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Sustainable close encounters: integrating tourist and animal behaviour to improve rhinoceros viewing protocols

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Abstract

Tourism may benefit conservation, but some wildlife viewing practices threaten the sustainability of both business and conservation initiatives. In north-west Namibia, conservation-oriented tourism provides tourists with an opportunity to encounter the critically-endangered black rhinoceros *Diceros bicornis* on foot. We used 123 tourist-rhinoceros encounters and employed a statistical modeling approach to: (1) identify the characteristics of human-rhinoceros encounters that caused rhinoceros disturbance and displacement; and (2) design rhinoceros-human encounter guidelines that improve sustainability. A model-averaging, information-theoretic approach identified tourist approach distance, viewing time and individual encounter exposure as the most significant predictors of rhinoceros disturbance level. A suite of rhinoceros viewing scenarios were modeled for acceptable disturbance risks, and adopted as a rhinoceros viewing policy. The policy reduced encounter displacements by 80% while maintaining a 95% positive feedback rating from guests. We demonstrate an evidence-based, policy-oriented management approach can help improve tourism's contribution towards the conservation of an endangered species.

Introduction

The multi-trillion dollar global tourism industry presents both challenges and opportunities to biodiversity conservation (Buckley, 2011). Wildlife tourism, particularly, continues to grow rapidly (Tapper, 2006; Balmford *et al.*, 2015) as demand by tourists to view and interact with wildlife increases (Higham, Bejder & Lusseau, 2009). In developing countries, such as Namibia, wildlife tourism can form a substantial portion of the local and national economy (Naidoo *et al.*, 2016). However, integrating tourism as a business with conservation has also led to negative impacts on wildlife (reviewed in Buckley, 2011). Species specifically impacted by wildlife tourism include penguins (Spheniscidae, Trathan *et al.*, 2008), Olympic marmots *Marmota olympus* (Griffin *et al.*, 2007), Rocky Mountain elk *Cervus elaphus* (Preisler, Ager & Wisdom, 2006), marine cetaceans (Higham *et al.*, 2009) and more recently the Arctic fox in Sweden (Larm *et al.*, 2017) and brown bears in North America (Penteriani *et al.*, 2017).

While tourism provides significant benefits to endangered species conservation (Buckley *et al.*, 2012; Morrison *et al.*, 2012), examples of impacts and costs to species protection also exist (Morrison *et al.*, 2012). The activities of tourists may disturb and displace wildlife from protected areas or trigger aggressive and threatening behavior towards people (Ranaweerage, Ranjeewa & Sugimoto, 2015). The habituation of wildlife to tourists (Knight, 2009) has also been linked to an increased risk of their being depredated or hunted (Geffroy *et al.*, 2015). Although many studies have evaluated tourism's impacts on wildlife, few were conducted in Africa (Larson *et al.*, 2016) despite the growing wildlife-based tourism industry on the continent (Balmford *et al.*, 2009).

Namibia has embraced wildlife-based tourism for conservation and socio-economic development (Jones, Diggle & Thouless, 2015). It is home to approximately one-third of the world's extant critically-endangered black rhinoceros *Diceros bicornis* and most of its *D. b. var bicornis* subspecies (Emslie & Knight, 2014; IUCN, 2017). The black rhinoceros of north-western Namibia is recognized by the IUCN African Rhino Specialist Group as an important population for species recovery due to its large size and persistence outside a formally protected area (Emslie, 2008). This status also heightens its significance to tourists (Naidoo *et al.*, 2016). Black rhinoceros, however, may be especially susceptible to tourist-induced displacement. They are thought to avoid areas of human activity and be easily displaced from critical resources (Cunningham & Berger, 1997; Walpole *et al.*, 2003). In arid environments, like northwest Namibia, (Mendelsohn *et al.*, 2003), where water availability and plant growth is poor and patchily distributed, being displaced from a resource is expected to impact wildlife survival and reproduction. Poorly conceived and implemented tourist-viewing practices that displace wildlife, particularly more sought-after species of high conservation and tourism value, could threaten the sustainability of tourism as a business and conservation efforts.

Designing strategies to manage the trade-off between black rhinoceros tourism and conservation should be based on evidence and those strategies should be evaluated evidentially (Sutherland *et al.*, 2004; Stewart, Coles & Pullin, 2005). In this article, we describe our work to test what factors contributed most to rhinoceros disturbance and displacement from tourist activities and to apply that understanding in the development of tourist-viewing protocols that are sustainable. Our study was designed to inform the vision of the local conservation-tourism partnership to "provide tourists with a rare opportunity to view the black rhinoceros in its natural setting whereby the rhinoceros remains completely unaware and unaltered by human presence" (Muntifering, 2016). To this end, we sought to develop an approach that optimizes the relationship between tourist-viewing experiences and reduced animal displacement in a way that could be applied more widely to a variety of taxa and contexts. Key to that advance is our method for integrating evidence from systematically collected data on tourist behaviour and experience with animal behavioural outcomes to guide management and policy decisions. Specifically, we sought to collect and evaluate evidence: (1) for the types and magnitudes of human and/or environmental factors driving rhinoceros behavior, particularly their displacement when encountered by tourists, and (2) to develop a model for tourist-rhinoceros encounters as a guide to policy-making and rhinoceros tourism practice.

Materials and methods

Study site and population

Our study was conducted in approximately 1365 km² of desert wilderness around Desert Rhino Camp (DRC: 13° 50′45″ E, 20° 1′30″S) within the larger government-administered Palmwag Tourism Concession within the Kunene Region of north-west Namibia. DRC was established in 2003 and originated as a cooperative venture between the private tourism company, Wilderness Safaris, and the non-governmental conservation organization, Save the Rhino Trust (SRT). DRC specializes in black rhinoceros tourism, and supports research and rhinoceros monitoring (Buckley, 2010). Black rhinoceros are typically easy to distinguish using unique natural and man-made ear notches, horn shape and size, and eye and nose wrinkles. SRT have monitored individual Namibian north-west black rhinoceros since the early 1990s (Brodie *et al.*, 2011) and most are well-known.

Data collection

Data was collected during four periods totaling 8 months between 2003 and 2005. Prior to data collection, five independent observers were trained in the data capture techniques and for standardized data collection with SRT tackers during trial rhinoceros encounters. An average of five rhinoceros tracking day trips on foot from DRC by a SRT rhino tracking team were scheduled each week. The team consisted of two to three SRT trackers (average ±1SD = 6.5 years' experience ±3) and one to two tourist guides, with the approach and withdraw from the rhino always under the control of the SRT trackers. One of the five independent observers would accompany the team to capture data during the rhinoceros encounters.

Black rhinoceros have exceptional olfactory senses meaning encounters should be planned and pursued with favorable wind direction (i.e., the rhinoceros is upwind from tourists). Rhinoceros tracked at DRC are never approached in unfavorable wind conditions that exacerbate the likelihood of animal disturbance or displacement.

Defining response variables

After each encounter a single highest observed rhinoceros response level (Unaware, Disturbed, or Displaced) was recorded by the independent observer. Unaware was defined as the rhinoceros showing no signs of awareness to the tracking team. Disturbed was defined as a change in the behaviour of rhinoceros in response to the tourist group, specifically at least the ears directed and held steady in the direction of the team for greater than 5 s. Disturbance could involve small distance (<50 m) walking of the rhino toward, tangential or away from the team. Displacement was defined as any movement following a disturbed state whereby the rhinoceros either walked or ran in excess of 50 m. We included the distance aspect to restrict the definition to substantial escape behaviour as opposed to trivial small-scale displacements (typically less than 50 m) that often occur as a result of curiosity to a potential threat. Disturbance and displacement served as binary response variables and assigned the value '1' with "unaware" given the score '0' in the subsequent analyses.

Deciding and defining fixed-effects

Explanatory variables for our observed rates of rhinoceros disturbance and displacement were developed *a priori*. In the absence of any previously developed hypotheses or tests for tourism-induced rhinoceros disturbance and displacement, we convened a focus group of five local rhinoceros and tourism experts, with approximately 60 years of cumulative experience monitoring rhinoceros on foot. We asked them to list and debate what causes rhinoceros disturbance and displacement when they encounter a tracking team. Collectively, they decided on nine causes and we used those to define and measure independent variables for the study and analyses that were also supported by literature review (Stankowich, 2008). Below we provide a brief justification for each of the explanatory variables used in the analysis (Table 1):

Cumulative time

Habituation is a process that moderates and attenuates an animal's behavioral response to human exposure (Geffroy *et al.*, 2015) over time. Tourism may cause habituation and is sometimes encouraged to improve tourists' experience (Knight, 2009; Shutt *et al.*, 2014). Cumulative time was an ordinal variable from 1 to 24 (months) describing the temporal progression of the study. We expected disturbance and displacement likelihoods to decrease over the 24 months if habituation occurred.

Season

Namibia has two climatic seasons: wet and dry. The wet season is typically from January through April and the dry season from May through December (Mendelsohn *et al.*, 2003). We expected rhinoceros to be more prone to disturbance and displacement in the dry season when resources are scarce.

Individual rhino encounter rate

Some rhino were encountered more than others during the study such that there were very large differences in encounter rate amongst the rhino population. We expected the rhinoceros with greater exposure to human encounters to be less sensitive to human disturbance than others (e.g. habituation). We created a binary variable for rhino encounter rate by classifying rhinoceros that received a tourist encounter at least once per month coded as a '1' and anything less frequent a '0'.

Viewing group size

Tourist group-size has been previously recorded as a factor that can induce disturbance in wild animals (Stankowich, 2008). For each sighting we recorded the total number of people, including tourists, guides and researchers, who approached the rhinoceros in each encounter. We expected that group size would be positively related to disturbance and displacement.

Closest approach distance

Reviews on tourist wildlife viewing suggest that physical proximity between humans and the wildlife plays a major role in driving disturbance and displacement (Stankowich, 2008), particularly for Asian rhinoceros (Lott & Mccoy, 1995). For each sighting we measured how close the group approached the rhinoceros, using laser rangefinders (± 1 m accuracy). We expected approach distance to be negatively related to disturbance likelihoods, i.e., the closer a group was to a rhinoceros, the more likely it was to have been disturbed and displaced.

Viewing time at closest distance

As time increases during each viewing event, so does the likelihood of noise and wind change. Time at the closest distance was recorded in minutes for each sighting. We expected viewing time to be positively related to rhinoceros disturbance likelihood.

Table 1 Summary descriptions for explanatory variables included in the disturbance and displacement models

Variable	Category	Numeric classification	Description (hypothesized relationship with disturbance response variable)
1) Composition	Dichotomous	0 = Single, 1 = Cow/calf	Whether the rhinoceros encountered was single or a cow/calf pair. (+)
2) Distance from closest location	Continuous	Meters	The closest distance that the group approached the rhinoceros. (–)
3) Cumulative time	Ordinal	1–24	The consecutive month when the encounter occurred beginning within the month the study was initiated. (–)
4) Time at closest distance	Continuous	Minutes	The total elapsed time (in minutes) of the encounter from the closest distance. (+)
5) Number of people	Continuous	Count total number of people in group	The total number of people in the rhinoceros encounter including all guides and trackers. (+)
6) Individual encounter exposure	Dichotomous	0 = low, 1 = high	For each rhinoceros encountered, whether the individual had experienced a relatively higher exposure to humans. (–)
7) Season	Dichotomous	0 = dry, 1 = wet	The season within which each encounter took place. (–)
8) Habitat	Dichotomous	0 = open, 1 = closed	Whether the encounter occurred in relatively open cover (such as plains or rocky hills) or closed vegetation (such as riverbeds) (–)
9) Initial behavior	Dichotomous	0 = inactive, 1 = active	Whether the rhinoceros encountered was initially found inactive (sleeping) or active (walking, standing, laying but alert). (+)

Rhino group composition

While mature black rhinoceros can be seen in groups, especially when a female is in estrus (Estes, 1999), we only observed two group compositions in this study; females with calves and single male individuals. Thus, the group composition is also indicative of gender since every independent female in the study had a calf and all single, independent rhinoceros were males. Female black rhinoceros with young are often more sensitive to human disturbance (Cunningham & Berger, 1997). We coded rhinoceros as either a single individual, or a cow with calf. We expected rhinoceros cows with young calves to be more sensitive to disturbance.

Initial behavior

Animal activity has an influence on their likelihood to detect a threat. More active animals are more likely to detect threats. We treated initial behavior, classified as either active (standing, browsing, walking or running) or non-active (sleeping). We expected rhinoceros that were active (i.e. more vigilant) to be more sensitive to disturbance.

Habitat

Research has found increased levels of habitat cover decreased levels of vigilance and flight response for wildlife under tourism pressure (Stankowich, 2008). Thus, we dichotomously categorized each sighting into a dominant habitat classed by open landscapes (i.e. plains, hills or slopes) or closed (i.e. riverbeds). We expected open habitats to produce higher disturbance likelihoods.

Statistical models and random-effects

The identity of encountered rhinoceros was recorded. Rhinoceros that could not be recognized, because unique identification features were absent or obstructed, were categorized as 'unknown'. Individual animals within species, populations and even small groups may respond differently to disturbance (Nakagawa & Schielzeth, 2010). We expected disturbance levels to vary between individual rhinoceros and so included rhinoceros identity as a random effect in our mixed-effects models (Hebblewhite & Merrill, 2008; Charles & Linklater, 2013).

We used a model-averaging information-theoretic approach (Anderson, 2008) and Generalized Linear Models to test the effects our independent variables had on both disturbance and displacement of encountered rhinoceros. All analysis was conducted using the statistical software package R, version 3.2.2 (R Development Core Team, 2015). For model selection and averaging procedures we used the *MuMIn* package (Bartoń, 2016) to perform the multi-model inference analysis (model-averaging) and the *lme4* package (Bates, Maechler & Bolker, 2016) to perform the mixed-effects modeling. Details of the methods used to develop the predictive scenario-based fixed effects Generalized Linear Models are provided in Appendix S1.

We measured the magnitude and direction of each independent variable's coefficients on our rhinoceros disturbance using multi-model averaging across the full set of candidate models that contained all possible variable combinations of our nine explanatory variables for a total of 512 models. The likelihood of each candidate model being the best (Akaike weights), and the relative importance for each independent variable was calculated and compared using Akaike Information Criterion adjusted for small sample size (AICc) and by summing the weights of each model that included each variable, respectively (Anderson, 2008). Following the model selection and evaluation process, a series of predictive scenario-based models were estimated to demonstrate the utility of the analysis in guiding the rhinoceros viewing activities at DRC. These models were then used to create a rhinoceros viewing protocol with multiple scenarios to fit various viewing circumstances.

Model validation

Models were validated by repeating our measures of rhinoceros displacement in 2008 and 2009. Rhinoceros displacement was compared with that expected and projected from the model built using data collected between 2003 and 2005. In addition, to provide a more holistic measure of our protocol's performance related to business sustainability over a longer time threshold, we assessed whether the new viewing protocol, which has remained in effect since its implementation in 2006, would maintain tourist satisfaction. We did this by examining scores published on Trip Adviser, the largest global internet review site with more than 600 million reviews posted by travelers for over 7.5 million businesses worldwide (Trip Adviser, n.d.). Since the main purpose for choosing to visit DRC is rhinoceros tracking (Sibalatani, 2005), we assumed that any reviews posted on Trip Adviser from DRC would have a substantial emphasis upon the actual rhinoceros tracking experience. Since the earliest available reviews were only posted in 2006, after the protocol was already implemented, we could not compare post-protocol with pre-protocol reviews. Yet, as our goal was to ensure satisfaction was sustained following the implementation of the viewing protocol, assessing whether review scores remained 'above average' following the implementation of the protocol was still a meaningful measure of sustainability.

Results

We recorded 123 rhinoceros encounter observations. These comprised 112 encounters with 33 known individuals and 11 encounters where individual were unable to be identified. Sixty-eight sightings (55%) comprised six rhinoceros regularly encountered at DRC. Forty-five of the encounters (37%) resulted in the rhinoceros remaining unaware, 45 (37%) were disturbed but not displaced, and 33 (26%) were displaced.

For the disturbance model, key variables identified in the model-averaging were time at closest distance ($\Sigma\omega_i = 1$), closest approach distance ($\Sigma\omega_i = 0.95$), and rhino-group composition ($\Sigma\omega_i = 0.89$), each accounting for roughly three times more importance than the other explanatory variables (Fig. 1). The confidence set of models ($\Sigma\omega_I \geq 0.95$) included 94 (18%) of 511 total possible models or 95% of the cumulative model weight was represented by the top 18% of the fitted models. Habitat, initial behaviour and season did not feature in any of the top disturbance models (Table 2).

For the displacement model, key variables identified in the model-averaging were time at closest distance ($\Sigma\omega_i = 1$), closest approach distance ($\Sigma\omega_i = 1$), and individual encounter exposure ($\Sigma\omega_i = 0.97$) (Fig. 1). The confidence set of models ($\Sigma\omega_I \geq 0.95$) included 53 of 511 total possible models with 95% of the cumulative model weight represented by the top 10% of the fitted models. Habitat and initial behaviour did not feature in any of the top displacement models (Table 2). Thus, disturbance and displacement were predicted well by two of the same variables: i.e., the closest approach distance and time at the closest distance.

Model-averaging did not deliver one dominant model, but rather a small set of models with similar, moderate levels of support for both disturbance and displacement model sets. Five models for predicting disturbance and displacement were found (ΔAICc < 2), which contained 31% and 33% of the cumulative model weight, respectively (Table 3).

Models predict that limiting disturbance to 25% or fewer encounters requires that groups approach no closer than 150 m for 5 min, 200 m for 20 min or 300 m for 50 min (Fig. 2a). Limiting displacement risk to 10% or fewer encounters predicted encounters should be achieved by approaching no closer than 100 m for 5 min, 150 m for 15 min or 250 m for up to 45 min (Fig. 2b). A structured decision process including guides, trackers, managers and advisers at DRC conducted in 2006 (Muntifering, 2016), selected the modelled displacement scenarios as the camp's viewing policy.

Model validation using 519 independent rhinoceros sightings during 2008 and 2009, following the implementation of the modelled viewing policy, found that rhinoceros displacements decreased from 26% (this study) to 5.4% falling well below our projected outcome of 10% disturbance likelihood. Our assessment of tourism satisfaction incorporated 127 online reviews posted between 2006 and 2018. Scores had an average overall rating of 4.73 ± 0.67 on a 5-point scale with 95% a 'Very Good' (4) or 'Excellent' (5) and 80% receiving an 'Excellent'. Since the rhino tracking activity is the main focus of the camp, it was assumed and almost always referred to in reviews, as a major factor in shaping overall guest satisfaction and thus there was no need to

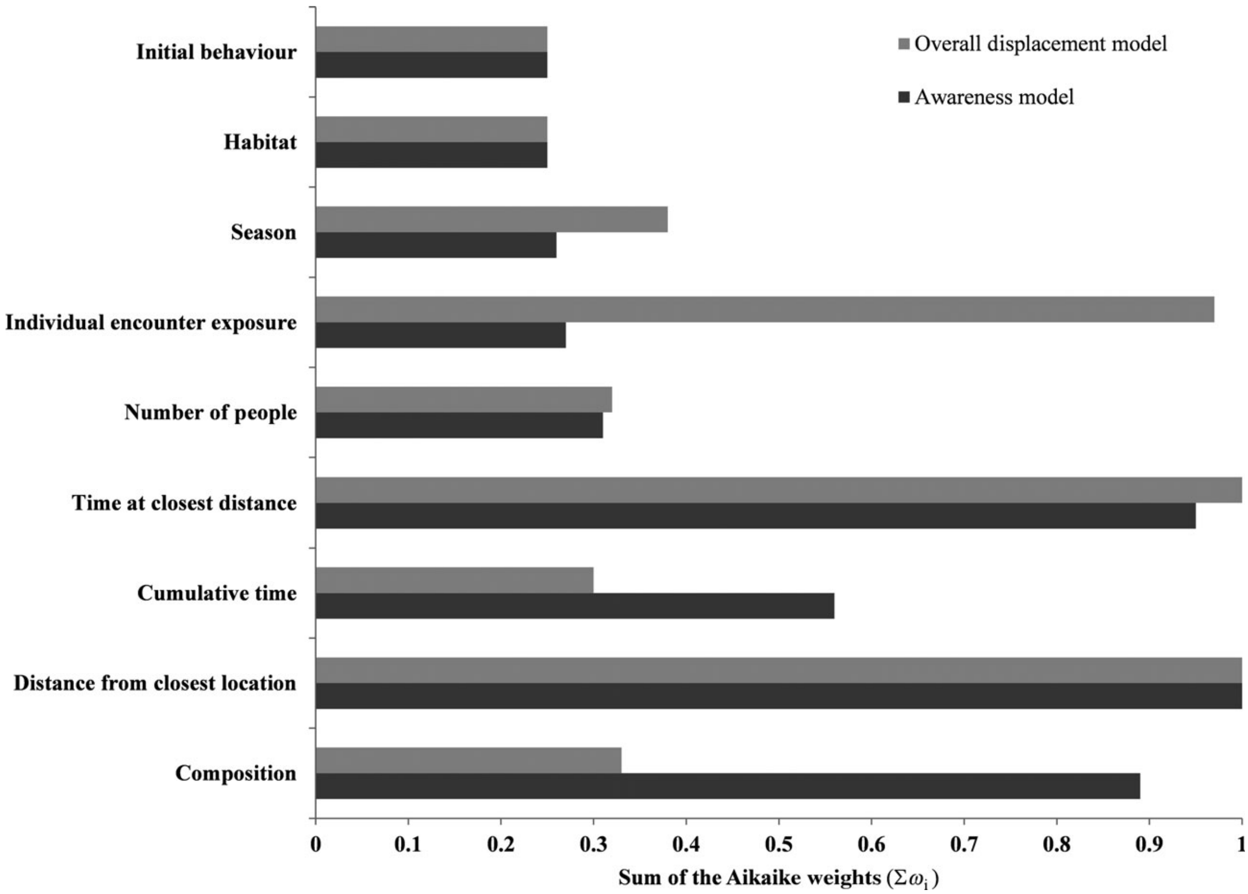

Figure 1 Relative importance of the explanatory variables in both disturbance and displacement logistic regression models

Table 2 Model-averaging results for the disturbance and displacement logit models. Parameters where $P \leq 0.01$ is indicated in bold

	Logit distrubance				Logit displacement			
Variable	Parameter	Std. error	Lower 95% CI	Upper 95% CI	Parameter	Std. error	Lower 95% CI	Upper 95% CI
Composition	−1.178[1]	0.478	−2.115	−0.241	−0.477	0.528	−1.511	0.558
Distance from closest location	**−0.018**[3]	0.005	−0.027	−0.008	**−0.027**[2]	0.006	−0.040	−0.015
Cumulative time	−0.064	0.040	−0.142	0.015	0.035	0.051	−0.066	0.135
Time at closest distance	**0.055**[2]	0.021	0.014	0.097	**0.114**[3]	0.026	0.062	0.165
Number of people	−0.049	0.067	−0.181	0.083	0.060	0.077	−0.090	0.210
Individual encounter exposure	−0.169	0.574	−1.295	0.956	−1.748[1]	0.615	−2.954	−0.543
Season	0.211	0.636	−1.037	1.458	0.760	0.701	−0.614	2.135
Habitat	−0.030	0.451	−0.915	0.854	−0.072	0.498	−1.048	0.904
Initial behaviour	0.021	0.456	−0.871	0.914	−0.061	0.491	−1.024	0.902

P = 0.05[1], ***P* = 0.01[2], *P* = 0.001[3].**

Table 3 Best models for both disturbance and displacement logistic regression with Δ AICc ≤ 2. Variables in the Disturbance and Displacement Model Sets are numerically denoted as: Composition = 1, Distance from closest location = 2, Habitat = 3, Initial behavior = 4, Cumulative time = 5, Number of people = 6, Individual encounter exposure = 7, Season = 8, Time at closest distance = 9

Model	d.f.	logLik	AICc	ΔAICc	Weight ωi
Disturbance model set					
1259	5	63.2009	136.91	0.000	0.0976
129	4	64.4919	137.32	0.408	0.0796
12569	6	62.9179	138.56	1.645	0.0429
1269	5	64.0671	138.65	1.732	0.0410
12579	6	62.9697	138.66	1.749	0.0407
Displacement model set					
279	4	55.5905	119.52	0.000	0.1080
2789	5	55.0605	120.63	1.114	0.0620
1279	5	55.1353	120.78	1.263	0.0576
2679	5	55.1976	120.91	1.388	0.0541
2579	5	55.3771	121.27	1.747	0.0452

attempt to distinguish specifically which factor(s) drove each rating.

Discussion

If tourism is to benefit conservation, a concerted effort is required to quantify the tourist-wildlife relationship towards making it sustainable. We empirically advanced our understanding of the tourist-black rhinoceros interactions as a guide to policy by integrating the measurement of tourist behaviour and experience with animal behaviour. Our study suggests that a relatively straightforward statistical modelling approach to crude measurements of tourist-animal encounters can provide clear, policy relevant guidelines that may help reduce negative impacts (rhinoceros disturbance and displacement) without compromising tourists' satisfaction. Importantly, a similar approach could be implemented across a wide range of taxa subject to non-lethal human encounters that are the basis of wildlife-based tourism.

Our key finding confirmed that, similar to other species, there is a direct and strong impact from human proximity to the animal of interest and their displacement (Preisler *et al.*, 2006; Penteriani *et al.*, 2017). This is particularly of interest for tourism, which often depends upon delivering intimate personal experiences with wild animals. Fortunately, the two key driver variables, approach distance and associated viewing time, are in control of, and can be managed by, tourist-group leaders. For tourists and tourism operators, while this decision may reduce the 'intimacy' of encounters, the scientifically-established recommendations is also a tool that can support guides and managers' explanation to tourists for why viewing events are restricted and how these restrictions were conceived to pre-empt the pressure to rule-break (Sandbrook & Semple, 2006). This research may also enhance tourist safety while viewing large wild animals – a clearly important trade-off against encounter intimacy.

Subtle signals found in the effect of both cumulative time and individual encounter exposure upon disturbance and displacement suggest some tourism-induced habituation is occurring. Although not significant, cumulative time was nearly twice as important (relatively) in the disturbance model than the displacement model, suggesting that rhinoceros become less vigilant when regularly encountering people. Rhinoceros with greater encounter exposure (i.e. exposed to regular tourism) are much less likely to become displaced than rhinoceros with less encounter exposure, indicating an increased level of tolerance towards humans. Despite the advantages that habituation may provide to enhance the viewing experience for tourists, especially for rare, elusive species (Shutt *et al.*, 2014), the costs may exceed the benefits for species at high risk of human-induced mortality, such as illegal hunting, that could be exacerbated by an increased tolerance towards humans (Geffroy *et al.*, 2015). In this context, the current escalating rhinoceros poaching rate across Africa (Knight, 2012) certainly is cause for concern despite relatively low poaching rates recorded on Namibia's communal lands (Muntifering *et al.*, 2015). Therefore, monitoring and managing for limited habituation may be critical for ensuring tourism activities do not result in placing rhinoceros, or other species under threat from illegal hunting, at greater risk of human-induced mortality. Tourists

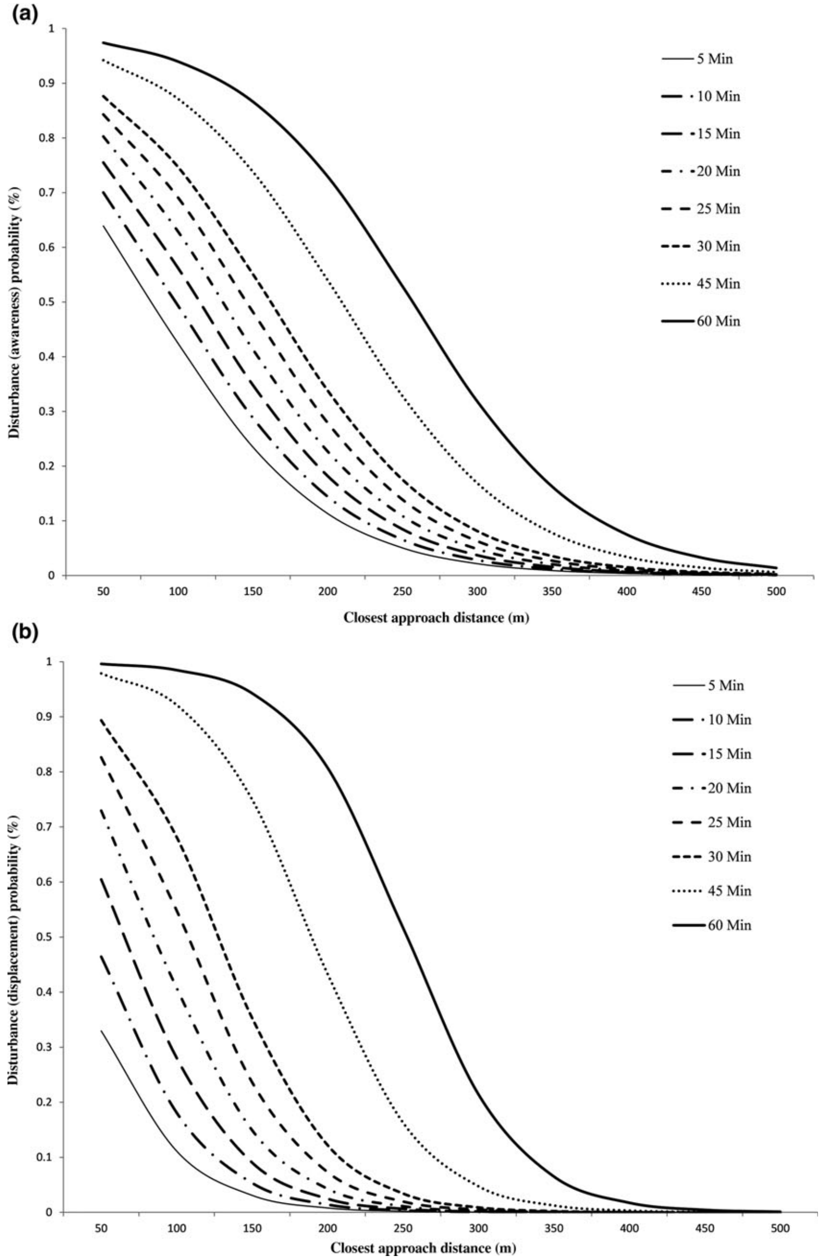

Figure 2 Scenario projections for the (a) disturbance and (b) displacement models illustrating the relationships between closest distance, viewing time and predicted rhinoceros behavior response

could be sensitized to this critical issue before partaking in rhinoceros tracking activities to temper pre-conceived expectations of close encounters for the sake of the species' security. A limitation with our study was the model training data were 12–15 years old. Although rhinoceros tourism in northwest Namibia is conducted similarly today, it is possible that black rhinoceros responses have changed over time (i.e., sensitized or acclimatized) or other populations of rhinoceros might respond differently to the same types and intensity of tourist activity. It would be useful, therefore, to repeat our data collection and analysis to assess the usefulness of our approach and conclusions for the current and other populations.

Policy implications

As wildlife-based tourism continues to grow in popularity, so will the pressure placed upon tourism management to produce intimate experiences for guests. While studies that document negative impacts of tourism upon wildlife are well represented in the literature, research that provides explicit and empirical guidance for policy formulation and science-based regulations

(Moorhouse *et al.*, 2015), are limited. Our modeling approach, grounded in statistical and behavioral ecology, advances this critical research-implementation gap by integrating human and animal behavior data in a manner that provides a practical, user-friendly and policy-relevant output allowing guides, trackers and managers to identify acceptable disturbance probability targets and associated viewing protocols. For example, model outputs have been simplified into practical guideline tools for tourist-group leaders of individual rhinoceros encounters (Muntifering, 2016). Further, such an approach is transferrable to other taxa that may experience similar tourism-related encounter pressure and where trade-offs in conservation and business objectives would benefit from an objective reconciliation process.

Our preliminary *post hoc* evaluation recorded a significant reduction in rhinoceros displacements at an acceptable level below 10% suggesting that the viewing protocol is helping reduce disturbance below our target threshold. Our estimates and recommendations are also reasonably consistent with other research which estimated that, despite having a reputation for poor eyesight, black rhinoceros could readily distinguish a 30 cm wide human up to 200 m away (Pettigrew & Manger, 2008). However, for rhinoceros tourism to be sustainable, tourists must also be satisfied with the opportunity offered. Our Trip Adviser data (e.g. reviewer rating scores), despite not being a random sample, suggests that guests were more than satisfied with the experience despite the introduction of new viewing regulations. While these results cannot be interpreted to have direct causal relationships with rhinoceros disturbance, it suggests that the conservation-oriented management interventions are reducing impacts without decreasing tourist satisfaction thus enhancing overall sustainability.

As human-induced pressures continue to infringe upon the world's last remaining wildlands outside of protected areas, incentive-based, sustainable use strategies such as wildlife-based tourism may be the only practical solution to conserve viable populations of wildlife in human-dominated landscapes. Designing and delivering evidence-based, policy-relevant research that reduces risks and uncertainty while enhancing ecological and social sustainability will play a major role towards ensuring these practices are successful for the wildlife and people they are meant to serve.

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Supporting information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Appendix S1. Detailed description of the methods used to develop the mixed effects Generalized Linear Models of black rhinoceros-human encounters.

Graphical Abstract

The contents of this page will be used as part of the graphical abstract of html only. It will not be published as part of main article.

Tourism may benefit conservation but some wildlife viewing practices threaten the sustainability of both business and conservation initiatives. Using a case from rhinoceros tracking tourism in north-west Namibia, we employed a statistical modeling approach to: (1) identify the characteristics of human-rhinoceros encounters that caused rhinoceros disturbance and displacement; and (2) design rhinoceros-human encounter guidelines that improve sustainability. The subsequent evidence-based rhinoceros viewing policy reduced encounter displacements by 80% while maintaining a 95% positive feedback rating from guests. We demonstrate an evidence-based, policy-oriented management approach can help improve tourism's contribution towards the conservation of an endangered species.