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Human and Ecological Risk Factors for Unprovoked Lion Attacks on Humans in Southeastern Tanzania

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*Lions (*Panthera leo*) have attacked over 1,000 people in Tanzania since 1990. We worked in the two districts with the highest number of attacks, Rufiji and Lindi, and conducted interviews in two villages with high attack numbers and two neighboring villages with no attacks. Logistic regression analysis of 128 questionnaires revealed the following risk factors: ownership of fewer assets, poorly constructed houses/huts, longer walking distances to resources, more nights sleeping outdoors, increased sightings of bush pigs (*Potamochoerus porcus*), and lower wild prey diversity. A comparative analysis revealed significant differences between the two districts: while high bush pig and low prey numbers affected both districts, hut construction was only significant in Rufiji, and walking distances, asset ownership, sleeping outdoors, and house construction were only significant in Lindi. Such information will help relevant authorities develop site-specific methods to prevent lion attacks and can inform similar research to help prevent human–carnivore conflict worldwide.*

Keywords human–wildlife conflict, predators, risk, mitigation

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Introduction

An increase in human population and the resulting ecological impacts have led to an increase in human–wildlife conflict throughout the world (Fall & Jackson, 2002), making it one of the foremost issues facing wildlife conservation today (Woodroffe, Thirgood, & Rabinowitz, 2005). This is particularly true for carnivores. Human population growth has led to encroachment into wildlife areas, alteration of carnivore habitat, and depletion of prey populations, while successful conservation has allowed for the recovery of several carnivore populations (Bagchi & Mishra, 2006; Treves & Karanth, 2003a; Quigley & Herrero, 2005). Carnivores have the potential to cause serious economic damage and even harm humans, diminishing public support for wildlife conservation and motivating the extermination of problem animal species (Loe & Roskaft, 2004; Treves & Karanth, 2003b). Persecution by people in response to conflict—real or perceived—is one of the main factors in carnivore population declines around the world (Woodroffe, 2001; Woodroffe & Frank, 2005).

A severe example of direct human–carnivore conflict recently occurred in Tanzania where lions attacked over 1,000 people between 1990 and 2007 (updated from Packer, Ikanda, Kissui, & Kushnir, 2005). The situation is unusual in that most attacks involved lions entering settlements and agricultural areas, apparently in search of humans (Baldus, 2004; Packer et al., 2005). Tanzania is home to 25–50% of all African lions, making it a critical country for lion conservation (Bauer & Van Der Merwe, 2004; Chardonnet, 2002). Not only are lions important top predators to the natural ecosystem, but they are also of great economic importance to Tanzania, where nature-based tourism, including trophy hunting and photographic tourism, is the second largest source of foreign revenue (Wade, Mwasaga, & Eagles, 2001).

Until recently, there have been few published studies of lion attacks on humans. The studies that do exist take a case-study approach, view the issue from a natural history perspective, or examine lion health as a cause of the problem (Baldus, 2004, 2006; Patterson, Neiburger, & Kasiki, 2003; Peterhans & Gnoske, 2001; Yamazaki & Bwalya, 1999). In 2005, Packer et al. published a study of 231 attacks across Tanzania, which broadly identifies important risk factors and patterns in human activities during attacks. The study found that lion attacks tend to be highest in districts with high abundances of bush pigs and low abundances of other natural prey. Most attacks occur when people are tending crops in their agricultural fields, and concurrently, 39% of the surveyed cases occur during harvest time (March–May). Bush pigs are a major risk factor, as people sleep in their fields in makeshift huts to protect their crops from this nocturnal agricultural pest. Farmers also report seeing lions enter their fields in pursuit of bush pigs. Along with tending and protecting crops, other common activities during attacks include walking alone in the early morning and evening hours, using the outhouse at night, and participating in retaliatory lion hunts.

Although the Packer et al. (2005) study identified activities that put people at risk and broad-scale risk factors related to lion prey and bush pigs, it does not examine variations in human activities linked to risk. Our study examines human and ecological risk factors in greater detail and at both the district- and village-level. We consider wildlife presence as well as human factors, including: asset ownership, distances to key resources, amount of time sleeping in agricultural fields/outdoors, and house/hut construction. We conducted the study in the two districts with the highest number of attacks reported in the Packer et al. (2005) study: Rufiji and Lindi. Within each district, certain areas experience a high number of attacks while others were free of conflict despite being in close proximity to attack hotspots, indicating that local variation in ecology and/or human activities may influence the probability of an attack. Examining variations in human activities and wildlife

presence at the village- and district-levels will therefore provide a more nuanced view of the risk factors for lion attacks.

Methods

Selection of Study Areas

This study focuses on the two districts with the highest number of lion attacks since 1990, as identified in the Packer et al. (2005) study (Figure 1). Rufiji district had 101 attacks between 1990 and 2007 while Lindi district had 190 attacks in the same period (updated from Packer et al., 2005). Rufiji's human population totals just over 200,000 in ~98 villages; Lindi is home to just over 250,000 in ~129 villages. However, Lindi, with an area of 6,732 km^2 is more densely populated (37 people/km^2) than Rufiji (21 people/km^2), whose habitable area covers 9,645 km^2. Rufiji contains part of a major protected area, the Selous Game Reserve, which is also a source of wild lions, whereas Lindi is not near any major protected areas. Thus, Rufiji has a large number of lions, bush pigs, and other natural prey, whereas Lindi has fewer lions, bush pigs, and other natural prey (Kushnir & Ikanda, personal observation, 2005).

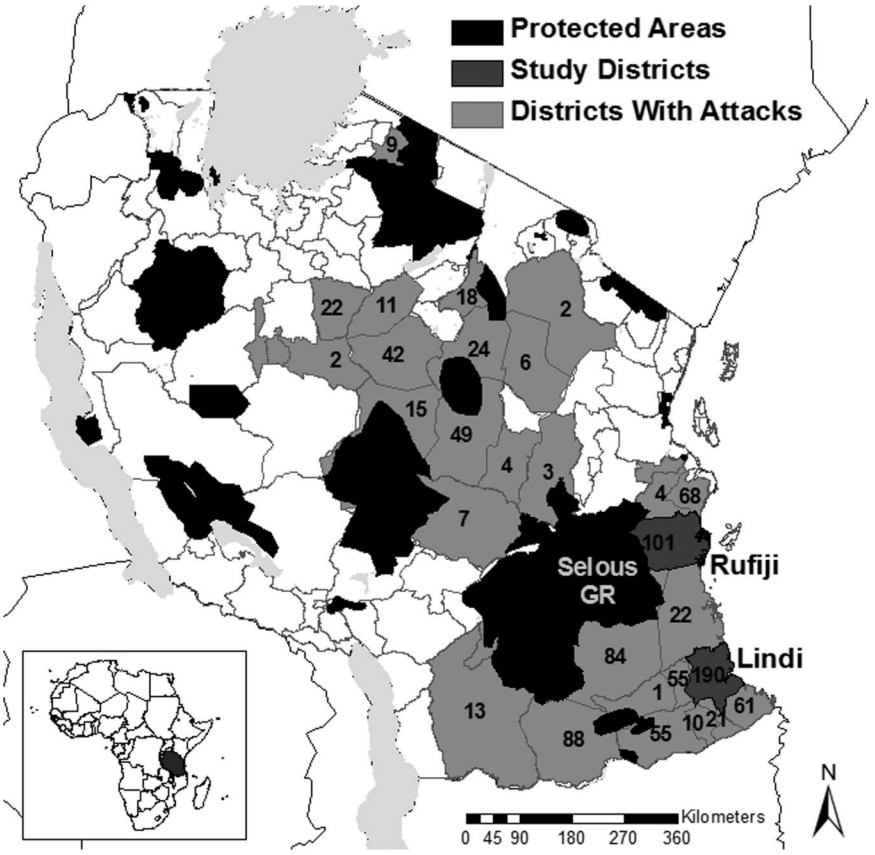

Figure 1. Number of attacks per district across Tanzania from 1990–2007 (updated from Packer et al., 2005).

Within each district, we chose areas that had the highest concentration of attacks according to government records. Figure 2 shows the Rufiji study area, the Rufiji River Valley, which encompasses two wards just east of the Selous Game Reserve. Figure 3 shows the Lindi study area, termed the Sudi-Mingoyo Area, which encompasses three wards in the southeastern portion of the district. Both areas experienced an outbreak of lion attacks that began between 2001 and 2002 and ended in 2004. In each study area, we selected two villages with a high number of attacks and two villages with no attacks in close proximity to attack villages and with similar land cover types. An "attack village" is one that experienced an attack on humans within the boundary of the village, including the land used for cultivation by its villagers. We made site visits to verify that villages selected as "non-attack villages" were attack free from1990–2007. By selecting villages in this manner, we are able to compare human activities and wildlife presence in villages with different attack histories while controlling for environmental conditions. In addition, all villages have similar livelihood strategies (small-scale agriculture), wealth status, and religion (primarily Islam). We confirmed the presence of lions in all villages so that differences in attacks were not due to the absence of lions.

Data Collection

We collected two types of data: human activity patterns during lion attacks, and human activities and wildlife presence in attack and non-attack villages. We began by cross checking Packer et al. (2005) data with district records and obtaining information on more recent attacks. We then traveled from village to village inquiring about all attacks that occurred from 1990–2007. We uncovered a number of unreported cases by inquiring

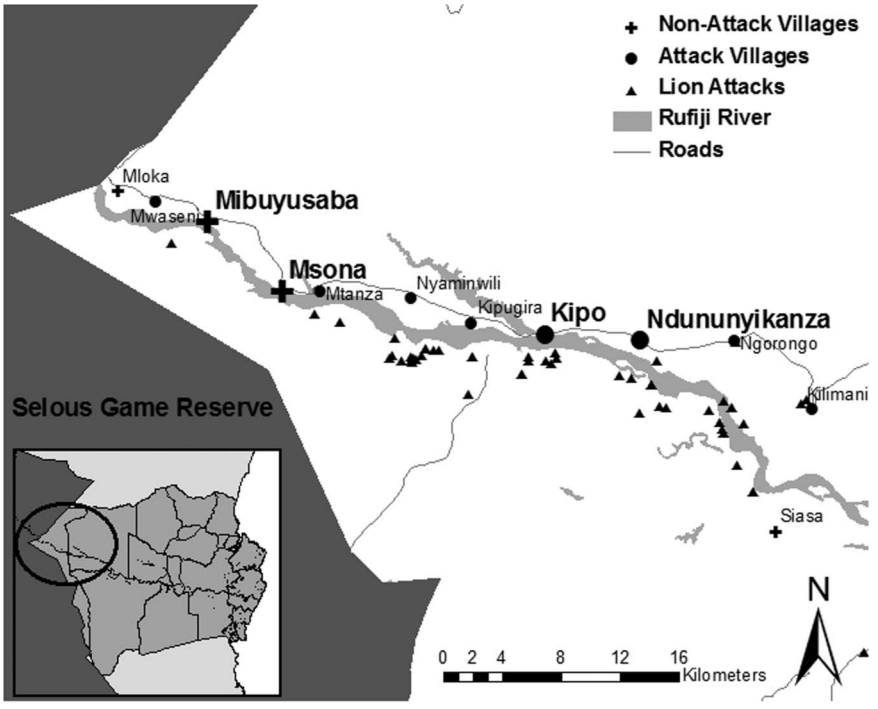

Figure 2. Rufiji River Valley study area, Rufiji district. Study villages are in bold with larger symbols.

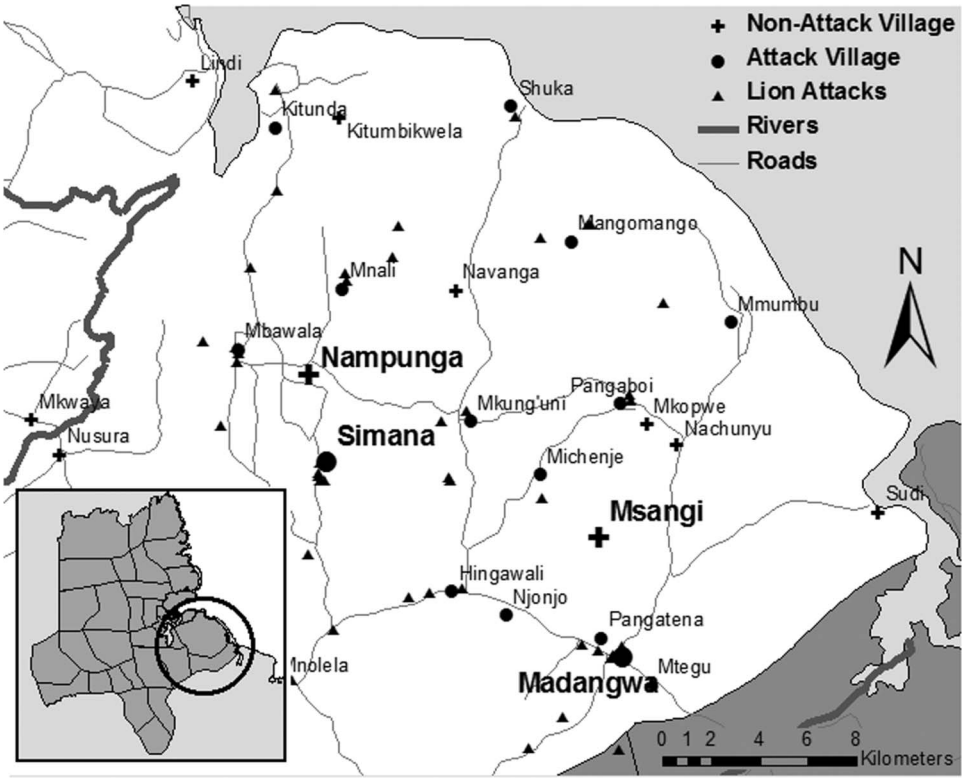

Figure 3. Sudi-Mingoyo study area, Lindi district. Study villages are in bold with larger symbols.

directly in each village; any remaining unreported cases are likely to be randomly distributed and of equal proportion in both districts. We focused solely on "unprovoked" attacks, which included any attack that did not occur during a lion hunt (discounting 17 attacks). We collected data on human activities during lion attacks through interviews with village leaders, survivors, or family members. The district records generally provide the date, name, age, and sex of the victim, and we collected additional data such as the time and location of the attack and what the victim was doing at the time of attack. Whenever possible, we obtained accounts from witnesses or people who visited the scene shortly after an attack to avoid bias from non-witness statements.

To compare villages with and without a history of attacks, we collected data on socioeconomics, daily activities, personal safety, wildlife presence, and attack prevention through questionnaire-based interviews. With the assistance of an interpreter, we conducted sixteen interviews in each of the eight study villages, for a total of 128 interviews. Households were selected at random through village registers, and male and female heads of household were selected alternately to assure an even gender ratio. Although some of the questions were household level questions, most of the questionnaire focused on individual-level data.

Data Analysis

We used chi-square analysis to compare human activity patterns during lion attacks between the two districts. To identify risk factors, we conducted a series of backwards linear step-wise logistic regressions. Logistic regressions compared human activities and wildlife presence

between villages with and without attacks by treating the study like a case-control design, where people in villages with attacks were assigned 1 and people in non-attack villages assigned 0. Three regression analyses were conducted: one with data from both Rufiji and Lindi and one each for Rufiji and Lindi separately. For the regressions, we consider variables significant if they had a $p < .05$, but considered any variable with $p < .10$ as worthy of discussion. Table 1 provides a description of each variable in the model.

Results

Variations in Human Activity Patterns During Lion Attacks Between Districts

A number of human activity patterns varied significantly between districts. Most notable were the location and activity of victims during attacks, and the time of day when the attack occurred. In Rufiji, the majority of attacks occurred inside structures in agricultural fields (45%), whereas in Lindi, cases largely occurred outside structures in agricultural fields (39%), outside homes in the village center (31%), as well as on roads or paths in areas peripheral to the village center (19%) ($X^2 = 104.02$, $p < .01$) (Figure 4). Although both districts experienced a large proportion of attacks in agricultural fields, site visits revealed that significantly more of the Lindi attacks (39%) occurred inside village centers as compared to Rufiji (11%) ($X^2 = 23.25$, $p < 0.01$). The victims' activities during attacks also differed substantially between districts ($X^2 = 87.66$, $p < .01$) (Figure 5). In Rufiji, 43% of attacks occurred when individuals were resting, sitting, or sleeping inside their home. In Lindi, attacks were more common when people were walking (36%), using the outhouse or bathing (27%), or resting outside their homes (18%). In Rufiji, most victims were accompanied by other people at the time of the attack (59%), but in Lindi, most victims were alone (65%) ($X^2 = 9.27$, $p < .05$). In Rufiji, the majority of cases occurred at night (62%), while most cases in Lindi occurred in the late evening (45%) ($X^2 = 22.39$, $p < .01$) (Figure 6).

Variations in Risk Factors Between Village Types and Districts

Results from the logistic regression using data from both districts identify factors that differentiate attack and non-attack villages. Compared to villages without attacks, people in attack villages walk longer distances to water, firewood, and neighbors, see bush pigs more frequently in agricultural fields, see fewer types of problem species and lion prey, spend fewer nights sleeping in agricultural fields, spend more nights sleeping outside for traditional ceremonies, such as funerals and weddings, own fewer assets, and live in weaker structures in village centers and agricultural fields (Table 2).

Results from the logistic regressions for each individual district identify district-specific risk factors. The logistic regression for Rufiji revealed four main factors that distinguished attack from non-attack villages (Table 3): people in attack villages see more bush pigs in agricultural fields and village centers, see fewer problem species and fewer lion prey types, and build weaker structures in agricultural fields than people in non-attack villages. Seven factors that distinguish attack villages in Lindi were identified by the logistic regression model (Table 4): people in attack villages own fewer assets, walk farther to firewood and water, spend more nights sleeping outdoors for traditional ceremonies, see bush pigs more frequently in agricultural fields, see fewer types of lion prey, walk to their agricultural fields on fewer days a year, and built weaker houses.

Table 1
Description of variables in logistic regression models

Variable*	Description
Main home located on agricultural field	According to interviewee and assessment of interviewer
Number of assets owned	Count of prompted list of eight assets
Number of problem species reported	Count of unprompted list of animals specified by interviewee as crop pests
Walking distance to firewood (minutes)	Walking distance in minutes from home as reported by interviewee, we averaged times if interviewee had more than one home (i.e., in village center and agricultural field)
Walking distance to water (minutes)	
Walking distance to neighbors (minutes)	
Days walked to agricultural field per year	We determined which months people go to agricultural fields, then how many days per week in each month, and calculated the total
Nights slept in agricultural field per year	We determined which months people sleep in their agricultural field, then how many days per week each month, and calculated the total
Nights slept outdoors per year	We identified what traditional activities caused each individual to sleep outdoors, then asked how many nights per year they sleep outdoors for each activity, and calculated the total
Days per year bush pigs sighted in village center	If interviewee specified that they see bush pigs in their village or agricultural fields, we determined which months, then how many times per week in each month, and calculated the total
Days per year bush pigs sighted in agricultural field	
Number of lions prey types sighted	Interviewees pointed to and named animals from a page of pictures of common lion prey, none of the animals were the same as crop pest mentioned.
House safety - Level 1: Elevated and non-elevated thatch hut - Level 2: Mud/brick house, thatch roof - Level 3: Mud/brick house, metal/wood roof	Interviews were always conducted at the main home of the interviewee. We observed and recorded information on each aspect of house construction (walls, roof, door, and floor). Note that coding was slightly different in the Lindi model because there were no thatch houses in Lindi.
Hut safety - Level 1: Elevated thatch and pole hut - Level 2: Non-elevated thatch and pole hut - Level 3: Mud/mud brick house - Level 4: Does not sleep in agricultural field	We considered huts to be any structure in which people temporarily reside in an agricultural field. We questioned interviewees on each aspect of hut construction (walls, roof, door, and floor). Note that coding was slightly different in the Rufiji model because mud/mud brick huts were rare.

*These represent only the variables that remained in the models after the backwards step-wise logistic regression. A number of additional variables were included in the original models but were not significant: number of livestock owned, walking distance to agricultural field (minutes), sighting of lions in village centers and in agricultural fields, sighting of lion signs in village centers and in agricultural fields.

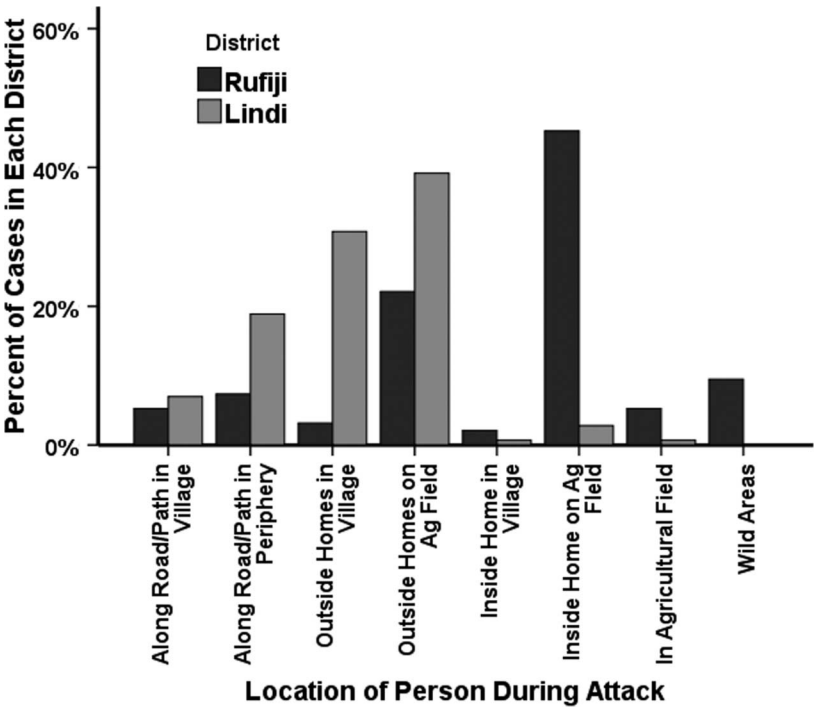

Figure 4. Percent of lion attacks at each location in Rufiji and Lindi districts ($X^2 = 104.02, p < .01$).

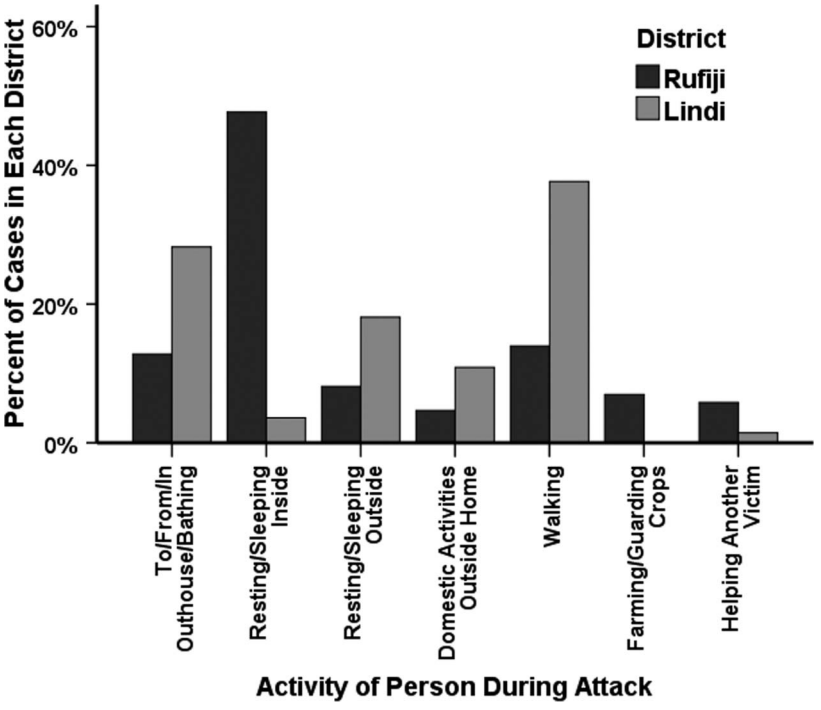

Figure 5. Percentage of attacks in each activity category for Rufiji and Lindi ($X^2 = 87.66, p < .01$).

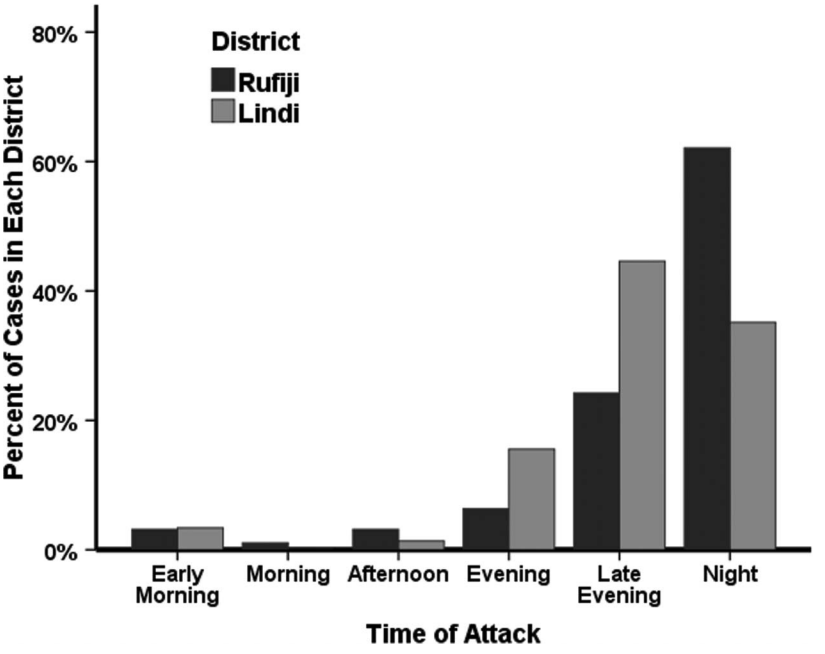

Figure 6. Percent of attacks at each time category for Rufiji and Lindi districts ($X^2 = 22.39, p < .01$).

Variations in Attack Prevention Between Village Types and Districts

The two districts showed significant differences in the precautions people took to protect themselves against lion attacks ($X^2 = 17.34, p < .05$) (Figure 7). Although in both Rufiji and Lindi people frequently stated that they stay inside after dark, the proportion in Rufiji (55%) was lower than in Lindi (79%). In addition, in Rufiji, a larger proportion of people construct stronger homes and fences (17%), and become more vigilant (13%). In Lindi, a higher proportion of people reported that they avoided moving around unnecessarily during the day (11%). Despite these differences between districts, there was no significant difference in precaution responses between attack and non-attack villages within each district.

We asked respondents about the effectiveness of measures to prevent attacks by lions on humans (Figure 8). In all of the measures but bush pig control, results from Rufiji and Lindi were not significantly different. Overall, people thought it would be effective to build safer structures in agricultural fields (60%), build safer homes (62%), walk in larger groups (52%), cut tall grass near homes (61%), and erect fences around their yard to enclose outhouses and cooking areas (66%). People thought it would be ineffective to avoid sleeping in agricultural fields (44%), change the location of agricultural fields (22%), and cut high grass along commonly used paths (45%). As for bush pig control, a slight majority (52%) in Rufiji said yes, or yes with stipulations, while in Lindi, 70% of people said bush pig control would not help prevent attacks ($X^2 = 6.02, p < 0.05$). In some cases, people stipulated how a particular measure might become more effective. For example, 19% of interviewees said yard fences would help as long as the fences were strong or tall.

We stratified responses about effective prevention measures by village type within each district. In Rufiji, people in attack villages were more likely to think that lion attacks could

Table 2
Results of combined logistic regression model for both districts showing risk factors for lion attacks

Variable	*B*	SE	Wald	*df*	*p*
Gender[a]	−1.65	0.786	4.39	1	0.036
Age[a]	−0.06	0.032	2.96	1	0.086
Main home located on agricultural field[a]	−1.78	2.166	0.67	1	0.411
District[a]	2.38	1.937	1.51	1	0.220
Number of assets owned***	−1.43	0.450	10.16	1	0.001
Number of problem species reported**	−1.01	0.452	5.04	1	0.025
Walking distance to firewood (min)*	0.02	0.013	3.10	1	0.078
Walking distance to water (min)***	0.04	0.015	9.04	1	0.003
Walking distance to neighbors (min)**	0.28	0.109	6.50	1	0.011
Nights slept in agricultural field per year*	−0.02	0.009	3.21	1	0.073
Nights slept outdoors per year**	0.03	0.015	3.97	1	0.046
Days per year pigs sighted in village center	0.01	0.005	2.31	1	0.129
Days per year pigs sighted in agricultural field***	0.03	0.008	10.26	1	0.001
Number of lions prey types sighted***	−0.83	0.270	9.43	1	0.002
House safety level 1 (thatch hut)			5.87	2	0.053
House safety level 2 (mud/brick house, thatch roof)**	−3.57	1.719	4.31	1	0.038
House safety level 3 (mud/brick house, metal/wood roof)**	−4.86	2.011	5.83	1	0.016
Hut safety level 1 (elevated thatch hut)			8.68	3	0.034
Hut safety level 2 (ground level thatch hut)	−2.04	1.819	1.26	1	0.262
Hut safety level 3 (mud/mud brick house)**	−6.18	2.431	6.45	1	0.011
Hut safety level 4 (does not sleep in agricultural field)***	−6.80	2.462	7.62	1	0.006
Constant	13.07	4.126	10.03	1	0.002

[a]These variables were controlled for and therefore never dropped from the model.
Significance $^{***}p < .01$, $^{**}p < .05$, $^{*}p < .10$.

be prevented by building safer huts ($X^2 = 5.43$, $p < .05$), not sleeping in agricultural fields ($X^2 = 4.52$, $p < .05$), shifting the location of agricultural fields ($X^2 = 3.95$, $p < .05$), and cutting grass around homes ($X^2 = 3.92$, $p < .05$). In Lindi, people in attack villages were more likely to think that walking in larger groups would help prevent attacks ($X^2 = 4.36$, $p < .05$).

Villagers in both districts and in both village types gave statistically similar responses when questioned on what should be done to reduce lion attacks. Government assistance was the most common response (42%), which includes providing security, hunting offending lions, and providing resources to respond to attacks. Only 18% mentioned killing lions, and 14% mentioned the need for village game scouts to respond to attacks. Less than 10% of respondents mentioned measures like providing villagers with guns, more cooperation between villages, personal precautions such as building stronger homes, advice about conflict mitigation from researchers, and clearing bushes.

Table 3
Results from logistic regression model for Rufiji district showing district specific risk factors

Variable	*B*	SE	Wald	*df*	*p*
Gender[a]	−0.08	0.976	0.01	1	0.933
Age[a]	−0.01	0.034	0.02	1	0.880
Main home located on agricultural field[a]	−0.64	0.876	0.53	1	0.467
Number of problem species reported*	−0.84	0.453	3.40	1	0.065
Days per year pigs sighted in village center*	0.01	0.005	3.66	1	0.056
Days per year pigs sighted in agricultural field**	0.01	0.005	6.00	1	0.014
Number of lions prey types sighted**	−0.43	0.191	4.96	1	0.026
Hut safety (elevated thatch hut)			6.09	2	0.047
Hut safety (ground level thatch/mud/mud brick structure)**	−4.26	1.743	5.97	1	0.015
Hut safety (does not sleep in agricultural field)	0.17	1.508	0.01	1	0.911
Constant	3.78	2.595	2.12	1	0.145

[a]These variables were controlled for and therefore never dropped from the model.
Significance $^{***}p < .01$, $^{**}p < .05$, $^{*}p < .10$.

Table 4
Results from logistic regression model for Lindi district showing district specific risk factors

Variable	*B*	SE	Wald	*df*	*p*
Gender[a]	−2.47	1.457	2.88	1	0.090
Age[a]	−0.03	0.052	0.29	1	0.587
Number of assets owned**	−2.01	0.884	5.19	1	0.023
Walking distance to firewood (min)**	0.08	0.032	5.90	1	0.015
Walking distance to water (min)**	0.09	0.034	7.40	1	0.007
Days walked to agricultural field per year*	−0.02	0.012	3.72	1	0.054
Nights slept outdoors per year**	0.10	0.045	4.63	1	0.031
Days per year bush pigs sighted in agricultural field**	0.05	0.023	4.85	1	0.028
Number of lions prey types sighted**	−1.84	0.801	5.29	1	0.021
House safety (mud/brick/cement house, metal/wood roof & door)			7.51	2	0.023
House safety (mud/brick house, thatch roof, metal/wood door)**	3.78	1.793	4.45	1	0.035
House safety (mud/brick house, thatch roof, thatch/pole door)	−1.40	1.723	0.66	1	0.418
Constant	5.19	4.466	1.35	1	0.245

[a]These variables were controlled for and therefore never dropped from the model.
Significance, $^{**}p < .05$, $^{*}p < .10$.

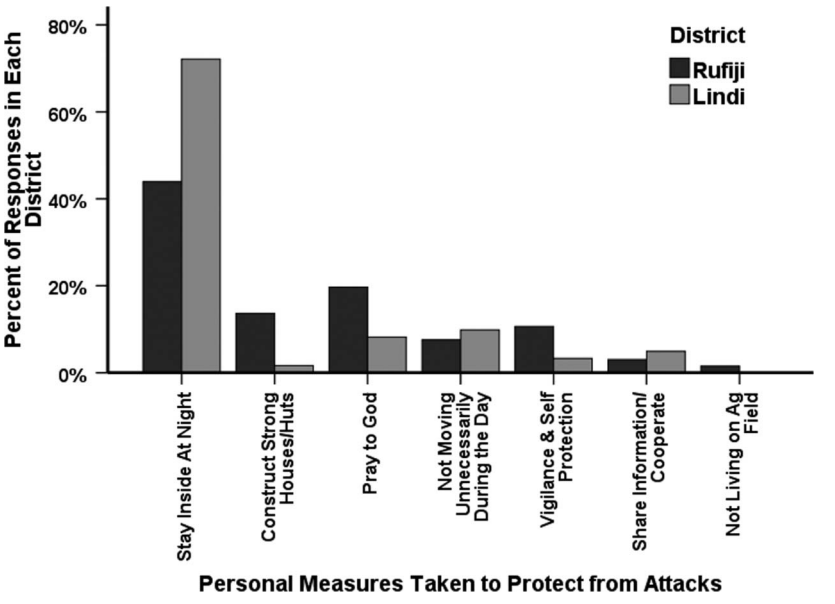

Figure 7. Measures people take to protect themselves from attacks ($X^2 = 17.34$, $p < .05$).

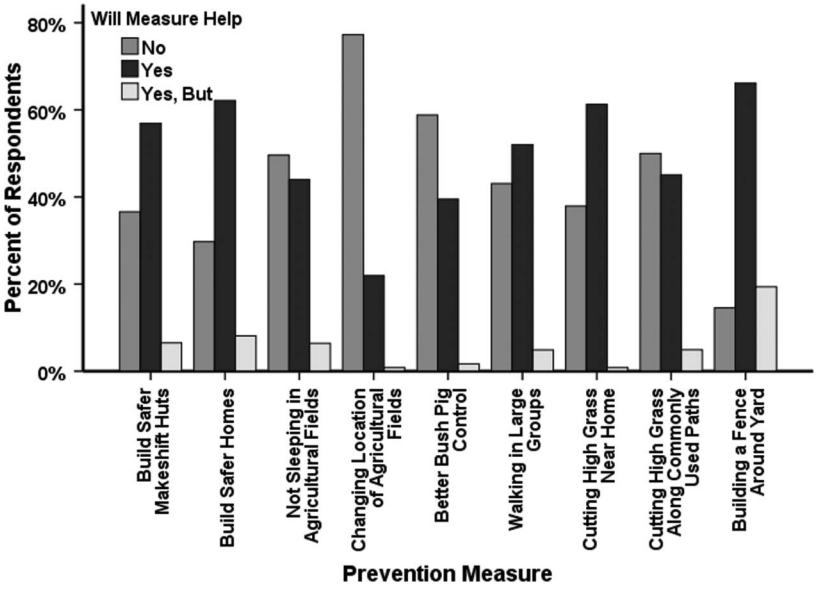

Figure 8. Responses of interviewees when asked if they thought specific actions would help prevent lion attacks.

Discussion

Qualitative Differences Between Districts

Differences in both ecology and culture provide a framework for understanding risk factors for lion attacks. The villages in Rufiji lie along the Rufiji River, on which the villagers are

dependent for water and food. Although the village centers lie on the north side of the river, the fertile areas are to the south. This means that people need to cross the river daily or live in their agricultural fields to tend and protect their crops. Since the primary livelihood is subsistence agriculture, villagers spend considerable time on the south side of the river. At the same time, the village centers—schools, shops, people's homes—and the main road lie to the north of the river, requiring villagers to travel between the village centers and the agricultural fields. Since most people have a home at the village center, they build temporary structures on the south side of the river, where they spend most of their time during harvest seasons for upwards of seven to ten months per year. The harvest season is a critical time to sleep in agricultural fields, as pests like bush pigs, warthogs (*Phacochoerus africanus*), vervet and blue monkeys (*Allenopithecus nigroviridis, Cercopithecus mitis*), yellow baboons (*Papio cynocephalus*), and even elephants (*Loxodonta africana*), come regularly to raid crops. Anecdotal evidence from villagers suggests that lions are predominantly found on the south side of the river and are at least partially blocked from moving into the villages by the river.

Much like in the Rufiji River Valley, people in the Sudi-Mingoyo Area of Lindi district subsist mainly on small-scale agriculture, but unlike in Rufiji, they have no clear physical feature that defines the location of agricultural fields. Thus, agricultural fields can be anywhere from a five minute walk to a two and a half hour walk each way from village centers, but overall they tend to be closer to village centers on average than in Rufiji. In addition, people rarely choose to sleep in their agricultural fields, but rather spend most of the year in their homes in the village centers. This is most likely because the main crop pests in Lindi, monkeys, are diurnal and do not require people to protect crops at night, whereas in Rufiji, one of the main crop pests are bush pigs, a nocturnal species. Another difference between Rufiji and Lindi is the location of water. Unlike in Rufiji, people in Lindi do not fetch water from a river; instead, they use water pumps in the village or travel to wells. The distance traveled each way to wells can be as long as an hour, and even when there are water pumps in the village, they may be dry, causing people to walk to neighboring villages.

District-Level Variations in Human Activity Patterns During Lion Attacks

Along with an awareness of the ecological and cultural difference between the districts, data on human activity patterns during lion attacks provides further information for understanding key differences between Rufiji and Lindi districts. In Rufiji, the majority of attacks occurred at night, inside structures located in agricultural fields while people were sitting, resting, or sleeping inside. Victims in Rufiji therefore tended to be accompanied by other people during the attacks. In Lindi, attacks mostly occurred outside homes in either the village center or agricultural fields, while people were conducting various domestic activities or walking along roads and paths outside the village center. The attacks in Lindi predominantly occurred in the late evening, while individuals were alone, walking home or preparing to retire for the night.

District-specific conditions explain these results. In Rufiji, the separation created by the river causes attacks to be located primarily in agricultural fields, where more lions are present and where people often sleep in unsafe structures. In Lindi, there are no barriers between agricultural fields and village centers, therefore lions move freely and attack people in both locations. Since most people in Lindi do not sleep in their agricultural fields, and since walking distances to resources are quite variable, people are more susceptible to attack while walking along paths and roads. In addition, since village homes are stronger than structures on agricultural fields, most attacks occur outside homes.

Village-Level Variation of Risk Factors

It is clear from the analysis of the questionnaire data that human activities and wildlife presence varies between villages with and without a history of attacks. Since we chose villages with similar ecological surroundings, these differences should help clarify the factors that increase the risk of lion attacks. Due to the small number of study villages, statistical differences could have resulted from chance or unmeasured variables, however, most of the significant factors relate to obvious risk factors. Additionally, differences do not come from lion absence, as all villagers reported lions roaming through their village during the 2001–2004 outbreaks and lion presence was not a significant variable in any logistic regression models.

Six key determinants emerge from the logistic regression of village-level variation that combines both districts: distance walked to resources, bush pig presence, wild prey diversity, sleeping outdoors, socioeconomic variables, and home safety. People in attack villages walk longer distances to firewood, water, and neighbors than people in villages without attacks. On average, people will walk 52 min per day for firewood with some people traveling 2 h each way, not including the time spent collecting firewood in unsafe areas. People usually retrieve water two to three times a day and walk an average of 20 min each way with some traveling up to 2 h to arrive at water. People also spend time visiting neighbors, traveling an average of about 5 min, although occasionally walking as long as 30 min, often in the evening hours. With no electricity and lions roaming freely, even a short walk to a neighbor's house after dark can pose a significant risk. Distance to agricultural fields was surprisingly not a significant variable in the model.

People see bush pigs more frequently in attack villages as compared with non-attack villages. Bush pigs increase the risk of attack in two ways. First, bush pigs are major nocturnal crop pests that force people to sleep in their agricultural fields and even leave their huts in the middle of the night to chase bush pigs away. Secondly, bush pigs are a key lion prey species in places depleted of other prey, drawing lions into human-dominated areas. To compound things further, the human population of Rufiji and Lindi is predominantly Muslim, so people will not eat and rarely kill any type of pig. This ensures that bush pigs thrive in agricultural areas, despite being a major pest. Similar examples of the relationship between large cats and wild pigs are documented in Sumatra, another largely Muslim society, where wild pigs (*Sus scrofa*) draw tigers (*Panthera tigris*) into oil palm plantations. Much like with lions, pigs allow tigers to live in highly disturbed human dominated areas because they thrive as crop pests in the same areas (Maddox, Gemita, Wijamukti, & Selampassy, 2003).

People in attack villages see fewer types of other crop pests and lion prey than people in non-attack villages. Other crop pests include warthogs, monkeys, baboons, rodents, and elephants. Lion prey includes giraffe (*Giraffa camelopardis*), Grant's gazelles (*Gazella granti*), impala (*Aepyceros melampus*), bushbuck (*Tragelaphus scriptus*), duiker (*Cephalophus spp.*), and dikdik (*Rhynchotragus kirki*). Both categories of animals indicate levels of wildlife diversity and abundance. These results support earlier findings that lion attacks occur in areas where lions have a harder time finding food (Packer et al., 2005).

Another difference identified by the model is that people in attack villages spend more nights sleeping outdoors for weddings, funerals, memorial services, cultural festivals, and religious events. On these occasions, people will travel to other villages or homes within their village and often spend a few nights sleeping outside. For example, at funeral ceremonies, visitors sleep outside the home of the deceased for two to three nights. Lions have been known to attack individuals in large groups of sleeping people (unpublished data), further supporting this finding.

Results show that villages with wealthier individuals are less likely to be attacked than poorer villages, presumably because of greater resources for more solidly built homes and other protective measures such as fences. Indeed people in villages without attacks tend to live in more solidly built homes, while people in attack villages are more likely to live in homes built from thatch and grass. People in attack villages are also more likely to live in grass and thatch structures in their agricultural field, whereas people in non-attack villages either build mud structures or do not sleep in their agricultural fields. One noteworthy result warranting further investigation is that people in non-attack villages sleep in agricultural fields more nights a year then people in attack villages ($p < .10$). This may be because more people in non-attack villages live full-time in their agricultural field and invest in safer structures. Our data on hut safety show that sleeping in a secure structure made of mud or mud brick in an agricultural field is as safe as sleeping away from the field altogether. By sleeping in a secure structure, people can remain safe even in agricultural fields where attack risk is high.

Given the different environmental contexts discussed above, we can identify location-specific risk factors. In Rufiji, most attacks occur in agricultural fields, and risk is associated with bush pig sightings, decreased lion prey diversity, and poor agricultural hut construction. Although risks in Lindi are also associated with bush pigs, prey diversity, and weaker home construction, there are no barriers to lion movement and attacks are not confined to agricultural fields. Thus, attacks in Lindi are also associated with longer walking distances to resources, and more nights spent sleeping outdoors for traditional ceremonies. Although only significant at $p < .10$, our data suggest that people in attack villages in Lindi may walk to agricultural fields fewer days a year than people in non-attack villages, suggesting that walking to agricultural fields is not a risk factor. This is further supported by the fact that distance to agricultural field was not significant in any of the three regression models.

Attack Prevention

In order to formulate methods to prevent future attacks and to understand how people perceive risk, it is important to determine how people react to lion attacks, what kinds of precautions they take, and what they think should be done to reduce attacks. Villagers in Rufiji and Lindi respond to location-specific risk factors. The most common personal safety measure in both districts is to stay indoors after dark. Yet in Rufiji, people also build stronger homes and fences and show greater vigilance. In Lindi, where attacks occur just outside homes or while walking in peripheral areas, people mainly stay indoors at night or reduce unnecessary movement during the day.

The same location-specific pattern emerges when analyzing individuals' responses about recommended preventive measures. People from both districts generally agree on the utility of each method except for bush pig control. Bush pigs are the primary reason why people reside in agricultural fields in Rufiji—the same place where most lion attacks occur. Thus, it follows that people in Rufiji recognize a direct link between bush pigs and lion attacks and are more likely to consider controlling bush pigs as a means to reduce attacks.

Aside from bush pig control, people in both districts agreed on which measures would help prevent attacks. Since all of the methods we recommended could conceivably reduce attacks, the measures considered helpful by the majority of villagers were actually the tactics people thought they themselves could undertake. These responses do not necessarily identify measures that could best prevent attacks but instead identify measures that people believe are feasible and effective at the village level. Building safer structures and

fences, walking in larger groups, and cutting grass around homes are all measures people can accomplish, even with limited resources. However, not sleeping in agricultural fields, shifting agricultural fields, controlling bush pigs, and cutting grass along all commonly used paths are all measures that are hard for people to accomplish, or may lead to repercussions they cannot afford such as a limited crop harvest. Any project aimed at reducing attacks needs to be cognizant of such local-scale feasibility.

Villagers' views on strategies to reduce lion attacks offer insight into who they feel is or should be responsible for addressing the problem. The most common response was that government should provide assistance by removing lions and providing guns, game scouts, and security. Villagers also mentioned government assistance in vague terms with no specifications on the form of assistance and looked toward researchers to provide assistance. Only a small number of responses accepted full personal responsibility for dealing with lion attacks (personal protection measures, intra- and inter-village cooperation), although some responses such as hunting and killing lions, and clearing bushes suggested partial personal responsibility. The response to this question suggests that people feel somewhat detached from solutions; although lion attacks directly affect them, they do not feel like they have the ability to prevent future attacks.

One noteworthy finding is that people do not immediately suggest the eradication of lions. Even those who advocate lion control rarely state that all lions should be eliminated, instead, they say that the offending lion(s) should be hunted. This shows a surprising level of tolerance for lions given the high number of attacks in both districts. Of course, it is possible that our identity as lion researchers influenced responses to these questions. However, having spent many months talking to village leaders, relatives of victims, and survivors of attacks, we have found that lion attacks are a very emotional topic, and people generally do not hold back when discussing their fear, lack of control, or anger over the slow response from wildlife managers. If they are open about these issues, we believe that they are also being honest about not wanting to eliminate lions.

Conclusion

Our study identified distinct district- and village-scale risk factors for lion attacks. Our results support current knowledge by linking villages with lion attacks to low prey diversity and a high abundance of bush pigs, and identify additional risk factors linked to human activities. We show the need to investigate local-scale variations when developing tools to prevent human–carnivore conflict. Solutions tailored for Rufiji would not always be relevant in Lindi, but certain factors, like bush pigs, lion prey, and home/hut construction, are more universal. Our results also show that local responses to conflict often mirror the main risk factors, but that measures suggested by researchers may not always be locally feasible. Local knowledge is critical to developing feasible solutions to human–wildlife conflict. Thus, conflict-prevention strategies should be cognizant of local conditions and be tailored to site-specific human and environmental factors.

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