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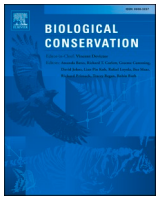

Barking up which tree? Characterizing farmers, farms, and a behavioral framework regarding livestock guardian dog use in South Africa

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ABSTRACT

Livestock guardian dogs are one of several predator control methods employed by livestock farmers around the world, but little is known about the factors that predict their use. Here we aim to understand the dimensions which influence guardian dog use by farmers. In a quantitative survey among 113 livestock farmers in South Africa, using Boosted Regression Trees, we explored and characterized the factors associated with guardian dog use. We showed that practical factors (e.g., predator type, number of farming enterprises, mitigation methods, and the frequency and extent of specific predator problems) were more likely to be significant determinants of guardian dog use than sociodemographic factors. However, psychosocial constructs relating to wildlife value orientations, empathy for predators, tolerance to predators, tangible and intangible cost, benefits of predators, like or dislike of predators, and number of positive experiences, were also determinants of guardian dog use. Utilizing the foundational constructs of the Theory of Planned Behavior (TPB) and Wildlife Tolerance Model (WTM) we built upon these findings to show that constructs of attitude, subjective norms, and perceived behavioral control explained 49 % of the variance in behavioral intention to use or continue using a guardian dog. The relationship between attitude and the behavioral intent to use or continue using a guardian dog had less significant association with guardian dog use than either perceived behavioral control or subjective norms had. Nonetheless, attitude was most strongly associated with the constructs of belief in a specific non-governmental organization, mutualistic Wildlife Value Orientations and perceptions of affordability, ease of use and the effectiveness of guardian dogs. The TPB model, incorporating elements of the WTM, provides a framework to guide and improve adoption of guardian dog programs or other intervention strategies within conservation contexts.

1. Introduction

Predators worldwide are under threat due to land use change, habitat fragmentation, climate change and persecution by humans (Belbachir et al., 2015; Lindsey et al., 2018). Persecution is largely linked to competition for resources such as livestock and given the large home ranges of many predators, conflict over livestock depredation is widespread (Graham et al., 2005; Inskip and Zimmermann, 2009; Thorn et al., 2011). Many populations of predatory species have begun to recover in recent decades thanks to conservation efforts (Ribeiro and Petrucci-Fonseca, 2004). With ever-expanding livestock practices and the existence of predators in mixed-use landscapes, livestock depredation poses a key threat to the coexistence of people and predators (Ripple et al., 2014). Where livestock farming is prevalent, enabling human-carnivore coexistence has significant conservation and socio-economic implications for both humans and predators (Khorozyan and Waltert, 2019). Privately owned rural land now represents key habitat and range areas for some endangered predator species (Durant et al., 2017), such that where livestock depredation by these (or other) species threatens farmer livelihoods, major challenges exist for predator conservation (Kerley et al., 2017; Khorozyan and Waltert, 2019; Marker et al., 2021). A wide variety of strategies have been used to mitigate livestock predation, ranging from fencing, to poisoning, hunting, deterrents or aversive agents and anti-fertility agents (van Eeden et al.,

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2018). Livestock guardian dogs (LGDs) are one strategy considered effective in reducing depredation (van Eeden et al., 2018; Kinka and Young, 2018; Whitehouse-Tedd et al., 2020; Marker et al., 2021; Whitehouse-Tedd et al., 2021a). The term 'Livestock guardian (or guarding) dog' is typically used to define breeds and landraces selectively bred to protect livestock by various deterrent and repelling behaviors (Shivik, 2006; Kinka and Young, 2018), as an alternative to lethal control methods, and consequently reducing predator mortalities, offering a more responsible form of predator control (Bigi et al., 2018).

Although guardian dogs have been used over thousands of years, in many regions their use was stopped with the decline in predators (Kinka and Young, 2018). More recently, with the return of predators and the desire for non-lethal methods to promote coexistence, there has been a resurgence in interest in their use. The Cheetah Conservation Fund in Namibia was the first organization to utilize specialist guardian dog breeds for predator mitigation in southern Africa, and have monitored, and evaluated their use over 25 years (Marker et al., 1996; Marker et al., 2021). South Africa has potential for wide application with over 69 % of its land area under rangeland (WWF, undated; DAFF, 2017). Livestock are mostly free ranging in South Africa and therefore vulnerable to depredation (Kerley et al., 2017), such that a guardian dog program similar to that of Cheetah Conservation Funds was established in South Africa in 2005 (Whitehouse-Tedd et al., 2020). However, despite many examples of their efficacy in reducing predation (van Eeden et al., 2018; Kinka and Young, 2018; Whitehouse-Tedd et al., 2020; Marker et al., 2021) they are not always used (Rigg, 2001; Marker et al., 2021). Therefore, to better understand the factors that determine guardian dog use or not, we chose South Africa as our study site. More specifically, our aim was to characterize farmers and their farms to determine how these influence guardian dog use. We also investigate the psychosocial factors that drive guardian dog use, since social and psychological factors associated with guardian dog use are largely unknown (Landry, 1999; Ribeiro and Petrucci-Fonseca, 2004; Whitehouse-Tedd et al., 2021b).

To achieve our aims, we used a novel approach by combining two theoretical models - the Theory of Planned Behavior (Ajzen, 1985) and the Wildlife Tolerance Model (Kansky et al., 2016). The Theory of Planned Behavior proposes that the key determinant of a person's behavior is their intention to engage in that behavior. Intention in turn can be influenced by three additional factors; attitude towards the behavior, social, also known as subjective, norms - perceived desirability of the behavior by people who are close to you, and perceived behavioral control - the extent to which you think performing the behavior is under your control (Ajzen, 1991). The Theory of Planned Behavior has been applied extensively in a diversity of disciplines and increasingly being applied by conservation scientists e.g. yellow-shouldered Amazon parrots (Ward, 2016); intention to conserve the hooded vulture (Kankam and Abukari, 2020), and in human-wildlife conflict and coexistence research (Amit and Jacobson, 2017; Swan et al., 2020).

The Wildlife Tolerance Model is a recently developed interdisciplinary model that aims to understand the drivers of human tolerance towards damage causing wildlife (Kansky et al., 2016; Saif et al., 2020; Marino et al., 2021; Kansky et al., 2021). The Wildlife Tolerance Model consists of two components: an outer model and an inner model. The *Outer Model* consists of variables such as the experience with a species, which includes recent spatial exposure to a species, and number of meaningful events a person has had with the species. The *Inner Model* consists of 11 variables hypothesized to influence tolerance. For example, empathy is one inner model variable – the hypothesis is that people with higher empathy levels towards a species will have higher tolerance.

We combined these two models by firstly using the Theory of Planned Behavior as the basic model to examine the extent to which attitudes, social norms and perceived behavioral control drive the use or not of guardian dogs. Then we included some inner and outer model variables of the Wildlife Tolerance Model to see if these variables could improve the predictive capacity of the Theory of Planned Behavior variables. Historically the focus of guardian dog research has been on reduction in livestock loss (Leijenaar et al., 2015; Whitehouse-Tedd et al., 2020), protective traits (Dohner, 2007) and corrective training (Whitehouse-Tedd et al., 2020) as potential determinants of guardian dog use. More recently their role as a conservation tool, their impact on wildlife and their potential to create "landscapes of fear" has received more attention (Eklund et al., 2017; Spencer et al., 2020; Whitehouse-Tedd et al., 2020). Therefore, our study is novel in its focus on the psychosocial and human dimensions of guardian dog use and adds a new dimension to guardian dog research.

2. Methods

2.1. Participant recruitment

The study took place in South Africa and included both commercial and subsistence farmers from across eight out of the nine provinces (Gauteng was excluded due to few farms) (Fig. 1). Livestock carrying capacity in South Africa increases from west to east as the rainfall increases. In the drier western and central areas, sheep tend to dominate, while cattle are more frequent in the eastern rangelands where it is considerably wetter (DAFF, 2017). We sampled a broad subsection of farmers (see more detail on selection criteria) across a range of geographies in South Africa and included those who already had a guardian dog as well as those who did not. Both livestock guardian dog organizations as well as predation mitigation management organizations were used to build a sample grouping of farmers, who both used, and did not use guardian dogs, but did record livestock predation events on their farms in South Africa. Every farmer named by the organizations was contacted by email and invited to participate – our sample was therefore comprised of those who responded positively to our invitation. In total 273 farmers were invited to participate, of whom 113 participants completed all sections (41 % completion rate). Of these, 44 were guardian dog users and 69 non-users. The remaining 160 were excluded from analysis because they either returned only partially completed surveys ($n = 64$) or did not respond at all ($n = 96$). Our sample size matched expectations based on previous studies (Rust et al., 2013; Leijenaar et al., 2015; Spencer et al., 2020; Wilkes et al., 2023). Farms were categorized as mutton sheep, wool sheep, cattle, goats, poultry, and game. Poultry and game farms were excluded from further analysis as these species are not usually protected by guardian dogs. Farmers currently using a guardian dog had the dog placed with them by a placement organization, and the dogs were therefore purpose-bred and reared; the age and duration of placement of the dog varied and we did not investigate differences according to dog sex. Farmers using guardian dogs acquired by informal means outside of the placement organizations' network were beyond the scope of this study.

Farmers in our study might have been using other mitigation methods of control in conjunction with the guardian dog. Farmers not using a guardian dog had never used a guardian dog as a mitigation method. Sample selection criteria was based upon farmers with guardian dogs who were recruited via organizations dealing with guardian dogs, and through farmer word of mouth (referral) whereby a farmer using a guardian dog referred another farmer to the non-governmental organization (NGO) to acquire a guardian dog. Farmer referrals are an important means of guardian dog recruitment (Wilkes et al., 2023). Note we did not recruit farmers to our study from another well-known guardian dog support organization, Endangered Wildlife Trust (NGO2 from hereon) as those farmers were already involved in a separate study and we wished to avoid survey fatigue. For farmers not using guardian dogs, Predation Management South Africa provided a database of farmers registered with livestock predation challenges and these farmers were initially screened by telephone call to ensure they had not used a guardian dog previously but were using alternate mitigation methods. Predation Management South Africa provides farmers with guidelines and advice to manage livestock predation. Since organizations with a

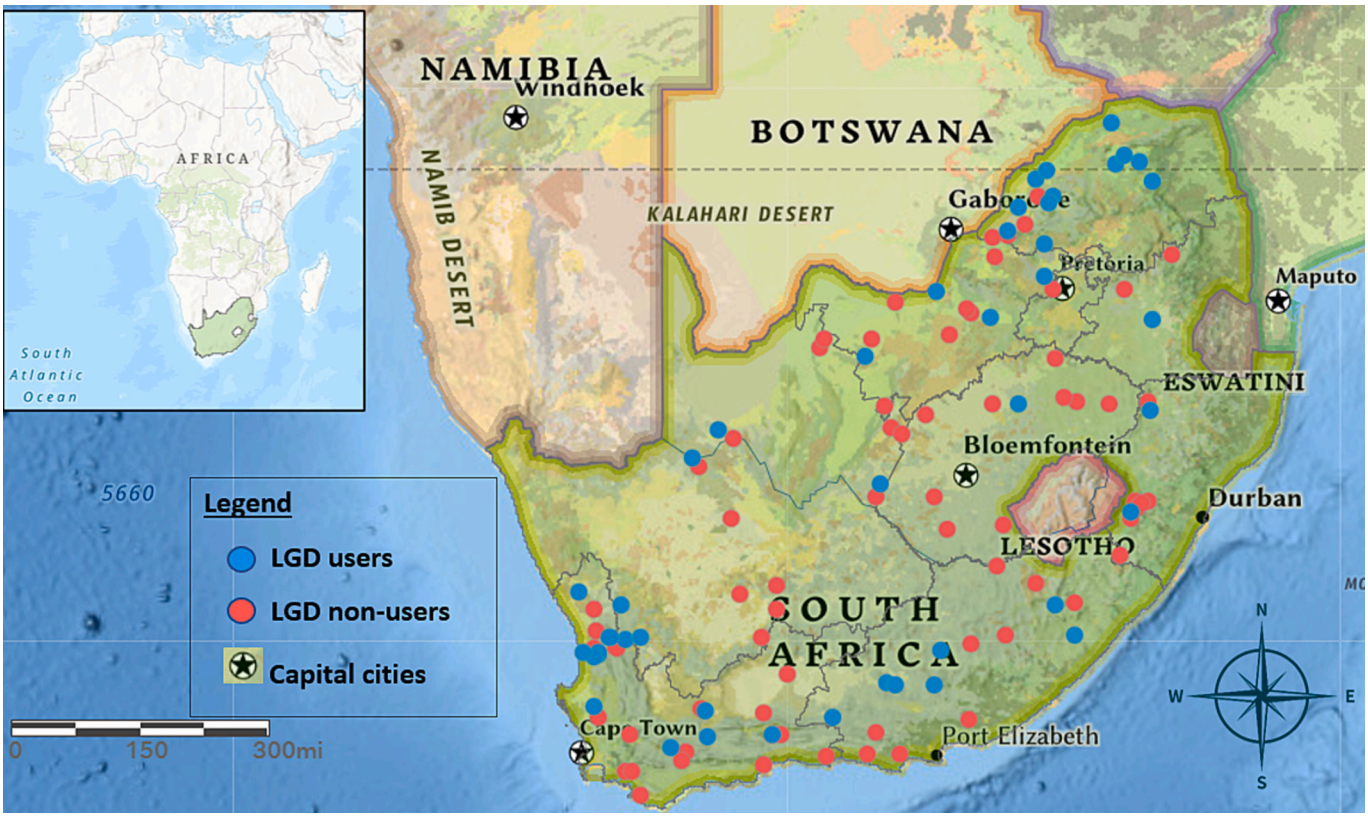

Fig. 1. Survey participant farm localities in South Africa for both guardian dog users and guardian dog non-users ($n = 113$), with shaded relief, land-cover imagery, administrative boundaries, and capital cities denoted by circled stars. Inset map - South Africa within Africa.

vested interest in the promotion of guardian dog use were named in our survey, we controlled for potential bias by ensuring their involvement in survey administration was restricted to only the provision of contact details. Predation Management South Africa's mandate is to consider all legal mitigation methods, including guardian dogs, their involvement was also restricted to the provision of contact details.

Respondents were initially contacted via telephone or email. In-person interviews were conducted until COVID-19 restrictions prevented face to face interactions, where upon interviews were done digitally via phone and email. Respondents were recruited into the study with an invitation email as part of the digital survey introduction, during which they were informed that the aim of the study was to understand the use of mitigation methods in a human wildlife conflict or coexistence context. In the case of guardian dog users, respondents were informed that this was a guardian dog mitigation method focused study, while no specification was made for non-guardian dog users. Both farmer groups, either using or not using a guardian dog, were investigated as to the other lethal and/or non-lethal mitigation methods they were using. The two stakeholder groups were subsequently compared in the survey sample, i.e., livestock farmers using guardian dogs and those not using guardian dogs (Fig. 1). Ethical approval was granted under the Cape Peninsula University of Technology (201016974/01/2020) and Nottingham Trent University (#ARE192039). Participation was voluntary, and all respondents gave signed informed consent for the use of their anonymized data and were aware of their right to withdraw at any point.

2.2. Survey design and data collection

We primarily designed the survey based on variables from the Wildlife Tolerance Model (Kansky et al., 2016; Marino et al., 2021; Saif et al., 2020; Kansky et al., 2021) and the Theory of Planned Behavior (Ajzen, 1985) (Supplementary material - Table S1). The Wildlife Tolerance Model (see Fig. S1) includes both sociodemographic variables such as income, age, cultural background as well as characteristics of the farm enterprise such as what is farmed, what are the problem predators and what mitigation measures are used. *Outer model* variables include the amount of exposure to predators, the types of experiences one has with predators (both positive and negative) and the costs and benefits associated with predators. These include both tangible costs such as the damage incurred as well as intangible costs such as the psychological stress and worry of having to deal with predators. Lastly, tolerance towards predators was measured using four dimensions of tolerance - spatial tolerance, damage tolerance, population size tolerance and killing tolerance. *Inner model* variables include psychosocial constructs such as Wildlife Value Orientations (both utilitarian and mutualism orientations, (Manfredo, 2008)), empathy to predators, belief in animals mind, and relationships with organizations dealing with guardian dogs. The Theory of Planned Behavior components were measured according to Ajzen, 1985. The attitude construct consisted of four items relating to guardian dog use, the social norm construct consisted of five items and the perceived behavioral control construct, which reflects the extent of difficulty a person perceives in carrying out the behavior and whether the action is within their own volitional control, consisted of three items (Ajzen, 1985; Hrubes et al., 2001). One statement was used to assess behavioral intention to use or continue using a guardian dog as the response variable - "I intend to use/continue to use a LGD to prevent livestock predation by predators" (the full survey is provided in supplementary material - Tables S1 and S2). A results summary is reported in supplementary material - Table S3, and all variables considered are reported in Tables S4 and S5. Our hypothesized relationships between the variables are depicted in Fig. 2. A pilot survey was conducted whereby 22 respondents ($n = 8$ for guardian dog users; $n = 14$ for guardian dog non-users) were contacted via telephone and invited to participate in a preliminary survey to confirm clarity of the questions, use of English language and measure completion times. As a result of the pilot study and to reduce acquiescence bias, the number of agree vs

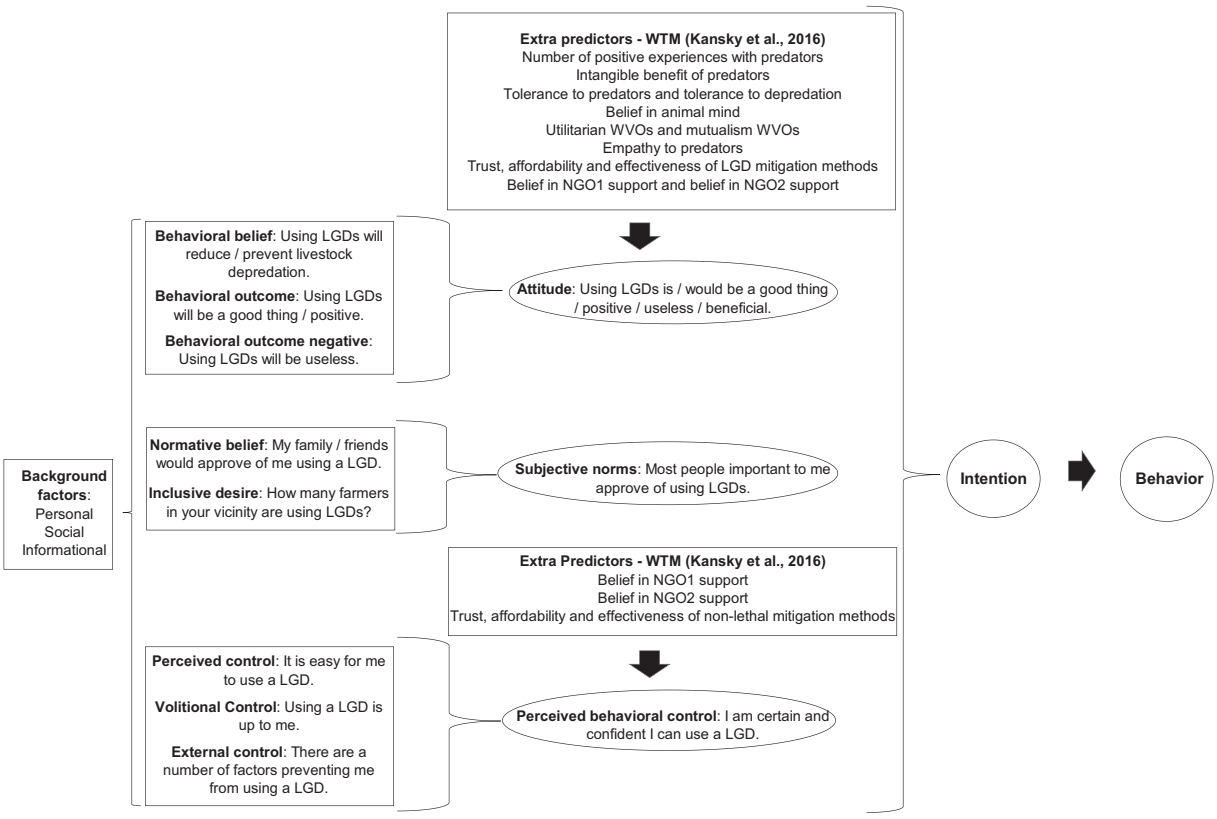

Fig. 2. Conceptual framework for Theory of Planned Behavior, depicting pathways to behavioral intent (adapted from Ajzen, 1991). Abbreviations of Non-governmental organization 1 (NGO1), Non-governmental organization 2 (NGO2), Livestock guardian dogs (LGD), Wildlife Tolerance Model (WTM), Wildlife Value Orientation (WVO).

disagree questions were reduced. All completed responses were answered on the online integrated management and survey platform, Alchemer (https://www.alchemer.com/). In a pilot survey we investigated several factors that may be involved in influencing guardian dog use before incorporating into the Theory of Planned Behavior model (Tables S1, S2).

2.3. Data analyses

To analyze the associative relationships between variables and their association with the response variable, LGD use, we used Boosted Regression Trees. Boosted regression trees are a model built on decision tree algorithms and boosting methods (Elith et al., 2008). In broadly testing all variables and the sociodemographic data, a nonparametric CART analysis was used to explore the data prior to conducting TBC and Wildlife Tolerance Model analysis. Initially we tested for interactive effects between variables and constructs prior to boosted regression tree modelling, using the Kendall rank correlation coefficient test. Based on these, we included all categorical and continuous variables in the boosted regression tree modelling. Variables assumed to be less relevant in the boosted regression tree analysis, were not immediately considered irrelevant as such variables may have had a mediation effect. Firstly, to ensure categorization of variables and robust sample sizes, we collapsed variables into various data categories to create three sections and nine sub-sections. The three main sections were: (1) the farmers, (2) the farmer's environment, and (3) social constructs (Tables S1, S2). Thereafter variable selection for the three boosted regression tree models was done by dropping unimportant variables, as the model ignores predictor variables that are not informative when fitting the trees in a form of simplification analysis (Elith et al., 2008). This prevented redundant predictors to increase the variance. Finally, in the boosted regression tree analysis, we tested 79 predictor variables and constructs made up of 21 sociodemographic and mitigation method variables (all relating to "the famers"), 25 predictor variables for the "farmer's environment" and 33 variables and constructs relating to the "social constructs". In exploring sociodemographic, farm and farmer, as well as Wildlife Tolerance Model variables, we considered that variables showing a low importance per the boosted regression tree analysis did not immediately mean such variables could not be potential mediators in the path modelling. This modelling is based upon partial least squares modelling, which is a powerful statistical technique to explore relationships among a set of model variables and identify the key pathways that exist among these variables (Hair et al., 2014). All analyses were done in R (R Core Team, 2019; version 3.6.2, 2019-12-12) using the GBM package for boosted regression tree. To test for reliability, Cronbach's alpha ($\alpha > 0.70$) was used. To test the categorical variables for goodness of fit, homogeneity, and independence, and considering the non-random associations between categorical variables, Fisher's exact test for counts below 5 was used. This suited the small sample size ($n = 113$). To test differences between continuous variables, *t*-Tests for normally distributed, and Mann Whitney *U* Test for non-normal data were used.

In developing the path model, and to determine the relationship between model variables, we used Partial Least Square Structural Equation Modelling. We applied a similar methodology to previous studies and use of Partial least square structural equation modelling (Kansky et al., 2016; Kansky et al., 2021). To examine the predictive power of the partial least square structural equation modelling model, the coefficient of determination (R^2) was used (Hair et al., 2012; Wong, 2013; Hair et al., 2014). We used SmartPLS software (Ringle et al., 2014) to build the path models, where R^2 values indicated model fit and the path coefficients the strength of a contribution of the variables. Path model diagrams are used to visually display the relationships between

the variables. We considered that the path coefficient should be larger than 0.20 as an indicator of its significance (Chin, 1998), but also noted that the significance did not always illustrate the operational performance fully and considered further significance testing using bootstrapping.

Lastly, we examined the reliability and validity of the scales. Variables that failed the suggested threshold for construct reliability and average variance extracted were dropped to improve the predictability of the model (Supplementary material – Table S3). Construct and variable reliability and validity was determined using Cronbach's alpha reliability coefficients as well as composite reliability (Bagozzi and Yi, 1988). Indicator and internal consistency reliability were established when composite reliability was 0.7 or higher (Bagozzi and Yi, 1988; Hair et al., 2019) (Table S3). We evaluated average variance extracted to check the convergent validity, using a threshold of, or at least close to 0.5, as being acceptable (Hair et al., 2019) (Table S3). Using bootstrap confidence intervals, the relative statistical importance of the path coefficients was reported (Hair et al., 2014). We used 500 complete bootstrapping samples to generate T statistics for both the structural and measurement model. With no missing values, there was no need for missing value replacement and therefore no risk of random data generation.

3. Results

3.1. Sociodemographic variables, the farmers, and social constructs

Eighty one percent of respondents were male and 19 % female. Most (83 %) were the farm owner, with 17 % being the farm manager. Afrikaans was the predominant home language spoken (50 %), followed by English (42 %). The remaining 8 % of respondents spoke either Zulu, Sepedi, Sesotho, Setswana, or German. Most farmers were commercial farmers (89 %), with only 11 % being subsistence farmers. Of the farmers, 71 % farmed only animals while 29 % farmed a mixture of animals and crops. The percentage of total household income derived from animal farming was significantly ($P = 0.012$) higher for guardian dog non-users (80 %) than for guardian dog users (73 %). Neither farm size (mean 2706 ha for guardian dog non-users and 2862 ha for guardian dog users), years spent living on the farm (average 23 years, SD 17) or farmer age could predict guardian dog use ($P > 0.05$). The percentage of subsistence farms was too low to analyze effectively (11 %), but we noted that two thirds (66 %) of subsistence farmers used a guardian dog, whereas only 35 % of commercial farmers used a guardian dog.

The predictor variable 'total number of non-lethal mitigation methods' accounted for a high relative (positive) influence (ri) at 21.15 %, when accounting for all variables tested regarding "who are the farmers?". After accounting for the average effects of all other variables in the "farmer's environment" model, the predictor variable with the highest relative (positive) influence on guardian use (ri = 20.06), was the 'extent of the problem for all predators combined'. The 'total number of predator types (species) on the farm' accounted for the third highest relative (positive) influence on guardian dog use when considering the farmer's environment (ri = 17.06). 'Exposure to jackal, caracal, leopard, and baboon' showed the fourth highest relative (positive) influence associated with guardian dog use (ri = 13.60).

There was no significant association between like vs dislike of predators ($P = 0.525$), nor the number of positive ($P = 0.517$) and negative experiences with predators ($P = 0.165$), relative to guardian dog use. There was no significant difference between guardian dog users and non-users based on the perceived tangible monetary benefits of living with predators ($P = 0.278$) or the intangible non-monetary benefits of predators on the farm ($P = 0.395$). There was no significant difference between guardian dog users and non-users based on the perceived intangible costs of living with predators ($P = 0.129$), nor the total tangible costs in terms of monetary (ZAR) value of all livestock lost due to depredation ($P = 0.163$). We also found no significant differences in wildlife value orientations of mutualism and utilitarian orientations nor the construct of empathy for predators between guardian dog users and non-users ($P = 0.278$). For tolerance measures such as the number of days a farmer would be willing for a predator to visit their farm/land ($P = 0.765$), number of days a farmer would be willing for a predator to visit their area/neighborhood ($P = 0.628$), preference for killing a predator under a series of scenarios ($P = 0.788$) or tolerance towards predator populations increasing ($P = 0.856$), there was no difference between guardian dog users and non-users.

3.2. Mitigation measures

The livestock depredation mitigation methods – hereafter referred to as mitigation methods – were divided into six lethal (poison, baited wildlife cage traps, shooting from a vehicle, night hunting, leg hold or gin traps and hunting wildlife with a dog pack) and 12 non-lethal mitigation methods (wildlife proof mesh boundary fencing, protective livestock collars, electrified fencing, human patrols, flashing cat's eyes tied to livestock, relocation of any problem predators by conservation authorities - synchronized breeding, radio collars, anti-fertility agents, night pens/bomas, aversive agents and guardian dogs). No significant difference was detected between guardian dog users and non-users in the number of mitigation methods used (lethal and non-lethal combined), or the number of lethal mitigation methods used. However, guardian dog users used a significantly higher number of non-lethal mitigation methods than guardian dog non-users ($P = 0.002$) (Supplementary material - Table S6). There were no significant differences between guardian dog users' and non-users' in the perceived affordability, ease of use and effectiveness of lethal mitigation methods (Supplementary material - Fig. S2; Table S6) or of non-lethal mitigation methods (Supplementary material - Fig. S3). However, guardian dog non-users found both flashing cat's eyes tied to livestock and protective livestock collars to be more affordable, easier to use and more effective than did guardian dog users (Fig. S3). Guardian dog users considered synchronized breeding, another non-lethal mitigation method, more affordable and slightly more effective but harder to use than did guardian dog non-users (Fig. S3). The three most frequently used non-lethal mitigation methods by all farmers (regardless of guardian dog use) were fencing methods being night pens/bomas, wildlife proof mesh boundary fencing and electrified fencing.

3.3. Theory of Planned Behavior model assessment - partial least squares structural equation model

Cronbach's alpha values showed good internal consistency reliability, where minimum acceptable levels for individual indicator reliability values was 0.40 and most values were >0.70 (Hair et al., 2019) (Table S3). Discriminant validity was established as the Heterotrait – Monotrait Ratio (HTMT), values were <0.85 (Supplementary material - Table S7). Using the Fornell and Larcker model, we noted that these values were larger than other correlation values among the latent variables, also indicating that discriminant validity was established (Supplementary material - Table S8). The relative statistical importance of the path coefficients was indicated where values close to or above 0.2 were considered significant (Hair et al., 2019) (Fig. 3).

3.4. Variation in behavioral intent towards guardian dog use in the Theory of Planned Behavior model

The coefficient of determination, R^2, was almost 49 % for the endogenous latent variable of the behavioral intent to use or continue using a guardian dog (Fig. 3). The pathways of attitude–behavioral intent, subjective norms–behavioral intent, perceived behavioral control–behavioral intent, non-governmental organization (NGO1)–attitude, NGO1–perceived behavioral control, NGO1–LGDs, LGD-Mitigation Method –attitude and LGD-mitigation method- perceived

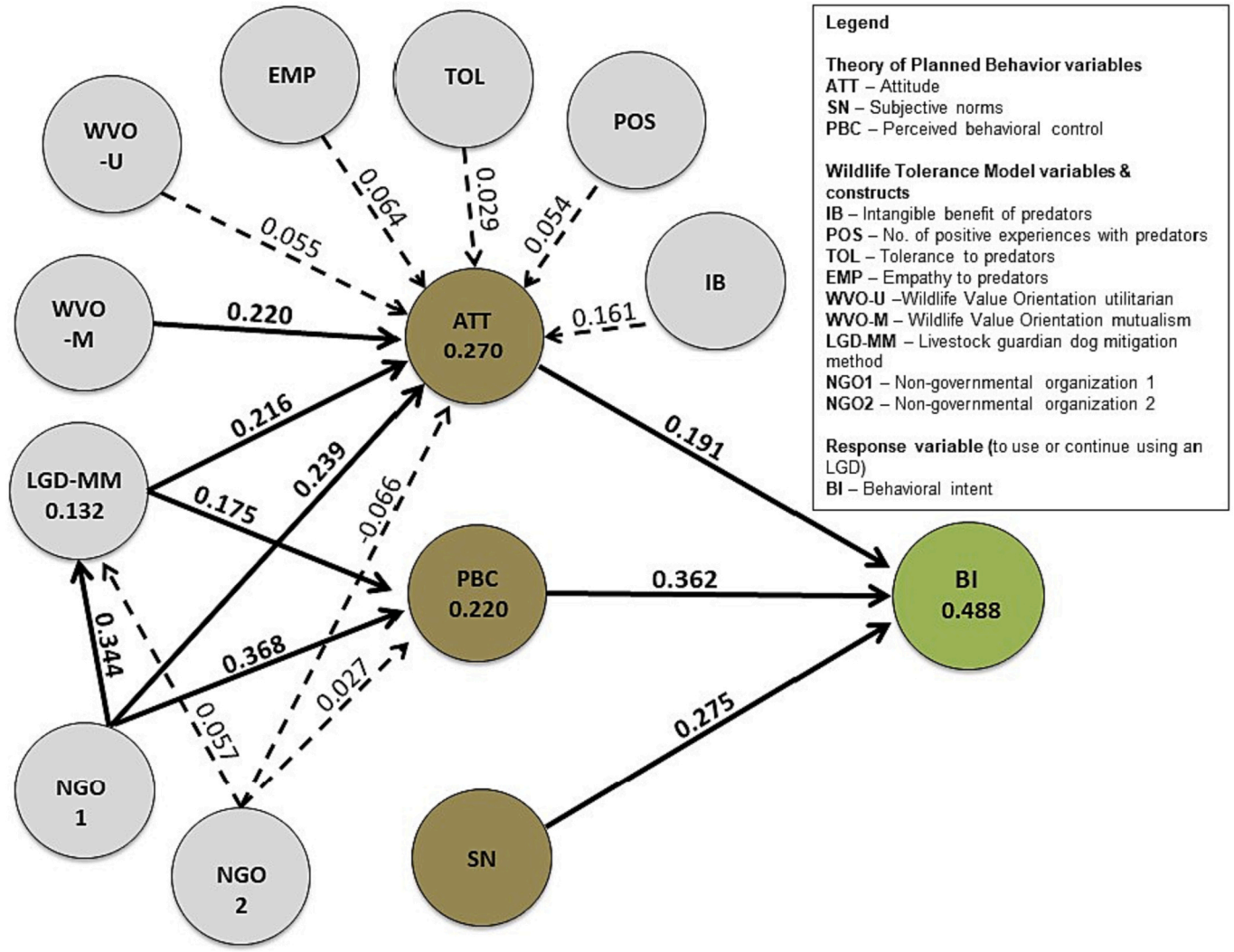

Fig. 3. Partial Least Square path modelling where lines joining circles are the paths linking latent variables, and values adjacent to lines are path coefficients. Values within the circles are the adjusted coefficients of determination (R^2). Dotted lines are non-significant path coefficients while bold lines are significant path coefficients. Circle color represents the response variable (behavioral intent, green shading), the Theory of Planned Behavior variables (attitude, subjective norms, perceived behavioral control, brown shading) and the Wildlife Tolerance Model adapted variables and constructs guardian dog-mitigation methods (the use of guardian dogs as a mitigation method to reduce depredation), NGO1 and NGO2 (gray shading). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

behavioral control were all significant ($P < 0.05$; Supplementary material - Table S9). Behavioral intent was measured by whether the farmer indicated they either intended to get a guardian dog in the near future to prevent livestock predation by predators or intended to continue to use a guardian dog to prevent livestock predation by predators in the next year.

3.5. Importance of Theory of Planned Behavior constructs associated with guardian dog use

The structural model suggested that perceived behavioral control had the strongest associated effect on behavioral intent to use or continue using a guardian dog ($\beta = 0.362$; $P < 0.01$) (Fig. 3; Supplementary material - Table S10). Subjective norms accounted for the second highest associated effect on behavioral intent to use or continue using a guardian dog ($\beta = 0.275$; $P < 0.01$) (Fig. 3; Table S10). Of the three Theory of Planned Behavior constructs, attitude towards guardian dog use, although significant, had the lowest associated effect on behavioral intent to use or continue using a guardian dog ($\beta = 0.191$; $P = 0.04$) (Fig. 3; Table S10).

3.6. Contribution of Wildlife Tolerance Model variables towards Theory of Planned Behavior variables

In considering the Wildlife Tolerance Model adapted constructs and variables for the outer model, 27 % of variation in attitude was explained. The greatest variation in attitude towards guardian dog use was associated with farmer's perceptions of NGO1 in terms of trust, degree of general performance, degree of communication, and level of knowledge and skills ($\beta = 0.239$; $P = 0.02$). Both affordability, ease of use and effectiveness of guardian dogs ($\beta = 0.216$; $P < 0.01$) and mutualistic wildlife value orientations ($\beta = 0.220$; $P = 0.06$) were significant paths relating to attitude (Fig. 3; Table S10). Of all the Wildlife Tolerance Model constructs and variables, the wildlife value orientation of mutualism had the greatest associated effect on attitudes towards guardian dog use but exhibited only a trend towards significance ($\beta = 0.220$; $P = 0.06$). Intangible benefits of predators had the second highest associated effect on attitudes towards guardian dog use, although this was not statistically significant ($\beta = 0.161$; $P = 0.132$).

Farmers' perceptions of the affordability, ease of use and effectiveness of guardian dogs showed a significant effect on the variation in

attitude towards guardian dog use (β = 0.216; $P < 0.01$) (Fig. 3; Table S10).

Twenty-two percent of variation in perceived behavioral control was explained by both perceptions of affordability, ease of use and effectiveness of guardian dogs, as well as perceptions of trust, degree of general performance, degree of communication and level of knowledge and skills of both NGO1 and NGO2 (Fig. 3). NGO1 had the largest effect on perceived behavioral control (β = 0.368; $P < 0.01$), with affordability, ease of use and effectiveness of guardian dogs also showing a lower although also significant effect on perceived behavioral control (β = 0.175; $P = 0.04$) (Fig. 3; Table S10).

Thirteen percent of variation in the affordability, ease of use and effectiveness of guardian dogs (guardian dog-mitigation method) was explained by farmers' perceptions of guardian dog support organizations in terms of trust, degree of general performance, degree of communication, and level of knowledge and skills. The guardian dog support organization NGO1 showed a significant effect on variation in the affordability, ease of use and effectiveness of guardian dogs (β = 0.344; $P < 0.01$) (Fig. 3; Table S10). The guardian dog support organization NGO2 had no significant effect on the affordability, ease of use and effectiveness of guardian dogs (β = 0.057; $P = 0.571$) (Fig. 3; Table S10).

4. Discussion

In recent times with the growth in ecological understanding, animal welfare and the recognition of the place we share with animals on this earth, a new thinking is developing around coexistence strategies as opposed to lethally eliminating the predatory threat to livestock farming (Bergman et al., 2013). The motivations of farmers employing different mitigation methods are poorly understood and by combining the Theory of Planned Behavior and Wildlife Tolerance Model we could use these theoretical models to investigate these motivations.

We found that the model explained 49 % of variation in guardian dog use with all three Theory of Planned Behavior constructs being significant drivers of intention to use or continue to use a guardian dog - positive attitudes towards guardian dog, perceived agency in skills and knowledge to use guardian dogs, and when significant others of a respondent thought guardian dogs were a good idea. Of these three variables perceived behavioral control was the strongest driver followed by subjective norms and attitudes. Of the Wildlife Tolerance Model variables, we hypothesized that tolerance towards predators, intangible benefit of predators, empathy towards predators, wildlife value orientations, number of positive experiences with predators and satisfaction with guardian dog support NGOs would drive attitudes towards guardian dogs, but found only mutualistic wildlife value orientations, the perceived efficacy, ease of use and affordability of guardian dogs and satisfaction with one NGO were significant drivers of attitudes towards guardian dog use.

Recognizing the psychosocial constructs and attitudes of landholders living near wildlife is useful for human wildlife conflict and coexistence understanding and intervention (Decker et al., 2012; Barua et al., 2013; Ketting, 2020). Our study indicated that in this specific case, psychosocial constructs relating to wildlife value orientations, empathy for predators, tolerance to predators, tangible and intangible cost and benefits of predators, like or dislike of predators and number of positive experiences were less important determinants of guardian dog use than were the more practical implications relating to predator type, mitigation methods, and the frequency and extent of specific predator problems. Likewise, sociodemographic factors like age, the duration of time spent living on the farm and the size of the farm itself were not important predictors of guardian dog use. Understanding the practical implications of factors influencing guardian dog use is only the beginning of building a framework that can be utilized to increase the efficiency of guardian dog program recruitment, and perhaps most importantly, to identify aspects of guardian dog use which require refinement or further explanation to ensure they are fit for purpose and aligned to the end-users needs and expectations.

4.1. Practical factors and their influence on guardian dog use

Farmers used a variety of lethal and non-lethal mitigation methods and reported their varying degrees of affordability, effectiveness, and ease of use, in aiming to reduce livestock depredation (Figs. S2 and S3). Although guardian dogs were considered less affordable and harder to use than poison, guardian dogs were considered a more effective mitigation method than this lethal control method. The number of non-lethal as opposed to lethal mitigation methods was significantly associated with guardian dog use, which may be indicative of farmers associating guardian dog use as a form of non-lethal or coexistence mitigation methodology. The number of livestock species farmed (i.e., “farming enterprises”) was significantly associated with guardian dog use. The use of guardian dogs has been shown to be an effective mitigation method for small stock, being goats and sheep specifically (van Eeden et al., 2018). In some parts of the world, groups of guardian dogs are used to protect multiple herds of stock (van Bommel and Johnson, 2014). In southern Africa, guardian dogs are generally placed on farms as singletons or in pairs; in these situations they are typically placed with only one livestock herd and species at any given time, as one or two dogs do not have the ability to protect across multiple herds of livestock (Marker et al., 2021). We propose that farmers with a higher diversity of livestock species will require a greater variety in mitigation methods used which could result in more frequent use of guardian dogs, especially for small stock protection. Related to herd size and livestock species, farm type (e.g., commercial, subsistence, communal and other categories) might also influence guardian dog use and needs to be considered in future research. In Namibia, livestock losses on farms where guardian dogs were used did not vary between farm types (according to their status as communal, freehold, or emerging freehold), although farmers on communal and emerging freehold farms reported better performance from their guardian dogs compared to farmers on resettled farmland (Marker et al., 2021). Depredation losses are likely to have significant social and local economic significance at the local scale, especially in communal and subsistence farming sectors (Kerley et al., 2017). The relative costs of guardian dog use, compared to a suite of lethal and non-lethal mitigation methods, in the first year based on the cost per ewe for a typical Karoo farm of 6000 ha with 1000 ewes in three herds (dry, lambing and replacement) is approximately 30 ZAR per ewe (Kerley et al., 2017). By the fifth year the guardian dog cost has reduced to approximately 18 ZAR per ewe (Kerley et al., 2017). The relative costs per ewe of guardian dog use over one year, three years and five years is therefore relatively low when compared to mitigation methods such as electric fencing, human shepherds, collar use or even hunting dogs.

On average, farmers using guardian dogs derived a lower amount of their household income from animal farming. This might be related to more recreational, or hobbyist style farming and we acknowledge that further research in identifying novel factors related to farm type in South Africa will be useful in understanding these associations with guardian dog use. If guardian dogs are more popular among a specific farm type, e.g., those who are less reliant on livestock income, or with a diversified range of farming enterprises or with smaller herd sizes for small stock, then this will aid guardian dog support organizations in targeting specific farms for guardian dog placement or further evaluating barriers to guardian dog use for farmers more reliant on livestock or with larger or single-species herds. Farmers were selected based primarily on existing guardian use and/or predator related interaction as opposed to geography or sociodemographic variables. Most farmers reporting on predator related incidents, for example through organizations like Predation Management South Africa, are commercial farmers. As indicated in previous studies (Potgieter et al., 2013), subsistence farmers with little or no stable form of income and associated challenge of providing sufficient food for the large-breed guardian dogs, do not commonly employ guardian dogs. We suggest however that further research on farm type

would be useful to understand its association with guardian dog use.

Where Theory of Planned Behavior modelling relating to conservation challenges focuses on three cognitive constructs (Hrubes et al., 2001; Daigle et al., 2002), our study showed that perceived behavioral control had the greatest associated effect on guardian dog use, followed by subjective norms and attitude. As such, farmers who perceive guardian dog use to be easy, consider normative support for their use to exist, and have positive attitudes towards their use, were also those who had the strongest intentions to use them. The more resources and fewer obstacles' farmers perceive to exist, the greater their perceived behavioral control and the stronger their intention to perform behaviors, such as utilizing a guardian dog. These resources and obstacles can be seen as practical constructs, supporting our initial findings that the practical resources and barriers relating to predator type, number of farming enterprises, mitigation methods, and the frequency and extent of specific predator problems were more important determinants of guardian dog use than psychosocial constructs. These practical implications can be seen as facilitating conditions, where it has been previously proven that such conditions reflect situational enablers or constraints to performing a particular behavior (Venkatesh, 2000).

4.2. Farmer's attitudes towards guardian dog use

The hypothesized relationship between attitude and the behavioral intent to use or continue using a guardian dog was significantly associated with guardian dog use, although slightly weaker than either perceived behavioral control or subjective norms. Attitude was most strongly associated with the constructs of belief in NGO1, mutualistic wildlife value orientations and perceptions of affordability, ease of use and the effectiveness in guardian dogs.

A series of Wildlife Tolerance Model constructs influenced attitude towards guardian dog use, where the wildlife value orientation of mutualism and the intangible perceived benefit of predators influenced attitude towards guardian dog use. Mutualistic individuals are characterized by a belief that humans and wildlife are meant to co-exist and/or live-in harmony (Teel and Manfredo, 2010; Teel et al., 2010). Our study showed that one also needs to consider that farmers with strong mutualistic tendencies will have more positive attitudes towards guardian dogs and in turn their intent to use or continue using guardian dogs could be higher. Our study also showed a moderately associative effect of the intangible benefits of predators on attitudes towards guardian dog use. Farmers who perceived greater intangible benefits of living with predators in terms of aesthetic value, appreciation value, existence value, cultural or symbolic value for themselves, their community, humankind, and nature, had more positive attitudes towards guardian dog use which is positively associated with the intent to use or continue using a guardian dog. The Theory of Planned Behavior model also revealed that practical implications related to NGOs involved in guardian dog use, including perceived trust, degree of general performance, degree of communication and level of knowledge and skills are also valuable predictors of guardian dog use, along with guardian dog factors such as their perceived affordability, ease of use and effectiveness.

Although we can predict that farmers with strong mutualistic tendencies may be more likely to have more positive attitudes towards guardian dogs (as a result of their non-lethal intention), wildlife value orientation was still only weakly influential in regards behavioral intention towards guardian dogs. Although the Wildlife Tolerance Model has been a useful diagnostics tool used to understand tolerance and inform conservation management (Kansky et al., 2016; Saif et al., 2020; Kansky et al., 2021; Marino et al., 2021) our study shows that Wildlife Tolerance Model determinants on attitude towards guardian dog use were less significant pathways to consider when determining the influences on guardian dog use.

4.3. Farmer's perceived behavioral control in relation to guardian dog use

The perceived level of autonomy in decision making and the perceived ease of implementation are well studied elements in farmer's decision-making processes (Ellis-Iversen et al., 2010; Elliott et al., 2011; Singh et al., 2016). Our findings support this as shown by the significant path of perceived behavioral control with intentions to use a guardian dog. Previous studies have also shown that farmers' behavior can be significantly affected by the influence of trusted advisors (Elliott et al., 2011; Bruijnis et al., 2013; Jones et al., 2015). Our study also showed a link between farmer's perceptions of trust in organization NGO1, the general performance of the organization as well as degree of communication and perception of level of the organization's knowledge and skills, along with farmers' perceived behavioral control of owning and managing a guardian dog. This highlights the importance of perceived behavioral control in understanding farmer behavior as well as the importance of guardian dog support organizations, like NGO1, in this method of conservation intervention and the significant influence they have in affecting farmer's behavioral intent. As the other NGO in this study was not afforded equivalent trust or perceptions by the farmers, likely related at least in part to the fact that our sample group was recruited through NGO1 and a separate organization (i.e., our respondents may have been unaware or had little contact with NGO2), we cannot generalize our findings across all support organizations. The onus is on individual NGOs to understand their participating farmers and other stakeholders to develop robust and trustworthy relationships.

Research considering trust in human-wildlife interactions, has shown that higher trust between stakeholders may reduce perceptions of risk and increase tolerance for predators (Bruskotter and Wilson, 2014; Kansky et al., 2021). This tolerance could be driven by improving stakeholder perceptions of their own control over the desired actions, and the ease with which these actions can be taken. Such was the case regarding guardian dog use in the current study and the level of trust afforded NGO1 appears integral to this perception. To this end, farmers trust the NGO to consider farmer interests within the guardian dog program. This relationship-building facet to any community-involving conservation initiative may require that the product (in this case guardian dogs) on offer may, at times, not be best suited to a particular farming context and guidance or recommendations by the NGO should be adjusted accordingly. Our findings emphasize the responsibility of guardian dog support organizations to consider the best interest of farmers and to prioritize trust-building efforts into their relationships with other stakeholders.

4.4. Subjective norms and their associated effect on guardian dog use

Behavior-science suggests that people may be influenced by the actions and perceived beliefs of others (Simpson and Willer, 2015) and that individuals show greater propensity to teamwork in the achievement of a common goal when social norms support a behavior (Niemiec et al., 2016). The opinions of family, peers and friends are often highly influential when a person makes a decision (Martínez-García et al., 2013; Kauppinen et al., 2013; Mills et al., 2017). In human-wildlife coexistence programs, these subjective norms influence the perceived effectiveness of interventions (Sakurai et al., 2015). Likewise, social pressure has been found to be the most important determinant of behavior, more so than attitude of the individual farmer (Bell et al., 2016). It follows that normative support for using guardian dogs had a significant association with farmer intent to use or continue using a guardian dog in our study. It has also been previously proposed that understanding the effect that a potential subjective norm has on attitudes, and possibly perceptions, could help predict the effectiveness and reception of policy implementation (Ketting, 2020). Similarly, our findings show that after perceived behavioral control, subjective norms show the greatest associated effect on guardian dog use. Focusing on the behavior of the target individual is crucial but the importance of

considering the influence of family, friends, peers, and advisors is hereby shown to be critical to guardian dog adoption and intervention success. Conservation organizations looking to understand and promote guardian dog use should consider engagement that goes beyond the targeted farmer, farm owner or manager. Opportunities for the dissemination of guardian dog program information should consider engaging with the wider farming community with an emphasis on understanding the wider attitudes towards guardian dog use. Such engagement presents an opportunity for these indirect stakeholders to voice their opinion and/or receive further information, which will likely foster improved community collaboration and help to tailor interventions towards achieving context-relevant success.

5. Future considerations

We need to acknowledge, in the ongoing debate regarding the relationship between cognition and behavior (Gold and Goodey, 1984), that in some cases the predictors of behavior do not always result in the expression of the behavior. For example, although the intent to use a guardian dog might be evident, the action of using one may not be realised. In our study over 50 % of farmer's not using guardian dogs, were nonetheless aware of guardian dogs and therefore appeared to have purposefully decided against their use. Further research in understanding the rationale behind these decisions and if it is related to external variables such as NGO support will be valuable. In contrast, over 90 % of farmers using a guardian dog reported being likely to use a guardian dog again in the future and 36 % of farmers not currently using a guardian dog would consider using one in the future. Awareness leading to intent and action is not a simple process to understand and therefore future research needs to consider the implications of intent to action. We also noted the potential for inadvertant bias due to the survey only being in English, although this was accounted for during the pilot study, where questions were simplified to suit a survey sample where the two dominant languages were English (42 %) and Afrikaans (50 %).

6. Conclusion

The critical role guardian dog support organizations play in predicting guardian dog use by farmers has been highlighted in this study. Notably our study shows that for guardian dog support organizations, advocating for conservation and coexistence based on some of the psychosocial elements of farmer values is likely to be less effective than addressing the practical implications of human-wildlife interactions experienced by farmers, particularly predator type, number of farming enterprises, mitigation methods, and the frequency and extent of specific predator problems. Greater consideration for these practical implications associated with guardian dog use will likely serve to improve matching farmers to depredation mitigation methods according to their needs and situation. Consideration of social pressures in the form of subjective norms and perceived behavioral control needs to be considered when investigating or predicting behavioral responses of farmers in human wildlife conflict or coexistence scenarios. Utilizing the flexibility of the Theory of Planned Behavior to incorporate elements of the Wildlife Tolerance Model enabled the development of a behavioral model. This framework can be extended to investigate other human wildlife interactions of conservation importance globally.

Authorship statement

All persons who meet authorship criteria are listed as authors, and all authors certify that they have participated sufficiently in the work to take public responsibility for the content, including participation in the concept, design, analysis, writing, or revision of the manuscript.

Furthermore, each author certifies that this material or similar material has not been and will not be submitted to or published in any other publication before its appearance in Biological Conservation.

CRediT authorship contribution statement

Conception and design of study: all authors

Analysis and/or interpretation of data: all authors

Revising the manuscript critically for important intellectual content: all authors

Approval of the version of the manuscript to be published: all authors

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

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