

TITLE

The role of psychology in determining human-predator conflict across southern Kenya

ABSTRACT

Conflict between people and carnivores leads to the widespread killing of predators in retaliation for livestock loss, and is a major threat to predator populations. Whilst this problem is international in scale, certain regions encapsulate the issue; in Kenya, a large, rural, pastoralist population comes into regular conflict with predators, which persist across southern Kenya. This paper uses a novel survey approach to explore the psychological elements of human-predator conflict, comparing various sites across the south Kenya landscape. We show that individuals' livestock management efficacy varies, both between and within communities, and that this variation is partially explained by normative and control beliefs regarding livestock management. Moreover, we show individual livestock managers' self-reported management issues are often an accurate reflection of their practical management difficulties. By comparing various aspects of psychology and behaviour, we document between-site differences in the patterns associated with conflict, and demonstrate that a one-size-fits-all approach to improving livestock management and reducing human-predator conflict is not suitable. This paper will present methods for exploring the social and psychological backdrop to livestock management practices in a process that is designed to be easy-to-use, and suitable across regions for the study of conflict and transboundary implementation of conflict reduction measures, with a significant focus on community involvement and needs.

INTRODUCTION

Human-wildlife conflict is a multi-disciplinary problem (Thirgood & Redpath, 2008), and successful conflict mitigation draws on fields from education (Espinosa & Jacobson, 2012) to economics (Nyhus et al., 2005). Social science disciplines often inform conservation, but can be misused or underutilised (Bennett et al., 2016). Recently, particular awareness has focussed on the need for social psychology to be more widely integrated into conservation science (Selinske et al., 2018). This is especially true for human-wildlife conflict issues, where psychology influences tolerance (Bruskotter et al., 2015; Kansky et al., 2016), and conflict behaviour (Beedell &

Rehman, 2000). Thoughtful applications of psychology to conservation have shown that, for example, behavioural control can predict hunting behaviour (St. John et al., 2017); and social motivations are important determinants of conflict behaviour (Marchini & Macdonald, 2012). The discipline of psychology offers powerful insights into various conservation problems, not least human-wildlife conflict, and may provide a useful perspective for understanding and developing tools to address conflict issues.

While environmental psychology is well established, emerging as a sub-discipline in the 1950s, the concept of conservation psychology is more modern. The term appeared in the late 1990s, defined as the study of 'relationships between humans and the rest of nature, [focussing] on how to encourage conservation' (Saunders, 2003). Psychological components are often central to frameworks for understanding human-wildlife conflict (Kansky et al., 2016; Kansky & Knight, 2014), but there is increasing focus on using explicitly psychological theories to understand conservation problems. The most widely applied of these psychological models is Ajzen's (1991) theory of planned behaviour, which argues that social norms, individual agency, and attitudes determine an individual's behaviour (Figure 1; Fishbein & Ajzen, 1975; Ajzen, 1991). The theory of planned behaviour has been used to understand numerous human-wildlife conflict problems, from light pollution around turtle nesting beaches (McDonald et al., 2014), to farmers' wildlife management behaviour (Beedell & Rehman, 1999). Wider application of the theory of planned behaviour is likely to prove useful in understanding and developing approaches to reduce conflict.

Many instances of human-wildlife conflict occur in agricultural and pastoral systems; these issues are notably severe in sub-Saharan Africa, where agricultural systems are being extended alongside relatively intact megafauna assemblages (Sillero-Zubiri & Switzer, 2001). For livestock producers, predators can be major sources of livestock loss (Ogada et al., 2003; Kuiper et al., 2015). The costs of livestock predation are high for smallholders (Muriuki et al., 2017; Holmern et al., 2007) and even where actual costs are small, perceived loss can cause high levels of conflict between livestock owners and predators (Kozierski et al., 2016). Various approaches to conflict-reduction have been attempted: bomas or kraals (overnight livestock pens, of variable quality) can be supplemented with vegetation (Lichtenfeld et al., 2015), chain link mesh (Sutton et al., 2017) or flashing LED lights (Lesilau et al., 2018). Livestock-guarding dogs (Marker et al., 2005) and general improvement in husbandry practice (Hazzah et al., 2014) have also been shown to reduce losses. But none of

these approaches are completely effective, nor have they been rigorously tested across different sites (van Eeden et al., 2018). Even where evidence-based strategies have been implemented, problems remain: enabling or motivating livestock owners to act on these recommendations is a consistent barrier to reducing conflict (Loveridge et al., 2010).

If poor management practices exacerbate human-wildlife conflict, understanding the psychology of livestock management may be key to encouraging improved husbandry. In this paper, we use a theory of planned behaviour model to explore the factors influencing livestock management performance. At its core, the theory of planned behaviour separates three distinct psychological components: normative beliefs – perceptions regarding the social appropriateness of behaviours (Ajzen & Fishbein, 1972); control beliefs – beliefs regarding an individual's agency over behaviour or outcomes (Ajzen & Driver, 1991); and attitudes – an individual's judgements about an object (Katz & Stotland, 1959). Separating these components has proven useful for behaviour change interventions, notably in health behaviour (Calan & Rutter, 1986; Conner & Sparks, 2005), so we employ the same approach. We use an additional psychological module to explore motivation, following on from the work of Pinder (1984) in industrial psychology. If a 'psychological landscape' can be defined as 'the suite of attitudes, beliefs, and intentions an individual possesses in relation to a particular object, problem, or behaviour', we expect these landscapes to have a strong influence on an individual's conflict-related behaviour (Daigle et al., 2002; St. John et al., 2018). In this paper, we ask how different components of individuals' psychological landscapes correlate with their livestock management performance, and how these factors vary locally, with a view to developing focussed conservation interventions.

Southern Kenya experiences high levels of human-predator conflict, which varies across the region (Hazzah et al., 2009; Schuette, 2012). Communities, who are generally traditional Maasai pastoralists, are highly dependent on livestock, making the area suitable to study patterns and variation in livestock management psychology. We wished to explore how these psychological landscapes related to human-predator conflict across southern Kenya. Higher standards of perceived norms – i.e. expectations of the behaviour of friends and neighbours – were expected to associate with better individual management performance. Various NGOs are highly involved with the communities we surveyed, so we expected control beliefs – individual agency over management standards – to have relatively little effect on the outcomes, as most individuals are thought to

have access to the resources required to perform livestock care. We also expected livestock managers' motivation to positively correlate with performance.

We created a survey with the following objectives:

- a. To determine the structure of normative beliefs, control beliefs, attitudes, and motivation in livestock-owning communities in southern Kenya;
- b. To study the relationship between psychological landscapes and livestock management, specifically whether more positive psychology or components thereof promote better management;
- c. To explore whether livestock management behaviour explains differences in livestock predation.

METHODS

2.1 Study areas

Research was conducted across three sites in southern Kenya (Figure 2) between March and November 2018. Sites are part of a contiguous trans-boundary arid rangeland system, which extends across southern Kenya and northern Tanzania, and wildlife is free to move across much of the landscape. The region has resident populations of lions (*Panthera leo*), leopard (*Panthera pardus*), spotted hyaena (*Crocuta crocuta*), and cheetah (*Acinonyx jubatus*) (Bauer et al., 2016; Stein et al., 2016; Bohm & Höner, 2015; Durant et al., 2015).

The South Rift, in Kajiado county (36.21°E, 1.58°S) consists of two Maasai group ranches (GR): Shompole and Olkiramatian. Land is communally owned, with ~200km² segregated as a community-managed conservation area (Western, 2017). Livestock management is traditional and for subsistence; both shoats (mixed herds of sheep and goats) and cattle are present at moderate-to-high densities (Schuette, 2012).

The Amboseli area, in Kajiado county, includes Amboseli National Park and six GRs, across which >75% of the population derive their livelihood from livestock (Manoa & Mwaura, 2016). Work was conducted on two Maasai GRs, Mbirikani (1,229km², 37.59°E, 2.51°S) and Rombo (~520km², 37.7°E, 2.9°S). Livestock husbandry is largely traditional (MacLennan *et al.*, 2009), and a fund exists on Mbirikani to provide recompense for livestock predation. Although there are some differences between GRs, social, cultural, and conflict

backgrounds are similar, so the Amboseli area was considered a single study region (Amboseli Ecosystem Management Plan 2008-2018).

The Tsavo ecosystem, in Taita Taveta County, covers two large national parks and the Kasigau Carbon Credit REDD+ project. Surveys were conducted in the Voi region (38.7°E, 3.4°S), which is surrounded to the North, West and South by National Parks. Both communally owned and private ranches are present in the area, with 14 of 28 smaller ranches involved in the REDD+ project.

2.2 Survey participants and collection protocol

Survey protocol was approved by the University of Oxford Social Sciences and Humanities Interdivisional Research Ethics Committee (Reference No. R53944/RE001). Key regions and core communities (those most typical of each region) were identified through discussion with NGOs and local people. We concentrated on the core communities in each region, and chose not to include responses from more widely dispersed – and less typical – community members. Once key regions were identified, research assistants were each allocated a study area. Choice of participants within these regions was opportunistic, through door-to-door surveying or interactions at communal locations e.g. markets. Study participants were livestock owners or managers over the age of 16. Only individuals who were the head of a household or directly responsible for herding/managing livestock were surveyed. Questions were translated into Maa and Kiswahili via a group discussion process, with translate-retranslate methodology where there was poor consensus over the translation. Each survey was administered as a face-to-face interview by local research assistants. Responses were recorded using the Qualtrics offline survey application (Qualtrics, 2015), a survey platform designed to be used as an app. Pilot surveys were timed, and a minimum realistic duration measured; as most questions followed an identical format, participants were able to respond rapidly, and the minimum survey duration was set at 20 minutes. Surveys that took less than this minimum response time were excluded from analysis. Overall, 207, 286, and 230 usable surveys were collected from the South Rift, Amboseli and Tsavo, respectively.

2.3 Survey design

In psychology, underlying explanatory variables – psychological constructs – are not directly observable, so surveys use multiple questions on the same theme as proxies for these underlying constructs. Our survey

(Supplementary Materials) consisted of ~175 questions, although the exact number varied, as question inclusion was contingent on previous answers. The survey was split into six modules:

1. Social and demographic properties (n = 19 questions) – age, education, positions of leadership etc;
2. Livestock management practices (n = 31) – herding, kraaling, veterinary care etc;
3. Normative beliefs (n = 31)– perceptions regarding the social appropriateness of behaviours;
4. Control beliefs (n = 16) – beliefs regarding an individual’s agency over behaviour or outcomes;
5. Attitudes (n = 31) – an individual’s judgements about an object, including emotional and cognitive components;
6. Motivation (n = 18) – the willingness of managers to carry out livestock-related activities.

Most responses used 5-point Likert scales: ‘Strongly agree’, ‘agree’, ‘neither agree nor disagree’, ‘disagree’, and ‘strongly disagree’, although some questions employed different 5-point scales (e.g. ‘extremely likely’ to ‘extremely unlikely’). As Likert scales operate in a non-linear, ordered manner, analysis requires ordinal approaches.

2.4 Data analysis

We wished to explore the psychological landscape of livestock managers, and to understand the relationship between psychology and livestock management standards. All analysis was carried out using the free statistical software R, version 3.5.1 (R Core Team, 2018). To explore the psychological landscape required metrics that captured different components of individuals’ latent beliefs. As these properties cannot be measured directly, we used Exploratory Factor Analysis, a form of Principal Components Analysis (R packages: ‘psych’, Revelle 2018; and ‘lavaan’, Rosseel 2012) to identify clusters in the survey responses for each of the six modules; each cluster was treated as a proxy for an underlying psychological factor (an approach common in psychology studies, e.g. Andriotis & Vaughan, 2003). Only the subsets of survey questions that gave clustered responses were used for further analysis. Using the theoretical background employed in survey design, we developed two to three psychological factors for each module (Table 1). Confirmatory Factor Analysis was carried out on each of these factors (n = 12), to test how the measured variables represented underlying psychological constructs (Floyd & Widaman, 1995). To test the fit of all factors to each of the six modules, we used the Comparative Fit Index (CFI), Standardised Root Mean Square Residuals (SRMSR) and Root Mean Square Error of Approximation (RMSEA) (Hooper et al., 2008). To test the internal validity of each individual factor,

Cronbach's alpha was used (Table 1); because we were not aiming to measure one specific property, but rather form a broad psychological overview of particular topics, a low alpha threshold of 0.5 was chosen. Two factors failed to reach this threshold and were omitted from further analysis. Having established the structure of factors within each module, and the validity of individual factors, we created variables from these constructs for use in analysis. Each factor contained between two and eight survey questions; to be used as an explanatory variable in the model, it was necessary to compile these responses into one metric for each factor. As all questions were scored on the same five-point scale, the responses were summed to create a single equally weighted numeric value for each factor. These numeric measures were then converted into a two- or three-level ordered qualitative score (poor; \pm mid; good), depending on the variation in the metric (Table 1).

To create a model exploring psychology in relation to livestock management performance, we needed a response variable for performance. A composite measure of self-assessed performance was created by combining Likert scale responses to questions concerning good livestock management behaviour, including measures of boma use; herding practices, veterinary care; livestock loss in the 12 months prior to surveying; and other indicators of good management. This metric produced an approximately normal distribution, showing that the composite reflected variation in livestock management performance (Figure 1, Supplementary Materials). This metric was converted into categorical response with three levels (poor, mid, good), with approximately the same number of samples in each category. A second management performance metric, which excluded terms for livestock losses, was created to evaluate the effect of management practice on losses. We wanted to include a term for affluence in the model; as the study communities are largely outside monetary economies, we again needed a composite measure. This composite included numerous variables to measure relative affluence in rural communities e.g. regularity of meat eating, number of wives (Supplementary Materials).

Overall, we had 12 separate psychological factors (Table 1), 'site', and 'affluence' variables. Because it was possible for these factors to have interdependence, correlation tests were run for all variables using R package 'arm' (Figure 2, Supplementary Materials). Two pairs of factors were found to be highly correlated (> 0.68), so the factor in each pair with the lowest Cronbach's alpha was dropped from further analysis. This left eight psychological factors (Table 1), 'site', and 'affluence' as variables. To understand the influence of each of the

ten variables on livestock management performance, we carried out an ordinal (for non-linear Likert responses) logistic regression analysis. Akaike's Information Criterion was used to distinguish the best-fitting combinations of explanatory variables. Interaction terms were not included as we had no prior reason to expect interactions between the variables. All combinations of the explanatory variables were tested. Models with $\Delta_i \leq 2$ were considered to have substantial support (Burnham & Anderson, 2004). Conditional model averaging of this subset of models using R package 'MuMIn' was used to create the top overall livestock management model, and one for each of the three sites. Plots were created using R package 'effects.' To test whether livestock management influenced differences in predation outcomes, we used a t-test and a generalised linear model, using a Poisson distribution, to compare count data of livestock losses and our management composite.

RESULTS

Descriptive Results

Across the region, the median household had six to ten cows and 21-50 shoats. Self-reports of livestock management behaviour indicated that most participants regularly – but not always – implemented good practices, e.g. bringing animals into a boma overnight, or herding during the day. Most households (94.9%) had access to a boma. Herders were commonly used, with unpaid adults, paid adults, and children primarily used by 45.0%, 34.9%, and 20.2% of households, respectively. Labour, including herders, was hired by 42.0% of households, and 50.0% of households provided supplementary feed for animals. Veterinary care was uncommon and 52.6% of households used no veterinary services. Combining all sources of mortality in the previous year, livestock deaths were a mean of 5.67 (± 16.9) cows and 15.6 (± 46.4) shoats per; this was unusually high because of a severe drought.

In the 12 months prior to the survey 40.8% of households reported livestock predation, and 42.2% of households had livestock predated while in a boma. During this period, mean household livestock depredation was one cow (± 3.7) and 4.1 shoats (± 9.6); however only 21.7% and 37.8% of households experienced

depredation of shoats and cows, respectively, so mean losses for each affected household were much higher, at 4.6 (± 6.7) cows and 10.8 (± 13.1) shoats.

Analytical Results

We explored how psychological factors affected livestock management behaviour, including the relative contribution of different factors, and whether these factors were the same across sites. Our preconceived factor structures were an acceptable fit to the latent psychological constructs (Normative beliefs: CFI = 0.97; SRMSR = 0.0027; RMSEA = 0.049; control beliefs: CFI = 0.69; SRMR = 0.095; RMSEA = 0.105; attitudes: CFI = 0.76; SRMR = 0.081; RMSEA = 0.087). Twelve AICc models were within $\Delta_i \leq 2$ and were considered top models (Table 2). Livestock management behaviour was affected by site and affluence, with all of the 12 best models containing both terms. Overall, normative and control factors appeared particularly important: two control factors were generally retained by each model (management difficulty, $n = 12$; management agency, $n = 10$), although management performance was less important ($n = 5$). Most models also had one normative factor (normative behaviour, $n = 8$; normative perceptions, $n = 3$). The only attitude factor retained by any top model was positive attitude ($n = 5$). The averaged model (Table 3) contained terms for site, affluence, normative behaviours and perceptions, all control variables, and positive attitude. There was strong evidence for a positive relationship between reported management difficulty levels and livestock management performance. Management performance was also positively associated with normative behaviours, and negatively associated with management agency, but these were only weakly supported (Figure 3). There was very strong evidence for effects of affluence (Figure 4) and site; to explore this further, we broke the analysis down by study site.

There were ten, six, and eight models within AIC $\Delta_i \leq 2$ for Tsavo, South Rift, and Amboseli, respectively, with no overlap in models between sites (Table 4). The averaged models contained different terms, ordered by importance:

1. **Tsavo:** affluence, normative perceptions, normative behaviour, management performance, positive attitude, and management agency.
2. **South Rift:** affluence, normative behaviour, management agency and difficulties, positive attitude, management performance, and normative perceptions

257 3. **Amboseli:** affluence, positive attitude, normative behaviour, management agency, and normative
258 perceptions.

259 For Tsavo, one or both normative terms appeared in 80% of the top models, falling to 66% and 50% for South
260 Rift and Amboseli, respectively. Control beliefs terms were present in 100% of models in South Rift, and 80% in
261 Tsavo, but only 38% of models in Amboseli. Management performance occurred in 80% of models in Tsavo,
262 compared to only 38% for agency and none for difficulties; by contrast, management agency and difficulties
263 were present in all South Rift models. Positive attitude was a term in all top models for Tsavo, but seldom
264 retained on other sites.

265
266 The index of livestock management behaviour was normally distributed across all sites. This index varied
267 significantly with predation outcomes, with livestock owners who experienced any predation of cows, shoats,
268 or donkeys in the previous 12 months having a lower management behaviour score than those who
269 experienced no predation (t-test, $p = 0.0019$). Our generalised linear regression revealed a small but significant
270 relationship between livestock management behaviour and livestock predation ($p = 0.036$; Figure 3,
271 Supplementary Materials).

273 DISCUSSION

274 Overall Findings

275 We show that various psychological constructs can partially explain differences in predation outcomes for
276 livestock managers in southern Kenya. Normative belief factors consistently appeared in averaged models,
277 with the behavioural norms factor approaching significance in the overall averaged model (Table 3). The
278 behavioural norms term contained questions on the livestock management behaviour of various groups, e.g.
279 'how many people in nearby communities manage their livestock well?'. We expected livestock managers to
280 assume their own management performance was average, i.e. poor managers assumed everyone else was
281 performing poorly etc. However, we found that as the normative behaviour score increased (i.e. as
282 respondents reported higher perceived standards in other groups), it became less likely that the respondent
283 themselves performed good livestock management (Figure 3a). This suggests respondents have an accurate
284 sense of their own relative performance: good livestock managers report relatively poorer performance in
285 other groups and vice versa. Although normative perceptions did not explain a large amount of variance, in the

low and mid-standard management classes there was a tentative positive correlation between performance and perceptions (Supplementary Materials, Figure 4) – so those people who thought their friends/elders/family valued good livestock management more deeply appeared to perform better. This needs further research, but if confirmed, community campaigns which highlight the local importance and value set by good livestock management may prove effective. We show that the lowest performers in a community are aware of their own position and may be susceptible to the influence of their peers, so psychology-based public opinion campaigns could prove a workable intervention.

Of the psychological modules, control factors appeared the most important, with management agency and difficulties (Table 3) featuring in the global model, although they were less consistent on a local level. The management performance variable (e.g. ‘to hire a herder for my livestock would be easy’) appeared in 80% of the models for Tsavo, whilst both management agency and difficulties appeared in all the South Rift models. Management difficulty (e.g. ‘to herd my livestock is difficult’) was the most important control term across sites, and was highly correlated with management performance (Supplementary Materials, Figure 5), i.e. those livestock managers who performed most poorly reported highest levels of difficulty, and vice versa. This term was designed to detect inability to access resources e.g. adequate fencing materials, so its significance in the model demonstrates that local people for whom there were barriers to good livestock management reported this proportionate to their need. Integration of local knowledge into landscape planning or ecosystem impact assessments is widespread (e.g. Kwiatkowski & Ooi, 2003) and increasingly common in conflict mitigation (White & Ward, 2011). Our findings confirm that variation in need within communities can be captured by a simple survey, and we suggest that identifying community sectors in need of support may help conservation interventions succeed.

Affluence was a highly significant term in both the overall and site-specific models (Figure 4), a similar finding to those of other studies (Zimmermann et al., 2005). As affluence increased, so too did the probability of better livestock management performance; this was true for all livestock management standards and sites. There were also major significant differences between sites, with no overlap in the top-ranking models for each site (Table 4).

Site-specific Findings

In Tsavo, normative terms for perceptions and behaviour were highly important. This was the only site not to include management difficulty in the averaged model. Our metric suggested that farmers in the Tsavo area had the highest management standard. This runs counter to our expectation: the Maasai have a long history of cattle management, but Tsavo is the least Maasai area, with a large influx of other ethnic groups over the past 30 years (Muriuki et al., 2011). The more sedentary approach to livestock management taken in Tsavo is fundamentally less risky than traditional Maasai husbandry, which may be reflected in the metric. Similarly, migrants who move to Tsavo to farm and choose to undertake this work may be expected to practice a very high standard of care. That normative terms were locally important could reflect the novelty or diversity of communities, with studies suggesting that conforming to norms can be relatively more important in recently formed or more varied communities (Schultz et al., 2008; Hogg and Reid, 2006).

In the South Rift, the averaged model contained normative behaviour, followed by management agency and difficulties. These control belief terms were more important here than elsewhere, with all three terms appearing. The management agency term measures respondents' sense of control over livestock management, e.g. 'if I wanted to, I could improve my kraal', whereas the management difficulties term measures the perceived difficulty of the same aspects of management, e.g. 'to bring my livestock into the kraal [...] would be difficult'. This was the only site where both agency and difficulties were important. Both factors had a positive relationship with management performance: actors who felt they had more control, and fewer difficulties, practiced more successful livestock management. Farmers in the South Rift had the most challenges to livestock management including low affluence levels, a serious drought the previous year, and high local density of predators in farming areas (Schuette, 2012). Livestock managers here have arguably the most difficult task, and the greatest risk of bad outcomes where management is poor; there may be a trade-off between the high productivity of large-scale mobility, and more difficult management. Agency and difficulties were relatively less important on other sites, so variation should be tested and, when high, targeted interventions implemented.

344 Amboseli is a world-famous National Park, and draws international attention (Kibicho, 2006). Consequently,
345 there are numerous conservation organisations working in the area. There was relatively little variation in
346 livestock management standards in Amboseli, and very little impact of control terms in the models; this may
347 suggest that most livestock managers' basic needs were being fulfilled. The most important psychological
348 model terms were positive attitude and normative behaviour, and both had positive relationships with
349 performance. The positive attitude term measured affective states, for example, 'how much does managing
350 your livestock make you feel content'. The importance of positive attitude in the models perhaps shows that
351 once serious threats to management have been removed, the individual preferences of livestock managers –
352 and interest in farming – become a much more important factor in their performance.

354 **Conclusions**

355 Interventions based on a psychological understanding of human behaviour have been practiced across a
356 growing range of disciplines, not least conservation (e.g. St John et al., 2017; Kinsky et al, 2016). We show that
357 various psychological constructs explain differences in the outcomes of livestock management in southern
358 Kenya, but that the most important psychological components vary between sites. This result demonstrates
359 that our survey maps psychological constructs that are relevant to human-predator conflict, and is therefore
360 useful for understanding conflict. Southern Kenya is a large area, and our results reflect differences across the
361 region, which suggests our approach may work across broad spatial scales. The inter-site variation we
362 document shows that assumptions about belief structure should not be made, and practitioners seeking to use
363 psychology to change behaviour must carry out local surveying to understand the psychological landscape of
364 their region. We call for wider implementation of both psychology in the study of human-wildlife conflict, and
365 comparative approaches similar to our survey. We show such surveys are able to capture site-specific nuances,
366 and may be key to providing fast, evidence-based information with which to tailor conflict-reduction
367 interventions.

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FIGURES AND TABLES

Figure 1: Diagram of psychological models. In figure **a.** a simplified depiction of the theory of planned behaviour, which suggests that attitudes, subjective norms and perceived behavioural control all inform behavioural intention, and in turn behaviour. In figure **b.** the study model, which considered the social and demographic background of participants in the design of the survey, and used a survey module on motivation to examine behavioural intention.

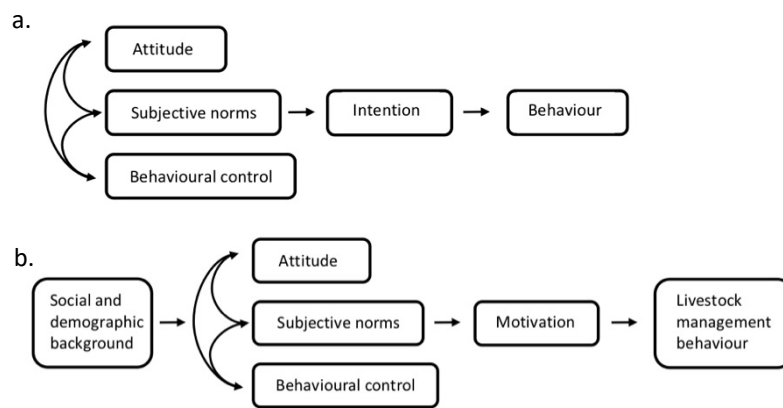
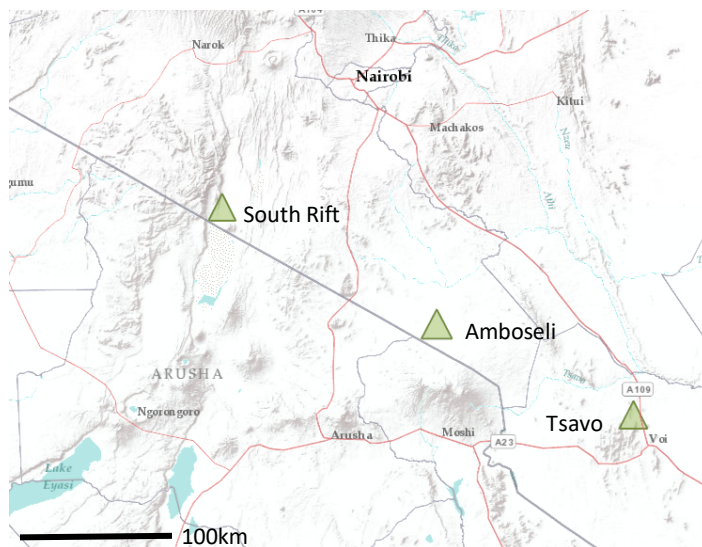


Figure 2: Map of study sites, southern Kenya. Green triangles indicate approximate study site areas.



567 **Table 1:** Psychological factor structures used in all models, with details on overarching psychological modules, specific factors, and factor properties.

Module	Factor ¹	Definition	Example ²	Properties	CFA ³	CA ⁴	Reference
Normative beliefs	Perception norms	Expectations regarding perception, i.e. how do people perceive the behaviour of others, and think others perceive their behaviour?	“My friends think it is important to herd their livestock during the day”	N=8 questions; levels = good, poor	CFI = 0.97 SRMSR < 0.01 RMSEA < 0.05	0.88	Ajzen and Fishbein, 1972
	Behavioural norms	Expectations of actual behaviour, e.g. how often does a respondent think a behaviour occurs?	“How many successful Kenyans [<i>do</i>] herd their livestock during the day”	N=3 questions; levels = good, poor		0.61	
Control beliefs	Management performance	How easy or difficult would the respondent find improving management behaviour?	“To improve my boma would be very easy”	N=3 questions; levels = good, mid, poor	CFI = 0.69 SRMSR = 0.095 RMSEA = 0.105	0.65	Ajzen and Driver, 1991
	Management agency	The extent respondents control management decisions and can perform those actions.	“ <i>If I wanted to</i> , I could improve my boma”	N=6 questions; levels = good, mid, poor		0.53	
	Management difficulties	Assessment of how difficult/easy the respondent finds carrying out a management behaviour.	“To kraal my livestock every night is difficult”	N=3 questions; levels = good, mid, poor		0.60	
Attitudes	Positive affect	Positive attitudinal response towards management activities.	“Livestock management makes me feel <i>calm</i> ”	N=3 questions; levels = good, mid, poor	CFI = 0.76 SRMSR = 0.081 RMSEA = 0.087	0.79	Katz and Stotland, 1959
	Negative affect	Negative attitudinal response to livestock management activities.	“Livestock management makes me feel <i>angry</i> ”	N=3 questions; levels = good, mid, poor		0.72	
	Self-assessment	Perception of the individual’s own livestock management skill.	“I am good at managing my livestock”	N=2 questions; levels = good, poor		0.62	
	Cognitive beliefs	Beliefs about good livestock management techniques.	“Employing an adult or trained herder is more effective [...] than using a child herder”	N=4 questions; levels = good, poor		0.67	
Motivation	Positive management properties	Positive aspects or perceptions of livestock management work.	“Livestock management gives me a lot of independence and freedom”	N=6 questions; levels = good, mid, poor	CFI = 0.96 SRMSR = 0.038 RMSEA = 0.056	0.77	Vroom, 1964
	Social importance	Perceived social importance of carrying out livestock management	“Livestock management allows me to provide everything my family needs”	N=2 questions; levels = good, poor		X	
	Outcome agency	The extent the respondent feels they control outcomes of livestock management.	“How I manage my livestock has a large effect on the number that are predated”	N=2 questions; levels = good, mid, poor		X	

¹ Factors in ***bold and italics*** passed all tests and were retained for the model; other factors were excluded.

² Italics added.

³ **Confirmatory Factor Analysis:** Tested using Comparative Fit Index (CFI), Standardised Root Mean Square Residuals (SRMSR) and Root Mean Square Error of Approximation (RMSEA).

⁴ **Cronbach’s Alpha.** Entries marked ‘X’ had low alpha scores, and were removed from subsequent analysis.

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572 **Table 2:** Top-ranking models ($\Delta AIC \leq 2$) exploring the influence of different combinations of psychological factors on livestock management performance, across three
573 study sites in southern Kenya.

Rank	Model	ΔAIC	Likelihood	Weight
1	site + affluence + behavioural norms + management performance + management agency + management difficulties + positive attitude	0	1	0.07850422
2	site + affluence + behavioural norms + management agency + management difficulties + positive attitude	0.09966627	0.95138817	0.07468799
3	site + affluence + behavioural norms + management agency + management difficulties	0.1629489	0.92175626	0.07236176
4	site + affluence + behavioural norms + management agency + management difficulties	0.36263363	0.83417104	0.06548595
5	site + affluence + management performance + management agency + management difficulties	0.91612722	0.63250724	0.04965449
6	site + affluence + management agency + management difficulties	1.00701582	0.60440673	0.04744848
7	site + affluence + behavioural norms management difficulties	1.57938852	0.45398358	0.03563963
8	site + affluence + management performance + management agency + management difficulties + positive attitude	1.66316402	0.43536	0.0341776
9	site + affluence + perception norms + behavioural norms + management performance + management agency + management difficulties + positive attitude	1.73176091	0.420681	0.03302524
10	site + affluence + perception norms + behavioural norms + management agency + management difficulties + positive attitude	1.78453302	0.40972605	0.03216523
11	site + affluence + management difficulties	1.85364192	0.39581001	0.03107276
12	site + affluence + perception norms + behavioural norms + management agency + management difficulties	1.87145603	0.39230016	0.03079722

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577 **Table 3:** Averaged AICc top model, showing the role of site, affluence, and psychological factors in determining overall livestock management performance on sites across
578 southern Kenya. Amboseli used as reference level for site.

Model term	Estimate	SE	z	P	
Site					579
South Rift	- 0.7509	0.2252	3.330	0.000869*	
Tsavo	1.9800	0.2595	7.620	< 2e-16**	581
Affluence	0.7333	0.1148	6.377	< 2e-16**	582
Perception norms	- 0.1331	0.2463	0.539	0.589605	584
Behavioural norms	0.2961	0.1679	1.760	0.078393	
Management performance	0.2512	0.1765	1.420	0.155467	586
Management agency	- 0.2785	0.1440	1.931	0.053442	587
Management difficulties	0.3357	0.1279	2.620	0.008803*	589
Positive attitude	- 0.1869	0.1314	1.419	0.155811	

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593 **Table 4:** Top-ranking models ($\Delta AIC \leq 2$) exploring the influence of psychological factors on livestock management performance on individual sites
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Site	Rank	Model	ΔAIC	Likelihood	Weight
Tsavo	1	affluence + perception norms + behavioural norms + management performance + positive attitude	0	1	0.07980199
	2	affluence + perception norms + behavioural norms + management performance + management agency + positive attitude	0.091662	0.955203	0.07622714
	3	affluence + behavioural norms + management performance + positive attitude	0.552712	0.758543	0.06053322
	4	affluence + perception norms + management performance + management agency + positive attitude	0.556993	0.756921	0.06040379
	5	affluence + perception norms + management performance + positive attitude	0.864038	0.649197	0.05180721
	6	affluence + behavioural norms + management performance + management agency + positive attitude	0.876462	0.645177	0.05148639
	7	affluence + management performance + management agency + positive attitude	0.962497	0.618011	0.04931853
	8	affluence + management performance + positive attitude	1.001155	0.60618	0.04837441
	9	affluence + behavioural norms + positive attitude	1.447126	0.485021	0.03870565
	10	affluence + perception norms + behavioural norms + positive attitude	1.500952	0.472142	0.03767785
Amboseli	1	affluence	0	1	0.10813489
	2	affluence + positive attitude	0.104113	0.949275	0.10264978
	3	affluence + behavioural norms	1.053143	0.590626	0.06386732
	4	affluence + management agency + positive attitude	1.194187	0.550409	0.05951841
	5	affluence + management agency	1.376443	0.502469	0.05433443
	6	affluence + behavioural norms + management agency	1.749429	0.416981	0.0450902
	7	affluence + perception norms + positive attitude	1.872798	0.392037	0.04239288
	8	affluence + perception norms	1.944084	0.37831	0.04090849
Shompole	1	affluence + behavioural norms + management agency + management difficulties	0	1	0.20546296
	2	affluence + behavioural norms + management agency + management difficulties + positive attitude	1.424047	0.49065	0.10081045
	3	affluence + management agency + management difficulties	1.442393	0.48617	0.09988997
	4	affluence + management agency + management difficulties + positive attitude	1.511295	0.469706	0.09650727
	5	affluence + behavioural norms + management performance + management agency + management difficulties	1.997639	0.368314	0.07567488
	6	affluence + perception norms + behavioural norms + management agency + management difficulties	1.999471	0.367977	0.07560559

Figure 3: Psychological components and livestock management performance. Y axes show probability. X axes show composite scores for different metrics; higher scores reflect stronger answers. Respondents are separated into three classes, based on their overall livestock management performance: poor (blue); mid (pink); and good (green). Ordinal logistic regression models of single variables.

Figure 3a. Normative behaviours. Composite of questions concerning the performance of different groups, e.g. friends, family, community. Example: ‘How well do other community members manage their livestock?’.

Figure 3b. Management difficulties. Composite of questions concerning the difficulty performing livestock management behaviours. Example: ‘To bring my livestock into a boma every night would be difficult’.

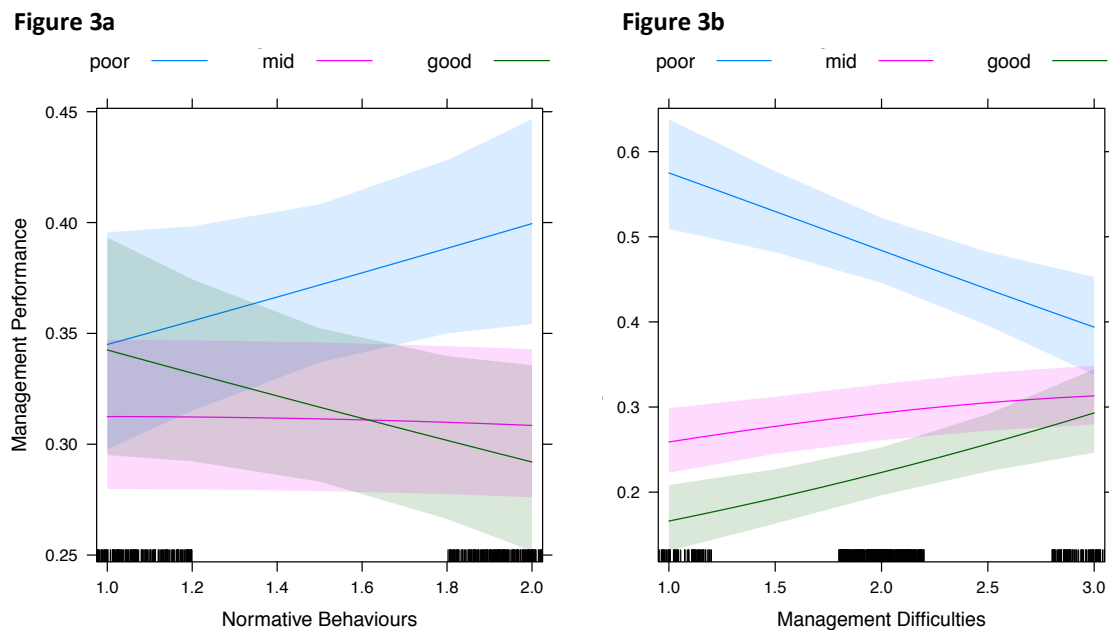


Figure 4: Affluence and management performance. Y axis shows probability. X axis shows composite affluence score. Ordinal logistic regression model of affluence composite on livestock management composite. Legend details different livestock management performance classes.

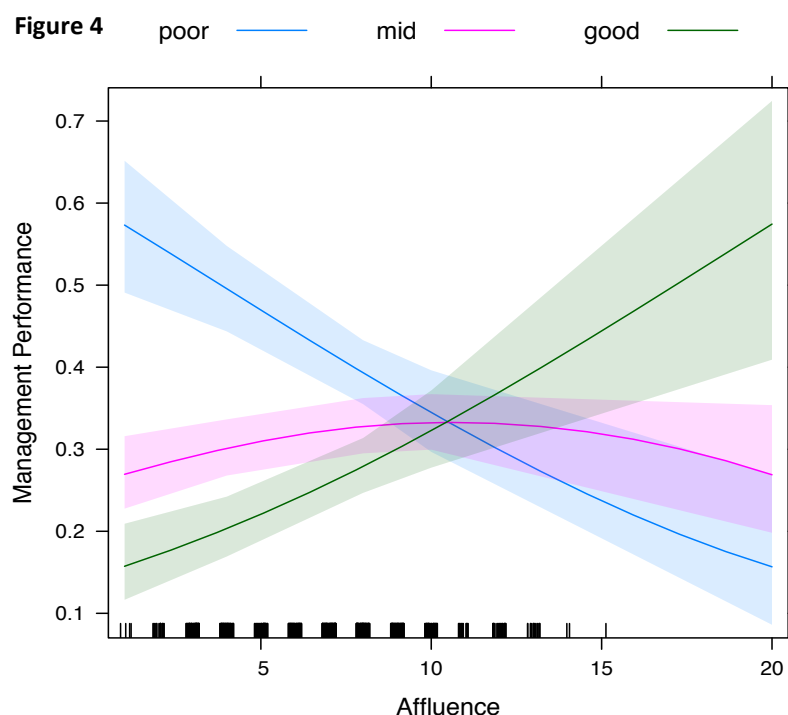


FIGURE LEGENDS

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