot be recommended due to the highly limited visibility of the current ear notches. Cooperation and coordination, especially between neighbouring reserves, as well as clearly defined objectives in terms of monitoring programmes, seem crucial in this case to avoid duplicate marked individuals.

Based on our findings, notching of rhino ears alone is of limited use for individual identification. Specialized rhino monitors that regularly keep track of individual rhinos, either from ground and/or air (Walpole 2002; Ngene et al. 2011) or with assistance of GPS or VHF transmitters, could help in collecting individualized data. When monitoring in teams, reserves should ensure to have at least one such proficient member in every team.

Alternatively or additionally, automated systems like computer-assisted photo identification could be used to improve identification results and to support reserves with manpower shortage (Hillman et al. 2003; Stein et al. 2010). A combination of distinctive, natural marks, like size and shape of the horns (Sandfort 2015), eye wrinkle patterns (Patton and Jones 2010), natural ear notches and tail size might represent a useful multivariate identification approach. Similar identification features have been successfully used to determine population size and demographics of black rhinos in Kenya (Patton and Jones 2007). The usefulness of further artificial marking methods, like brandings, ear tags or tattoos (Kasanen et al. 2011; McGregor and Jones 2016) would require field testing in rhinos. In this context, it must be considered that capture and the use of anaesthetics for the marking of rhinos always poses a risk for the immobilized animal (Fahlman 2008).

Since there is a legal obligation to take DNA samples and microchip all rhinos when they are handled, these animals' ears could be notched at the highest visibility positions (positions 2 and 8) to mark the animal as sampled. The excised patch of skin will serve as DNA sample at the same time (DEA 2016). Private donors could still participate at such events, allowing fundraising and awareness campaigns to continue.

Conclusion

Our findings show that rhino ear notches are of very limited use for visual identification of individual animals in the field, especially at distance and in areas with an obstructed view. Identification success is largely dependent on the distance between animal and observer, habitat type, age and experience of observer, and the use of binoculars. To increase the benefit of notching, well trained rhino monitors should be employed, who are capable of tracking and identifying individual rhinos through experience of regular and ongoing observations. Suitable forms for observations and adequate binoculars must be in their standard equipment. Further research and testing of other marking and monitoring methods is recommended.

Acknowledgements

This study was part of a larger project on the evaluation of rhino notching programs in the Greater Kruger Area. Support and information were kindly offered throughout the project by several reserves in this area as well as from the Greater Kruger Environmental Protection Foundation. We thank Kevin Robertson, Alan Gardiner and Collen Mkansi from the SAWC for their support in preparing and performing the study and Leonie Hofstra for sharing experience and knowledge in rhino observation methods. We are grateful to Paul Griesberger for statistical help and advice. The support from all participants in rhino ear identification was fundamental and is highly appreciated.

References

Adcock K, Amin R. 2005. Black rhinoceros. In: Fulconis R. *Save the rhinos: EAZA Rhino Campaign 2005/6*. Info Pack, London, p. 61–65.

Anderson SH. 1999. *Managing our wildlife resources*, third edition. Prentice Hall, New Jersey.

DEA (Department of Environmental Affairs). 2016. Draft amendment of the norms and standards for the marking of rhinoceros and rhinoceros horn, and for the hunting of rhinoceros for trophy hunting purposes. Republic of South Africa. *Government Gazette (Staatskoerant)* 39589.

EDPRG (The Eye Diseases Prevalence Research Group). 2004. Causes and prevalence of visual impairment among adults in the United States. *Archives of Ophthalmology* 122:477–485.

Emslie RH, Knight MH, Duffy R. 2013. Rhino poaching: How do we respond? UK Department for International Development. *Evidence on Demand: Climate, Environment, Infrastructure and Livelihood Professional* 37.

Emslie RH, Milliken T, Talukdar B, Ellis S, Adcock K, Knight MH. 2016. *African and Asian rhinoceroses–status, conservation and trade*. A report from the IUCN Species Survival Commission (IUCN

SSC) African and Asian Rhino Specialist Groups and TRAFFIC to the CITES Secretariat pursuant to Resolution Conf. 9.14 (Rev. CoP15).

Fahlman A. 2008. Advances in wildlife immobilisation and anaesthesia. PhD thesis. Swedish University of Agricultural Sciences, Uppsala.

Fox J. 1991. *Regression diagnostics*. SAGE Publications, Newbury Park.

Haas TC, Ferreira SM. 2015. Conservation risks: When will rhinos be extinct? *IEEE Transactions on Cybernetics* 46(8):1721–1734.

Hall-Martin A. 1986. Recruitment in a small black rhino population. *Pachyderm* 7:6–8.

Hillman GR, Würsig B, Gailey GA, Kehtarnavaz N, Drobyshevsky A, Araabi BN, Tagare HD, Weller DW. 2003. Computer-assisted photo-identification of individual marine vertebrates: a multi-species system. *Aquatic Mammals* 29(1):117–23.

Hothorn T, Hornik K, Zeileis A. 2006. Unbiased recursive partitioning: a conditional inference framework. *Journal of Computational and Graphical Statistics* 15(3):651–674.

Hussek A. 2018. 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. Master's thesis. University of Natural Resources and Life Sciences, Vienna.

Kasanen IHE, Voipio HM, Leskinen H, Luodonpää M, Nevalainen TO. 2011. Comparison of ear tattoo, ear notching and microtattoo in rats undergoing cardiovascular telemetry. *Laboratory Animals* 45:154–159.

Lamprecht J. 1992. *Biologische Forschung: Von der Planung bis zur Publikation* (Biological research: from planning to publication). Paul Parey, Berlin/Hamburg.

Mazerolle MJ. 2004. Appendix 1: Making sense out of Akaike's Information Criterion (AIC): its use and interpretation in model selection and inference from ecological data. Mouvements et Reproduction des Amphibiens en Tourbières Perturbées, PhD thesis. Université Laval, Québec.

McGregor M, Jones D. 2016. Tattoo pens as a low-cost approach to in-field permanent identification of medium-sized mammals. *Wildlife Society Bulletin* 40(1):169–173.

Miles J. 2005. Tolerance and variance inflation factor. *Encyclopedia of Statistics in Behavioral Science* 4:2055–56.

Milledge SAH. 2007. Illegal killing of African rhinos and horn trade, 2000–2005: the era of resurgent markets and emerging organized crime. *Pachyderm* 43:96–107.

Newman C, Buesching CD, Macdonald DW. 2003. Validating mammal monitoring methods and assessing the performance of volunteers in wildlife conservation—'Sed quis custodiet ipsos custodies?' (Who will guard the guards themselves?) *Biological Conservation* 113:189–197.

Ngene S, Bitok E, Mukeka J, Gakuya F, Omondi P, Kimitei K, Watol Y, Kariuki L, Okita BO. 2011. Census and ear-notching of black rhinos (*Diceros bicornis michaeli*) in Tsavo East National Park, Kenya. *Pachyderm* 49:61–69.

Patton F, Jones M. 2007. Determining minimum population size and demographics of black rhinos in the Salient of Aberdare National Park, Kenya. *Pachyderm* 43:63–72.

Patton F, Jones M. 2010. Determining the suitability of using eye wrinkle patterns for the accurate identification of individual black rhinos. *Pachyderm* 48:18–23.

R Core Team. 2016. R: *A language and environment for statistical computing*. R Foundation for Statistical Computing, Vienna.

RStudio Team. 2015. *RStudio: integrated development for R*. RStudio, Inc., Boston.

Sandfort R. 2015. Estimating Alpine ibex (*Capra ibex*) abundance from photographic sampling. *Mammal Review* 45:191–195.

Stein AB, Erckie B, Fuller TK, Marker L. 2010. Camera trapping as a method for monitoring rhino populations within the Waterberg Plateau Park, Namibia. *Pachyderm* 48:67–70.

Tomášová K. 2005. White rhinoceros. In: Fulconis R. *Save the rhinos: EAZA Rhino Campaign 2005/6*. Info Pack, London, p. 56–60.

Walpole MJ. 2002. Factors affecting black rhino monitoring in Masai Mara National Reserve, Kenya. *African Journal of Ecology* 40:18–25.