Identifying rule-breakers in conservation: UK fly-fishing, Madagascar bushmeat consumption, and persecution killing of carnivores on south African ranches.

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Abstract

Many approaches to conserving and managing natural resources depend upon rules, but the existence of rules alone does not guarantee compliance. Information on rule breaking behaviour is needed for designing interventions to improve compliance. However, directly investigating rule breaking is difficult as perpetrators may not wish to identify themselves. The randomised response technique (RRT) was developed to reduce the threat to respondents, making them more willing to admit to illegal behaviour. We investigate the efficacy and limitations of this technique with fly fishers in the UK and bushmeat consumers in Madagascar. RRT resulted in higher levels of reporting of illegal behaviour, particularly for more sensitive behaviours, however it didn't work well among older people of low literacy. Because of the limitations of RRT (it requires large sample size and is not well understood by all types of respondents), other, non-sensitive indicators of sensitive behaviours would be useful. Previous studies have suggested that attitudes can indicate behaviour, or that the psychological bias resulting from people's tendency to imagine that others are more like them than they really are can be used to identify rule-breakers, although there has been very little validation. We investigate potential indicators of whether an individual rancher has killed protected carnivores on his land. We found that farmers' attitudes towards carnivores and their estimate of the prevalence of carnivore persecutors among their peers were important predictors of carnivore killing. Too much is now known about the limitations of directly asking people about sensitive behaviours for conservationists to blindly use conventional face-to-face interviews to obtain estimates of rule breaking.

Introduction

There are many approaches to the conservation of biodiversity and management of natural resources, many of which depend, at least in part, on rules that restrict human use (Keane et al. 2008). For example: many countries have wildlife laws protecting certain species rules control the management of harvested populations; and rules determine what can be done within a protected area. However, rules alone do not change behaviour (Rowcliffe et al. 2004). Understanding levels of rule breaking would be valuable for developing interventions to improve compliance. Unfortunately, studying compliance directly is difficult as rule breakers may be unwilling to reveal themselves or to discuss their actions for fear of punishment (Gavin et al. 2010; Keane et al. 2008). Rule breaking can be considered a sensitive behaviour as if respondents answer questions honestly they may suffer repercussions (Sieber and Stanley 1988). Disciplines such as public health and criminology have developed methods that address the challenges of collecting data on sensitive topics. However, these have not yet been applied widely within the context of conservation and natural resource management where most studies aiming to quantify rule breaking by gathering data directly from the public (which includes potential rule breakers) have used questionnaires delivered through face-to-face interviews (St John et al. 2010a).

Such face-to-face direct interviews can be a cost effective method for obtaining robust information on legal and socially acceptable exploitation of wild species (Jones et al. 2008). However, when such exploitation is illegal, or otherwise sensitive (goes against social norms for example) biases can reduce the validity of data (Fisher 1993; Warner 1965). This problem has been raised by a number of authors studying illegal natural resource extraction from protected areas (St John et al. 2010a). Social desirability bias (the systematic error caused by respondents providing dishonest answers in order to project a favourable image of themselves

relative to prevailing social norms, Fisher 1993; King and Bruner 2000) and non-response bias (a non-random and significant proportion of individuals refusing to take part in a survey, either wholly, or partly, Lahaut et al. 2002) are particularly important in studies of sensitive behaviour. Assurances of confidentiality tend to increase response rate and validity (including reduced social desirability bias) when the topics are sensitive (Singer et al. 1995). When using a self-complete questionnaire anonymity can be guaranteed by not requesting personally identifying information. However specialised methods exist that as well as guaranteeing anonymity, also minimise respondents' feeling of risk associated with revealing sensitive, and potentially incriminating information (Lee 1993). The randomised response technique (RRT) (Warner 1965), was developed by social scientists studying illegal behaviour and protects both the respondent, and the researcher since no incriminating data can be directly linked to a respondent, Sudman et al. 1977; Warner 1965). In this study we bring together three bits of work addressing the question of how illegal behaviour can be quantified in the context of conservation. First we investigate the applicability of RRT to two conservation rule-breaking context (Part 1), we then use knowledge of RRT to design a study to validate the use of simple, non-sensitive indicators of sensitive behaviour (Part 2).

Part 1: Investigating whether RRT improves the reporting of sensitive behaviours

By using a randomising device (e.g. dice), RRT inserts an element of chance in the question-answer process which increases respondent privacy (Lensvelt-Mulders et al. 2005; Warner 1965). There are a number of RRT designs described in the literature, the merits of which are discussed in depth by Lensvelt-Mulders et al. (2005). 'Forced response' RRT (Lensvelt-Mulders et al. 2005) is one of the most statistically efficient RRT designs and is the one used in this study. Respondents are instructed to either: answer a sensitive question truthfully or to

say YES or say NO (irrespective of the truth), depending on the number they roll on a die (Boruch 1971 in Lensvelt-Mulders et al. 2005). For example respondents may be told: if the die lands on one, two, three or four please answer the question truthfully; if the die lands on five, simply answer YES; if the die lands on six, simply answer NO. The result of the die is never divulged to the interviewer. By knowing the probability of respondents answering the sensitive question, and the proportion of respondents instructed to say YES, the proportion of the population with the sensitive characteristic (the number of truthful YES responses) can be calculated without any individual identifying themselves (Lensvelt-Mulders et al. 2005; Warner 1965).

RRT has been used across a range of sensitive behaviours including benefit fraud, academic cheating, and illegal abortion (see references in St John et al. 2010a). In comparative studies RRT has provided higher estimations of sensitive behaviours compared to anonymous self-complete questionnaires (Donovan et al. 2003; Scheers and Dayton 1987), and face-to-face questionnaires (Silva and Vieira 2009) which has been taken as evidence of more honest reporting. In validation studies where true levels of the sensitive behaviour were known, RRT returned higher levels of correct responses than conventional methods (Lensvelt-Mulders et al. 2005).

Part 1 Case studies

Fly fishing in north Wales, UK. In the UK fly fishing is a popular sport governed by a set of rules designed to sustain fish stocks whilst protecting waterways and their biodiversity. By law fly fishers in the UK are required to hold a valid Environment Agency (EA) rod license. The EA conduct enforcement patrols and failure to comply can result in the confiscation of equipment and a fine of up to £2 500. National byelaws prohibit the killing of brown trout

(Salmo trutta) outside of the season (22 March and 30 September in Wales), enforcement is the responsibility of the EA and offences are handled in accordance with the Salmon & Freshwater Fisheries Act 1975: Section 19 (4). Other rules are set by the fishery and failure to comply might result in a ban. Currently there are no data available to provide estimates of rule breaking for different fly fishing rules.

Bushmeat consumption in Madagascar: Madagascar is recognised globally as one of the hottest of the global biodiversity hotspots (Myers et al. 2000). Although it is widely recognised that wild meat forms a part of rural people's diet and there has been concern about the sustainability of this hunting, and particularly the pressure on more vulnerable species (Golden 2009), the issue of bushmeat hunting in Madagascar has received much less attention than hunting in other biodiversity-rich tropical countries. Although the country's wildlife laws are poorly understood in general, it is quite widely known that lemurs are protected (Keane et al 2011) and in some areas there has been extensive environmental education which may make it difficult to investigate bushmeat hunting or consumption by asking direct questions. We investigated consumption of six bushmeat species in two regions of Madagascar using both the RRT and more traditional direct questioning. Our objective was to investigate the circumstances under which RRT may offer advantages over more direct approaches for understanding the scale of bushmeat consumption.

Part 1 Data collection

Fly-fishing: Surveys with fly fishers were administered to a total of 151 fishers at two privately managed fisheries in Wales on 19 days between May and July 2009 by FSJ. The fisheries were selected because a personal contact introduced FSJ to the fisheries owners'

who approved the study; the owner was never present when interviews were conducted. Fishers encountered more than once were not re-interviewed.

Bushmeat: Interviews were carried out with a total of 1574 villagers in 6 communes in three regions of Madagascar between November 2009 and June 2010 concerning consumption of seven bushmeat species and chicken (a non-sensitive species widely consumed). Interviews were carried out by staff of the NGO Madagasikara Voakajy led by Julie Razafimanahaka (see acknowledgements for list of research assistants). Two of these communes (Ambatovola and Andasibe) boarder a long established and relatively well enforced protected area: the Andasibe-Mantadia National Park. Hunting of any wild species is forbidden within the park and park staff regularly patrol the villages surrounding the park carrying out environmental education and enforcement activities. Questions about hunting would be particularly sensitive in these two sites. We selected a third commune from within the same district where such questions would be much less sensitive. The forests surrounding Lakato have only recently been designated as protected and there has been there has been little or no environmental education and/or enforcement of environmental legislation as yet. We also worked in three communes in the west: Mahabo, Ampanihy and Tsiningia. We are not able to classify these sites as sensitive or non sensitive and they have a complex history of environmental education and/or enforcement of environmental laws. We encountered serious problems with using the RRT method in Tsiningia (see discussion) and data from this site is therefore not presented in the results section.

Survey instruments were made up of two parts: a series of questions related to rule breaking and a simple demographic survey including information on fishing behaviour. Respondents were randomly allocated one of the two survey instruments (self-complete questionnaire,

RRT survey). Question wording was identical for each of the three survey instruments. All questions referred to the last 12 months to minimise recall inaccuracy.

Self-complete survey: Respondents were asked to circle YES or NO responses to the six compliance questions in the fisheries study or to the question have you eaten this species or not (for five species) in the bushmeat consumption study.

Randomised response technique survey: The RRT survey followed a 'forced response' model whereby respondents were required to answer the sensitive compliance question truthfully if the die landed on one, two, three or four. Respondents were asked to simply say the word YES, without reading the question, if the die landed on five; and to say NO without reading the question if it landed on six. Because the interviewer does not know whether a respondent is saying YES because they have broken the rule or because the die landed on a five, the interviewer does not have any sensitive information from the respondent. The probabilities associated with each response (based on the fisheries study) are given in Figure 1. Respondents were given a non-transparent plastic beaker containing one die, one example question card, and six compliance question cards each of which displayed the randomising device instructions. All cards were identical in design, only the questions differed. Respondents first had the method explained to them using the example question. Two strategies were adopted to maximise respondents following the RRT instructions: the analogy of following the rules of a game was used; and respondents were encouraged not to read the question if they threw a five or six, but to directly say YES or NO respectively. Questions were short, so the time taken to read and respond was minimal; as such the interviewer was not able to distinguish forced responses from truthful responses by considering the amount of time that respondents took to answer each question. The proportion of rule-breakers in the

sample was then estimated using the 'forced response' model (Boruch 1971 in Lensvelt-Mulders et al. (2005):

$$\pi_A = \frac{\lambda - (1 - P_1)\pi_F}{P_1}$$

where π_A is the proportion of the sample who have broken the rule, λ is the proportion of all responses that are YES, P_1 is the probability of having to answer the sensitive question truthfully and π_F is the probability of the response being YES, conditional on being forced.

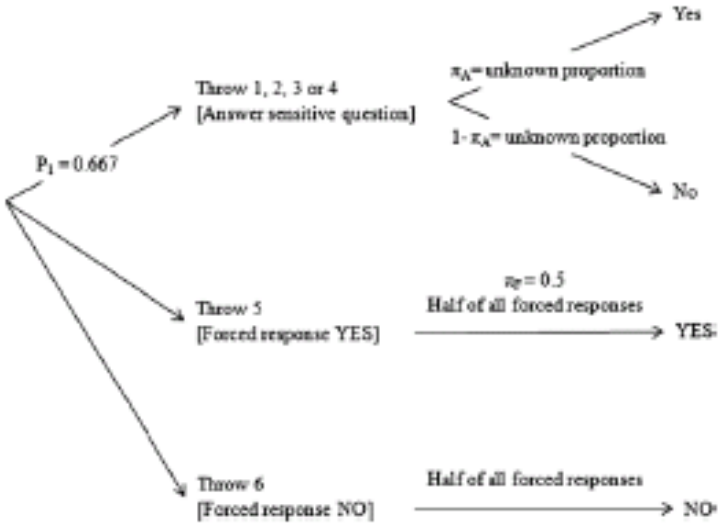

Figure 1: The decision tree for a forced response RRT using a single dice (from St John et al. 2010a)

The bushmeat study worked in a similar way apart from instead of die, coloured pencils in a bag were used with black inviting the response 'never eaten', white the response' have eaten' and any colour inviting the respondent to answer the question truthfully.

Part 1 Data analysis

Data were analysed using SPSS PC version 16.0 (SPSS Inc. Chicago USA). Ninety-five percent confidence intervals of the proportion of rule breakers in each category were estimated from 1000 bootstrap samples for the self-complete and RRT data. Bootstrap sampling of the RRT data estimates uncertainty arising from the RRT method as well as

sample uncertainty. We concluded that there was a significant difference between methods when the bootstrapped 95% confidence intervals for the mean difference did not include zero.

Part 1 Results and discussion

Flyfishers: Just six people refused to participate in the survey (non-response rate <3%). In all cases this was before the method had been selected. Of the 151 respondents 61 answered the self-complete questionnaire, 90 completed the RRT survey. The proportion of fishers who break each of the six fly fishing rules estimated using the two methods is shown in Figure 2. RRT estimated a significantly higher proportion of fishers failing to comply with the legal requirement to possess a rod license (mean difference between RRT and self-complete 0.25), and buy a valid permit (mean difference between RRT and self-complete 0.15). RRT estimated a higher proportion of fishers disregarding bait restrictions than the self-complete questionnaire (mean difference between RRT and self-complete 0.12); these two methods estimated similar proportions of fishers exceeding the bag limit (mean difference 0.02), these results were not significant.

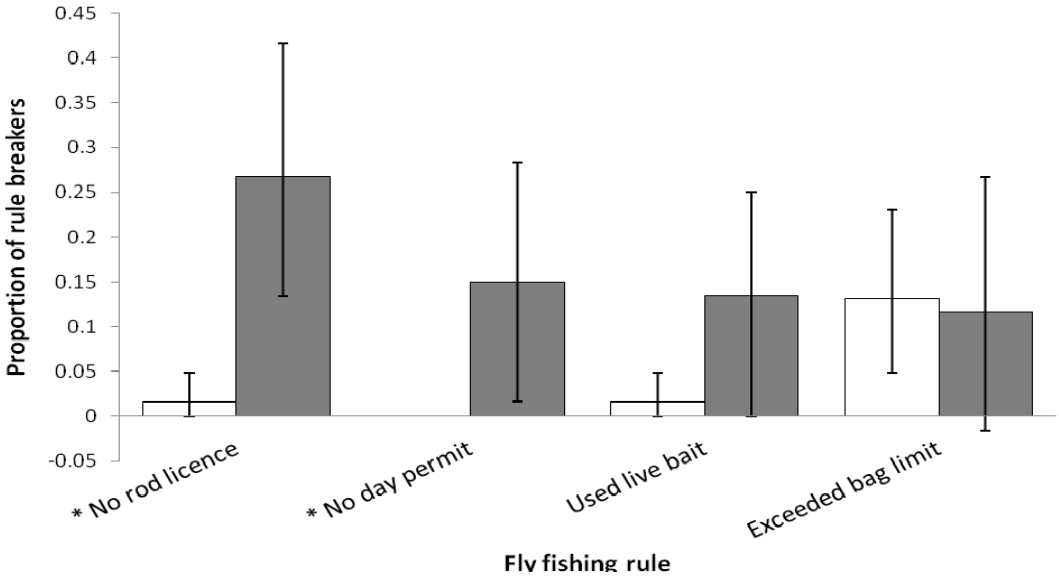

Figure 2 The proportion of fishers which break each of the four rules, estimated using the two methods (white: self-complete, grey: RRT). Error bars show 95% confidence intervals. Negative error bars occur for RRT where by chance the die forced fewer positive responses than expected; a larger sample size would reduce this problem.

Whilst killing brown trout outside of the fishing season is against the rules and therefore a potentially sensitive behaviour, it became evident whilst collecting the data that the opportunity to break this rule did not exist at the research sites. Brown trout are limited in number and reportedly difficult to catch (when asked this question most fishers responded with a laugh, stating that they had never caught one). We therefore do not include estimates for brown trout as they were close to zero for both methods. For the other four questions, we found large discrepancies between estimates of rule breaking using the three methods. Each method guaranteed anonymity in that no personal information was taken. However, RRT is a risk-reducing methods specially designed to reduce the level of threat perceived by respondents when asked to reveal sensitive, or potentially incriminating information (Lee 1993). RRT tended to result in higher estimates of rule breaking than the self-complete questionnaire. This effect was particularly marked for the most sensitive question (fishing without a valid rod license), but was also seen for two of the three questions of medium sensitivity (no day permit; used live bait). Higher levels of reporting of sensitive behaviours

have been taken as evidence of more honest reporting in other studies (Lensvelt-Mulders et al. 2005; Scheers and Dayton 1987; Silva and Vieira 2009; Solomon et al. 2007). So we suggest that RRT did appear to be successful in eliciting more honest responses. RRT and the self-complete questionnaire produced very similar estimates for the question on exceeding the bag limit. By admitting to breaking this rule, fishers get the opportunity to boast about their fishing ability which may lessen the perceived sensitivity of the question. In addition, if the bag limit is exceeded, extra fish can be paid for, so breaking this rule is unlikely to result in a ban. RRT results suggest that more than one quarter (27%) of fishers have abused the legal requirement to hold a valid rod license in the last 12 months alone. This represents a considerable financial loss to the Environment Agency.

Bushmeat consumption: There was very little difference between the proportion of respondents who had consumed the various bushmeat species estimated using direct questions and RRT for the non-sensitive sites (Figure 3). However in the sensitive sites, there was significantly higher reporting for some species, arguably species which respondents may see as particularly sensitive (2 protected species: brown lemur and the sifaka) and the flying fox, which the researchers are known in the area as being interested in. In the communes in the west, there was no significant difference between the estimates using either method.

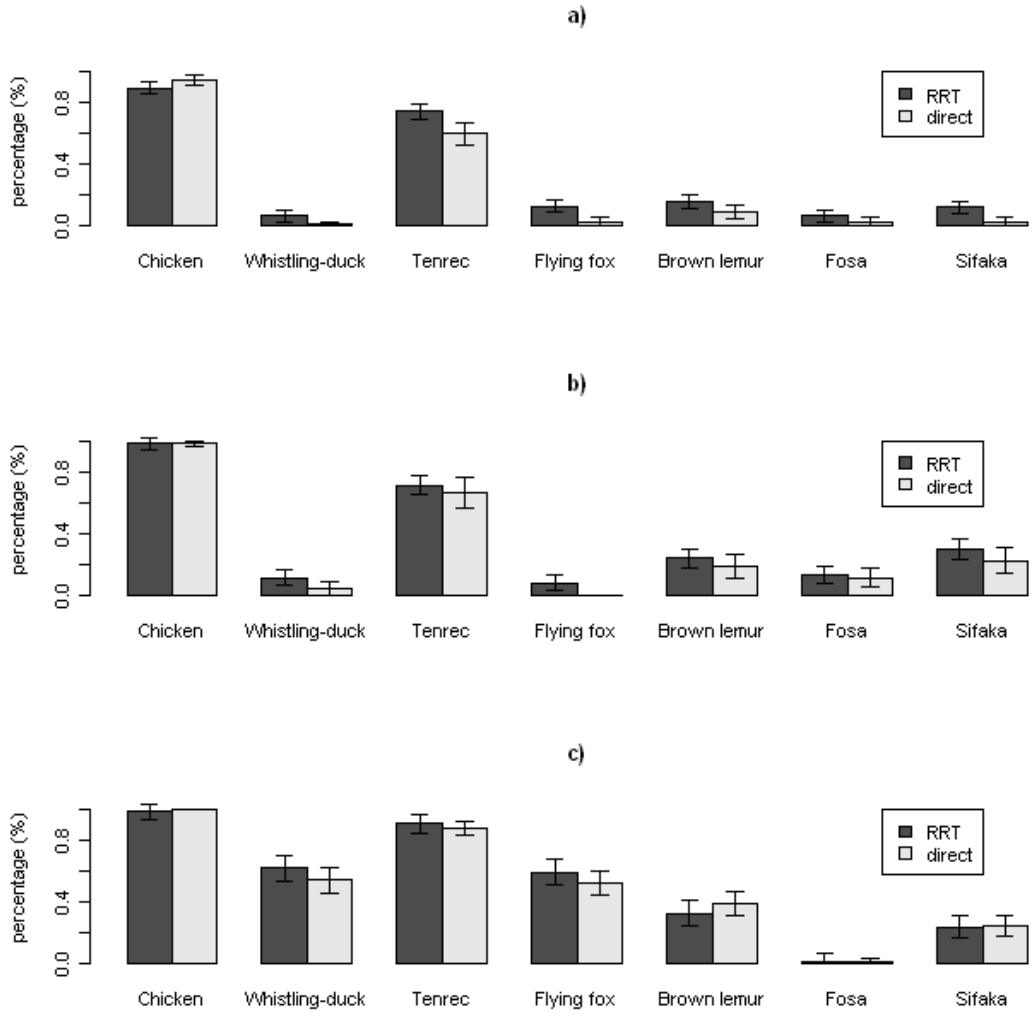

Figure 3: Estimated proportions of respondents who have consumed each of seven species in the last year. Error bars show 95% confidence intervals. a) Sensitive communes in eastern Madagascar (Andasibe and Ambatovola), n=761. b) Non-sensitive commune in eastern Madagascar (Lakato), n=442. c) Communes in western Madagascar (Mahabo and Ampanihy), n=371.

This study offered the opportunity to test RRT with many more people over a large area and with quite different backgrounds. We always trained a local assistant (from the village concerned) to work with the research team (all Malagasy and in most cases at least one member was from the region concerned) to explain the method to participants. We found this extremely beneficial and on the odd occasions where a member of the research team attempted to explain the method it was much less well understood and needed 'interpreting' by the local field assistant. Even with this local explanation, some people, particularly older,

less literature people struggled to understand the method. A small percentage of people reported being annoyed by the method and suggested that we want to know something that we just ask, rather than complicate things. In one area where we worked (Tsingina) we found that respondents were particularly confused by the RRT method and seemed irritated by it and we eventually had to abandon it. Having said this, in the areas for which we present data above, the majority of people did appear to be comfortable with the method and understood it well. However, for most species in most sites, reported levels of consumption were similar under RRT and direct questions. We believe this is because the majority of rural Malagasy are not aware of the nations wildlife laws (Keane et al 2011) making bushmeat consumption not particularly sensitive. Only where there had been extensive conservation interventions and training about wildlife laws, did RRT reveal higher levels of consumption than direct questions.

Part 1 summary:

As with other comparative studies (Donovan et al. 2003; Scheers and Dayton 1987; Silva and Vieira 2009; Solomon et al. 2007), we found that RRT returned significantly higher estimates of non-compliance than the conventional questionnaire where questions were sensitive. This suggests that whilst anonymity may increase reporting, other mechanism can further increase the validity of sensitive data. RRT however has two principal disadvantages compared to conventional methods: 1) the method adds random noise to the data (due to the forced YES and NO responses), therefore large samples are needed to obtain estimates with acceptable errors (Lensvelt-Mulders et al. 2005) and 2) it can only work if respondents understand the protection offered. Certain groups of respondents may simply not understand the method-reducing its value. We conclude that if the topic under investigation is sensitive, the compromise in efficiency is compensated for by the apparent increase in data validity

(Lensvelt-Mulders et al. 2005). However researchers should be aware that the method may not be suitable for use with all respondents.

Part 2: Can simpler, non sensitive indicators of sensitive behaviour be identified?

Part 1 above has suggested that RRT, when properly explained to respondents, is a useful method for investigating illegal behaviour in the context of conservation or natural resource management. However, it needs a large sample size because of the noise introduced by the randomising device, and it can be difficult to explain to respondents. It would therefore be valuable if non-sensitive indicators of sensitive behaviour could be identified.

A number of studies have looked at people's attitudes towards species, habitats or management interventions, assuming that attitudes are useful indicators of behaviour (Holmes 2003; St John et al 2010b). However the evidence for attitude being a reliable and useful indicator of behaviour is mixed. For example, participants in a conservation project in Uganda, help more positive attitudes towards wildlife than people who had not been targeted by the project, but there was not evidence that this has any influence on their involvement in poaching and incursion into the protected area (Infield & Namara 2001). Many such studies exist which do not ensure that the attitudes investigated were clearly connected to the behaviours of interest (St John et al 2010b). As a result, there is still a lot of debate as to whether attitudes can be used as an indicator of behaviour.

Petroczi et al. (2008) suggested that the psychological bias known as the false consensus effect could also be used as an indicator of sensitive behaviour. The term 'false consensus' describes the tendency people have to imagine that others are more like themselves than they

really are, meaning that people tend to estimate the population-level prevalence of an activity to be high if they themselves are involved (Ross et al. 1977). Although this has been investigated in a public health context (Sherman et al 1993), the potential application of the false consensus effect to natural resource management has not been explored.

To test the effectiveness of an indicator, an accurate assessment of whether someone has carried out the sensitive behaviour is needed. We build on the work described above which validates the use of the RRT for investigating sensitive behaviour. We then use a case study of human-wildlife conflict in South Africa to investigate whether attitudes and the false consensus effect and can be reliable indicators of involvement in sensitive behaviours.

Habitat loss and has resulted in people living in proximity to wildlife in many parts of the world and resultant conflict over economic wellbeing and security (Treves & Karanth 2003). Carnivores are pre-disposed to conflict with humans due to their large home ranges and diet, (Inskip & Zimmermann 2009). Many countries have legislation protecting carnivores (Agarwala et al. 2010) but carnivore persecution continues to be a conservation problem in many parts of the world (Woodroffe et al. 2007). Illegal carnivore persecution has been measured indirectly in different ways (Hedmark & Ellegren 2005; Linkie et al. 2003), but such indirect methods tell us little about the characteristics of the people persecuting carnivores making it difficult to target interventions to reduce the problem.

In this study we first use RRT to estimate the proportion of South African farmers in north-eastern provinces killing five carnivore species and performing two illegal behaviours: failing to hold a valid permit to kill a protected carnivore; and using poison (without a permit) to kill carnivores. Secondly we adapt the logistic regression model to incorporate the known

probabilities of the forced RRT responses (van der Hout & Kooiman 2006) and use this to investigate individual predictors of carnivore killing focusing on farmers': attitude towards the existence of carnivores on ranches and estimated prevalence of carnivore persecutors. This allows us to quantitatively investigate the usefulness of these non-sensitive indicators of sensitive behaviours for the first time.

Part 2 case study: human carnivore conflict in south Africa

South African cattle and game farmers have commercial interest in protecting their stock from carnivores and in this context some carnivores are killed because they are thought to have predated stock (Lindsey et al. 2005). The South African Biodiversity Act of 2004 aims to protect certain species including the near threatened (IUCN 2010) brown hyena (*Parahyaena brunnea*) and leopard (*Panthera pardus*) but a permit can be obtained to control species covered by this Act (e.g. by shooting or poisoning) if they are causing damage to stock or pose a threat to human life Department of Environmental Affaires and Tourism 2007). Failure to comply with the Act can attract a fine of up to R100, 000 (~ $15,000) or three times the commercial value of the specimen concerned, up to five years in prison, or a combination of fine and imprisonment. Snakes (except for the Gaboon adder (*Bitis gabonica*) and African rock python (*Python natalensis*)), black-backed jackal (*Canis mesomelas*) and caracal (*Caracal caracal*) are not protected under the Act but they are included in this study to introduce variability into the sensitivity of behaviours under investigation. All five carnivore species are widely distributed across the study area (Friedmann et al. 2002).

Part 2 Data collection

The survey was piloted on colleagues and improved before a formal pilot of 16 farmers from cattle, game and mixed stock farms at game auctions in north-eastern provinces of South

Africa. No further improvements were necessary so the pilot data from farmers (n = 16) were included in the final analysis. Surveys were administered to a total of 99 farmers at cattle and game auctions in north-eastern provinces between May and September 2010 by FAVStJ and Lauren Jones. RRT questions referred to the last 12 months to minimise recall inaccuracy whilst also allowing an adequate time for the behaviour to have occurred.

Each respondent was asked, using forced response RRT to respond to questions about whether they had killed each of 5 named species in the last year on their ranch. Attitude statements were target, action, context, and time specific (Conner & Sparks 2008). Using a five point Likert scale respondents were asked to indicate their level of agreement with two attitude statements (a) ‘These days (time) I think that jackals (target) should be killed (action) on ranches (context)’ (attitude towards killing); and (b) These days I think that killing jackals on ranches is wrong’ (attitude towards conserving). Both attitudes statements were completed for each of the five carnivores (ten statements in total). The statements were reverse scored, agreement with ‘should be killed on ranches’ scored -2 [strongly agree] to +2 [strongly disagree], whilst agreement with ‘killing is wrong’ scored +2 [strongly agree] to -2 [strongly disagree]; meaning that lower scores corresponded to attitudes that are less favourable to conserving carnivores on ranches. To investigate the relationship of prevalence estimates with reported behaviour respondents were asked to state, how many farmers out of ten in the province, they thought had undertaken each of the seven behaviours presented in the RRT questions in the last 12 months.

Part 2 Data analysis

Data were analysed using R version 12.2.0. To examine the relationship between respondents' reported behaviour concerning each carnivore (their RRT responses) and their attitudes and

perceptions, we fitted a generalised linear mixed model (GLMM) with a binary response and binomial error distribution. The grouping structure of the data, whereby each respondent answered questions about several species, was reflected in the model by including individual respondent IDs as a random effect. Species, attitude towards killing the species, attitude towards conserving the species, perceived question sensitivity, beliefs about the existence of sanctions, and estimated prevalence of persecutors were all considered as potential fixed effects within the model.

Prior to modelling, Likert scale data were checked for internal consistency using Cronbach's alpha coefficient (Nilsen et al. 2007, Santos et al 1999), and correlation coefficients were calculated for each pair of variables using Spearman's correlation. Strongly correlated predictor variables were removed to avoid problems of multicollinearity.

Models with binary responses typically employ a logistic link function. However, simple logistic regression is not appropriate for RRT data because the forced responses introduce bias and additional variability into the data. We therefore wrote a customised link function which incorporated the known probabilities of the forced RRT responses (van der Hout & Kooiman 2006). The resultant model was:

$$\log\left(\frac{\pi - \theta}{\theta + s - \pi}\right) = \alpha_j + \beta_1 x_1 + \cdots + \beta_N x_N,$$

where α_j is the common intercept term for responses given by individual j, $\beta_{N,i}$ is the coefficient for the Nth covariate and x_N is the vector of values for the Nth covariate.

The model was fitted by penalised quasi-likelihood (PQL) using the glmmPQL function from the MASS package, which readily accepts user-defined link functions 9Venables & Ripley 2002). PQL is a flexible approach which allows approximate inference in GLMMs [40], and has been widely applied (Bolker et al. 2009). However, the use of quasi-likelihood precludes standard likelihood-based approaches to model selection, such as Akaike's Information Criterion (AIC) and likelihood ratio tests, and in some circumstances it is known to produce biased estimates (Breslow 2003). Consequently, we adopted the following model selection procedure. First, we fitted a series of generalised linear models (GLM) for all possible combinations of predictors for each carnivore separately. The fit of these models was assessed using AIC (Burnham & Anderson 2002), and the structures of the best-fitting models were used as a basis for choosing the fixed effects structure for a GLMM incorporating all species. Finally, the parameter estimates from the GLMM were compared with those derived from the separate species' GLMs as a simple check to rule out the presence of large biases.

Part 2 Results and discussion

For all questions where responses were recorded on a Likert scale, Cronbach's alpha coefficient was above 0.7 showing high internal consistency (Santos 1999). Cronbach's alpha was 0.795 (n = 98) for the attitude statements about killing each species; and 0.882 (n = 97) for attitude statements about conserving each species.

Ninety-nine farmers completed the survey. Most farmers were aware that there was no penalty for killing most snakes (87%, n = 83), jackal (85%, n = 82) and caracal (59%, n = 57), and most were aware that there was a penalty for killing brown hyaena (60%, n = 56) and leopard (88%, n = 84).

Due to the low prevalence of farmers killing brown hyaena we did not carry out modelling for this species. Preliminary examination of the data showed the two attitude statements to be correlated (Spearman's rank coefficient r_s = 0.60, p = <0.001), so to avoid issues of multicollinearity, the variable representing attitude towards conserving the species was excluded from further analysis; respondents' beliefs about the existence of sanctions correlated with their estimated prevalence of persecutors (Spearman's rank coefficient r_s = 0.47, p = <0.001) and was also discarded. Visualisation of the remaining predictors suggested that their effects were approximately linear, so for parsimony we modelled them as continuous rather than categorical variables.

Agreement with the attitude statement (I think the species should be killed on ranches), and question sensitivity were negatively and significantly related (t = -3.326, df = 247, P = 0.001; and t = -2.063, df = 247, P = 0.04 respectively); whilst estimated prevalence of persecutors was positively, but not significantly related (t = 1.478, df = 247, P = 0.140) to the likelihood of admitting to killing any given species.

Scenarios simulated from the fitted model illustrate the relative strength of each indicator (attitude, question sensitivity, and estimated prevalence of persecutors) at distinguishing differences in whether farmers kill carnivores. Results suggest that attitude is the most useful indicator for distinguishing between groups of farmers who are more, or less likely to have killed carnivores. Although those who believe that many of their peers have killed carnivores are more likely to have killed carnivores themselves, the indicator would provide less information for distinguishing carnivore killers. Farmers that estimated that all other farmers kill carnivores, have the attitude that the species should be killed on ranches, and who think

473 the RRT questions are not at all sensitive are significantly more likely to admit to killing
474 carnivores than farmers that reported the opposite in responses.
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476 By adapting the logistic regression model to incorporate the known probabilities of forced
477 RRT responses, we were able to investigate individual predictors of carnivore killing. A
478 number of studies have investigated people's attitudes towards carnivores (Lindsey et al.
479 2005; Nilsen et al. 2007; Bagchi & Mishra 2006, Zimmermann et al. 2005; Oli et al. 1994)
480 but none have previously investigated the relationship of these attitudes with peoples
481 conservation-related behaviours, e.g. killing of protected species. A farmer's negative
482 attitudes towards a carnivore as a result of stock loses, may be mitigated by offering
483 compensation for losses (Agarwala et al. 2010), but if the negative attitudes never resulted in
484 farmers persecuting protected carnivores then such interventions may be considered a poor
485 conservation investment. Incorporating attitude as an indicator of behaviour into our GLMM
486 allowed us to investigate directly whether farmers' attitudes towards the existence of
487 carnivores on their ranches reflect their reported behaviour. Results suggest that farmers who
488 hold the attitude that carnivores are pests and should be killed on ranches (negative
489 conservation attitude) are indeed more likely to have admitted to killing carnivores in the last
490 12 months. By carefully specifying attitude in terms of a target, action, context and time scale
491 of the behaviour (St John et al. 2010b) we did find that attitude can be a useful indicator of
492 behaviour.
493
494 The positive relationship between estimated prevalence of persecutors with the likelihood of
495 killing carnivores supports the existence of the false consensus effect (Ross et al. 1977),
496 whereby people who engage in socially undesirable behaviours provide higher estimates of
497 the prevalence of that behaviour in the population, than do people not engaging in the

behaviour (Monin & Norton 2003). Our data supports the suggestion by Petroczi et al. (2008) that asking respondents to estimate the proportion of people in the population that they think perform sensitive behaviours, offers some potential in identifying groups of people who perform sensitive behaviours.

Final conclusions

Human behaviours such as illegal hunting, fishing, wildlife trade, or killing due to human-wildlife conflict can be important threats to biodiversity, making understanding and influencing such behaviours an essential part of the solution. Rule-breaking in conservation has been quantified indirectly in many different ways: transects recording timber removal and snaring within forests (Olupot et al. 2009); satellite imagery of deforestation rates (Steininger et al. 2001); comparison of fish landing statistics with processing plant production (McCluskey and Lewison 2008); survey of snares and bushmeat markets (Noss 1998); and analysis of stock-piled ivory against seizures of illegally traded ivory (Sharp 1997). The merits and limitations of some methods of indirectly measuring illegal resource extraction have been discussed by Gavin et al. (2010). Whilst each of these methods provides an insight into the levels and impacts of illegal resource extraction, they tell us little about the characteristics of rule breakers. This has direct management implications with respect to designing interventions to improve compliance. In the absence of direct knowledge of rule breakers, managers have a limited ability to target interventions to change their behaviour, for example through awareness schemes or through targeted enforcement activities. With limited resources available to manage natural resources worldwide, ways to improve the efficiency of management interventions should be explored. To this end, improving the way in which we gather direct data on rule breaking can play an important role.

When the subject of a survey is sensitive, as is the case with illegal bushmeat consumption or carnivore persecution, it is naïve to expect that respondents will provide honest responses when asked questions directly. The randomised response technique allows researchers to gain more accurate estimates of sensitive behaviours and we have shown that it can be adapted in order to identify indicators of behaviour. RRT is not appropriate is all situations and we suggest that the results reported here provide evidence that carefully specified attitude statements and people's estimates of the prevalence of sensitive behaviours in the population (the False consensus effect) may be useful as simple and cost-effective indicators of an individual's involvement in illicit behaviours. Such information can be used to identify groups of people to engage in behaviour-change interventions.

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