Research Article

Assessing Human–Wildlife Interactions in a Forest Settlement in Sathyamangalam and Mudumalai Tiger Reserves

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Abstract

India, a megabiodiversity nation, is home to 4,800 species and 1.3 billion people. The proximity of people and wildlife produces a wide variety of human–wildlife interactions particularly with forest-dwelling communities embedded deep within protected areas (PAs). We evaluated people–park relationships through the 421 families in Thengumarahada located between Sathyamangalam and Mudumalai Tiger Reserves in India. This settlement was originally granted land rights in 1948 but has been subleased many times over. We examined attitudes toward wildlife, PA, experiences of conflict, and challenges faced by people. Logistic regression models evaluated the factors associated with household losses and their attitudes. Thirty-four percent of households reported crop loss and 10% reported livestock predation. Crop loss was associated with growing rice and bananas and negatively with forest cover. Depredation was primarily associated with 87% of households grazing livestock in the forest. Usage of mitigation measures was not significantly associated with reducing conflict. Despite conflict losses and government pressure, only 34% of families expressed an interest in settling outside the reserved forest. People's motivations to remain in the forest hamlets included free resource availability (28%) and tradition-familiar livelihoods (29%). People's mistrust of the forest department was heightened by the lack of awareness about (29%) and payment of compensation (3%). Given the frequency of conflict, the lack of infrastructure, inadequate compensation payments, and limited interest in relocation, balancing people–wildlife relationships in the forests of Sathyamangalam and Mudumalai Tiger Reserves remains a formidable task.

Keywords

compensation, crop loss, India, livestock depredation, perception, wildlife

Introduction

Anthropogenic activities fragment natural landscapes, leading to increased interactions between wildlife and people inside and outside protected areas (PAs; Watson et al., 2016). Such interactions could be positive such as nature-based tourism that encourages people's affinity for wildlife and wild places while providing revenue and employment (Sinha, Qureshi, Uniyal, & Sen, 2012). Other benefits include pollination or hydrological services (Chang, Karanth, & Robbins, 2018; Kremen et al., 2007; Nesper, Kueffer, Krishnan, Kushalappa, & Ghazoul, 2017; Tscharntke et al., 2011). In contrast, negative interactions with wildlife are perceived to be severe when wide-ranging large mammals such as tigers, leopards, and elephants injure or kill livestock and people or damage crops and property (Athreya, Odden, Linnell, Krishnaswamy, & Karanth, 2013; Campbell-Smith, Sembiring, & Linkie, 2012; Dhanwatey et al., 2013; Dickman, 2010). Repeated failures of mitigation measures or delays and lack of transparency in compensation payments further intensifies such conflicts, leading to retaliation against wildlife (Athreya, Odden, Linnell, & Karanth, 2011; Karanth & Kudalkar, 2017). Thus, government and private agencies focused on PA management are continually tasked with balancing needs of people and wildlife.

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Globally, PAs covering 13% of land area are integral to conservation efforts (Venter et al., 2014). Many Indian PAs are embedded in fragmented anthropogenic landscapes. The lack of contiguous habitat makes it critical that existing PAs provide high-quality undisturbed habitats to sensitive endemic species or large-bodied, wide-ranging species (Das et al., 2006; Goswami, Vasudev, & Oli, 2014; Walston et al., 2010). The Indian government manages PAs in accordance with the Wildlife Protection Act of 1972. Indian PAs fall under International Union for Conservation of Nature (IUCN) Category II National Park, Wildlife Sanctuaries fall under IUCN Category IV Habitat/Species Management Area, and Conservation and Community Reserves fall under IUCN Category VI Protected Area with Sustainable Use of Natural Resources (Environmental Information System, 2018). In addition, the forests surrounding notified PAs often serve as corridors by allowing wildlife movement between larger PAs or smaller reserved forests (Joshi, Vaidyanathan, Mondo, Edgaonkar, & Ramakrishnan, 2013). Dispersing wildlife encounter people leading to the formation of *conflict hotspots* (Goswami, Sridhara, et al., 2014; Karanth & Kudalkar, 2017; Karanth & Surendra, 2018; Ogra, 2009). Human–wildlife conflict (HWC) is most severe within and surrounding PAs, given the rapid development of settlements and land-use change (Karanth, Jain, & Weinthal, 2017; Karanth & Kudalkar, 2017; Vasudev, Fletcher, Goswami, & Krishnadas, 2015).

In India, more than 66,900 incidents of HWC were reported to the government in 2013–2014, our study year. During this period, the state of Tamil Nadu paid compensation for 1,250 incidents of crop and property damage, 95 incidents of livestock predation, 70 cases of human injury, and 50 instances of human death, with a total of US$ 403,000 (INR 27.6 million; US$ 1 = INR 68) spent on compensation (Karanth, Gupta, & Vanamamalai, 2018). However, many incidents remain unreported, and therefore addressing conflict remains a focal priority. Species such as wild pig *Sus scrofa* and Asian elephant *Elephas maximus* are commonly associated with crop damage, while tiger *Panthera tigris*, leopard *Panthera pardus*, and jackal *Canis aureus* are associated with livestock depredation (Karanth & Kudalkar, 2017; Karanth & Surendra, 2018; Kumar, Bargali, David, & Edgaonkar, 2017).

In Tamil Nadu, we focus on the Thengumarahada settlement and its associated tribal hamlets located in the wildlife corridor linking Sathyamangalam Tiger Reserve (STR henceforth) and Mudumalai Tiger Reserve (MTR, henceforth). India's Forest Rights Act (2006) protects the rights of such local tribal hamlets to use forest products and land (Reddy et al., 2012; Saravanan, 2009). In 1948, the Madras Presidency permitted the people of Thengumarahada to farm the forest land. According to the original land leasing agreement, people were allowed to reside in and cultivate forest land. Subsequently, many of the residents have subleased the land for at least four decades and moved outside. Currently, all but three of the families in the settlement are considered to be unlawfully inhabiting forest land and are denied compensation following HWC (G.O. Ms. No. 2324, 1968; Jayachandran, personal communication, August 20, 2013). In Thengumarahada, we explored people–park relationships by evaluating patterns of crop loss and livestock depredation, local perceptions of the PA, PA management, and wildlife. Understanding the challenges faced by the people who interact regularly with wildlife is a vital aspect of developing viable conservation strategies. PA-specific case studies provide specific insights into the complex interactions between people and wildlife and can influence timely and relevant conservation management directed toward individual PAs (Karanth & Kudalkar, 2017; Packer et al., 2013).

Methods

Study Site

Our study took place in the settlement of Thengumarahada and two adjoining tribal hamlets—Hallimoyar and Kallampalayam—located in the foothills of the northeastern slopes of the Nilgiri Hills, a biodiversity hotspot. The settlement is located on the bank of the Moyar River, which is a major water source for people and wildlife living in and around these forests (Figure 1). The forests are contiguous with MTR (11°32′–11°43′ N, 76°22′–76°45′ E) to the west and STR (11°29′–11° 48′ N, 76°50′–77°27′ E) in the northeast, falling within the buffer zone of both PAs and acting as a vital wildlife corridor between Biligiri Rangaswamy Temple Tiger Reserve, Sigur Plateau, MTR, and Bandipur Tiger Reserve which together comprise the United Nations Educational, Scientific, and Cultural Organization (UNESCO) World Heritage site (United Nations Educational, Scientific, and Cultural Organization, 2012). Mudumalai National Park was established in 1940 and notified as a tiger reserve in 2007. The forests connecting MTR and STR were the home of the notorious brigand Veerappan, known for sandalwood and ivory smuggling, poaching, and kidnapping people. His presence marked a period of turmoil and a lack of organized conservation efforts in the region for decades (Government of Tamil Nadu, 2010; Jayachandran, personal communication, 2013). Following his death in 2004, the Sathyamangalam reserved forests were declared as a wildlife sanctuary in 2008 and upgraded to a tiger

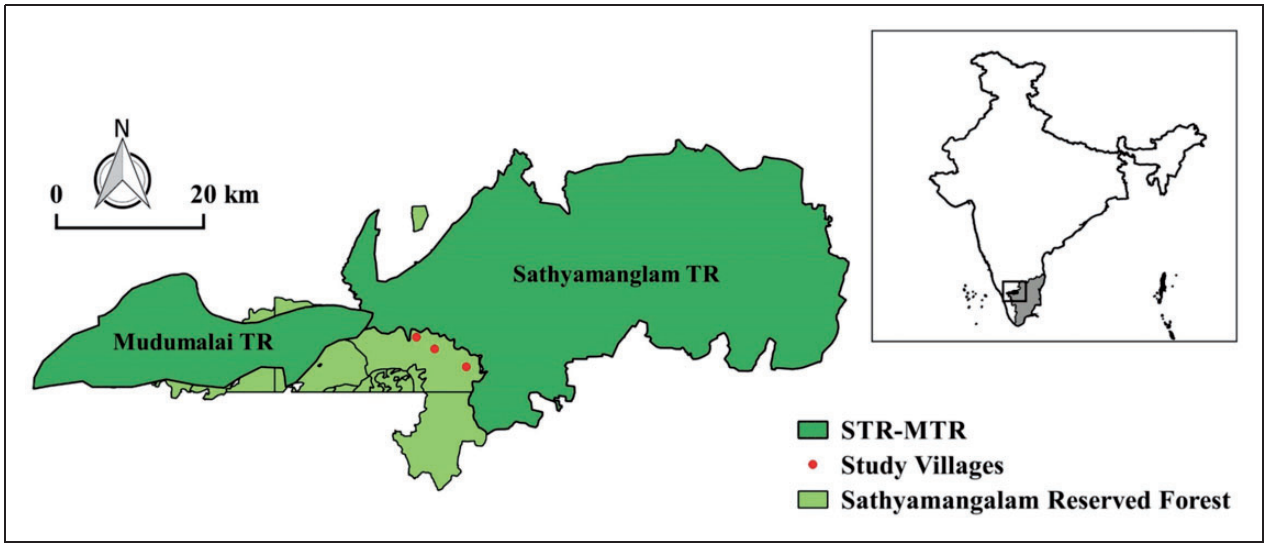

Figure 1. Location of study villages adjacent to Sathyamangalam (STR) and Mudumalai (MTR) reserves in Tamil Nadu.

reserve in 2013, making it the fourth tiger reserve in Tamil Nadu. STR's unique geographic location ensures connectivity, serving as a conduit for species movement and gene flow between the Western Ghats biodiversity hotspot and the Eastern Ghats (Government of Tamil Nadu, 2010; Reddy et al., 2012).

Prior to India's independence, the reserved forests between STR and MTR were unoccupied by settlements. In 1948, people of Kil Kotagiri village petitioned the government for allotment of fertile land in the Moyar River valley and received approximately 1,000 acres of land for the cultivation of crops by a lease arrangement (G.O. Ms. No. 4096, 1948). Despite the allotment of land to the Thengumarahada Cooperative Farming Society, the land was designated as Reserved Forest and was accordingly subject to regulations regarding alternate use and conversion of forest land (Forest Conservation Act, 1980; Jayachandran, personal communication, 2013). The agreement was that the government could resume rights to the forest land at any time or when it is required for any public purpose (G.O. Ms No. 53, 1961; Jayachandran, personal communication, 2013). The lease was renewed regularly until 1961, when the 500 acres leased was permanently assigned to the Society. The Society was given the right to allocate land for cultivation to its members, who must reside within the village to cultivate their land (G.O. Ms. No. 2324, 1968). However, due to repeated subleasing by residents of Thengumarahada, only 3 out of the 141 Society members resided within the village and cultivated land during our study period. All other residents using Society land in the village were considered to be encroaching upon the forest land illegally (G.O. Ms. No. 2324, 1968; Jayachandran, personal communication, 2013). Most villagers paid an average sublease amount of INR 8,400 (US$ 130), with an average lease duration of 6 months. The Society is responsible for renewing all subleases (Jayachandran, personal communication, 2013). Today, the settlement is a mix of communities comprising of Irulas, Soligas, Badagas, and immigrants from the neighboring towns and villages (Census, 2011; Government of Tamil Nadu, 2010). The human population density in the Nilgiris district where Thengumarahada and its surrounding hamlets are located is 287 persons/sq. km, and the livestock density is 41/sq. km (Census, 2011; Livestock Census of India, 2012).

The forests of STR and MTR are classified in the South Western Ghats moist deciduous forest and South Deccan Plateau dry deciduous forest ecoregions. STR and MTR are home to a wide array of ecologically valuable species, including the Asian elephant (*Elephas maximus*), Bengal tiger (*Panthera tigris*), Indian leopard (*Panthera pardus fusca*), gaur (*Bos gaurus*), barking deer (*Muntiacus muntjak*), chousingha (*Tetracerus quadricornis*), and blackbuck (*Antilope cervicapra*; Government of Tamil Nadu, 2010; Suresh, Dattaraja, & Sukumar, 1996).

Household Structured Surveys

Structured household questionnaires were administered by three trained assistants to 421 individual households after obtaining their consent to participate in the interview across the three villages within the reserved forests connecting STR and MTR. Households were randomly selected based on the accessibility and willingness of the household member to participate in the survey. The

interviews were conducted in the local language Tamil and were designed to collect demographic, forest-use, and HWC data from 2013 to 2014. One adult respondent of each household were interviewed about household size, education levels, agricultural practices, land and livestock ownership, and access to forest land and resources. Respondents were also asked to provide detailed information about losses incurred due to wildlife conflicts, the species involved, mitigation measures used, and the perceived access to local government compensation programs. Information on local perceptions of STR and MTR, the forest department, and wildlife species frequently encountered in the buffer zone of the two PAs was also gathered, following protocols established earlier (Karanth, Gopalaswamy, Defries, & Ballal, 2012; Karanth, Gopalaswamy, Prasad, & Dasgupta, 2013). Questions were restricted to the most recent year (2013–2014) to minimize recall error. Centre for Wildlife Studies institutional review board approved the survey protocols.

To complement the survey data, we also incorporated spatial data such as land cover (National Remote Sensing Centre Indian Space Research Organisation, 2014) and elevation (National Aeronautics and Space Administration Land Processes Distributed Active Archive Center, 2011). Distance to the nearest water body, forest cover and type, and elevation for each household were also included in the models as predictors of crop loss, livestock depredation, and attitudes toward conservation efforts in the two tiger reserves (Karanth et al., 2013; Karanth & Surendra, 2018).

Variable and Model Selection

Survey and spatial data were used to generate a set of models predicting crop loss, livestock depredation, and perceptions of wildlife conservation in STR-MTR. We selected 16 variables that we expected to be associated with crop loss, 9 for livestock predation and 18 for attitudes toward wildlife and wildlife conservation in STR and MTR (Table 1). We tested collinearity using Pearson's correlation coefficient and eliminate variables from pairs with Pearson's $r > .60$. We expected educated, older individuals with larger plots of land to view conservation more positively owing to higher wealth and longer experience of living alongside wildlife (Agarwal, 2000; Bhattarai & Fischer, 2014; Gore & Kahler, 2012; Harihar, Ghosh-Harihar, & MacMillan, 2014; Karanth & Kudalkar, 2017; Ogra & Badola, 2008). We predicted household size and gender to be determinants of attitudes toward conservation but did not conclusively hypothesize about the directionality of said attitudes (Ogra & Badola, 2008). We expected families facing low HWC and those receiving higher total compensation and have mitigation ability to be potentially favorable toward conservation (Karanth & Nepal, 2012; Madhusudan, 2003; Nagendra, Rocchini, & Ghate, 2010). We also expected respondents who used forest resources and reported conflict with the forest department to be less likely to favor conservation actions in the forests (Naughton-Treves, 1998; Ogra, 2009; Sekhar, 1998; Talukdar & Gupta, 2017). Women are more exposed to daily hardships of gathering resources from inside the forest and managing the household, thus placing them at the receiving end HWC (Agarwal, 2000; Barua, Bhagwat, & Jadhav, 2013; Dickman, 2010; Ogra, 2008). Therefore, we expected to see a gender bias in our results, with women more likely to be hostile toward conservation efforts.

Table 1. Variables Analyzed as Potential Predictors of Crop Raiding, Livestock Depredation, and Perceptions of the Park.

	Crop raiding	Livestock depredation	Perceptions of STR
Land size	+	NA	+
Rice	+	NA	NA
Groundnut	+	NA	NA
Banana	+	NA	NA
Soya	+	NA	NA
Number of crops	+	NA	NA
Marigold	–	NA	NA
Forest cover	+	+	NA
Distance to water	–	–	NA
Household size	–	–	±
Number of crop raiding mitigation methods	–	NA	+
Grazing	NA	+	NA
Number of large livestock	NA	+	NA
Number of small livestock	NA	+	NA
Total number of livestock	NA	+	NA
Number of livestock predation mitigation methods	NA	–	+
Female	NA	NA	–
Literacy	NA	NA	+
Age	NA	NA	+
Do STR-MTR exist to protect wildlife?	NA	NA	+
Do STR-MTR benefit you?	NA	NA	+
Conflict with FD?	NA	NA	–
Benefits from FD?	NA	NA	+
Resource extraction from forest?	NA	NA	–
Have conservation efforts worsened your livelihood?	NA	NA	–
Has government visited postconflict incident?	NA	NA	+
Total income loss	NA	NA	–
Have you experienced HWC?	NA	NA	–

Note. STR-MTR = Sathyamangalam and Mudumalai Tiger Reserves; HWC = human–wildlife conflict; FD=Forest Department.

Models of crop and livestock loss were based upon households reporting these losses during the study period. We expected a positive association between land size and crop raiding, with households growing a greater variety of crops facing more crop loss (Gadd, 2005; Karanth et al., 2012). Households using a greater number of and greater variety of mitigation measures were expected to show a negative association with both crop raiding and livestock depredation (Bhattarai & Fischer, 2014; Dhanwatey et al., 2013; Karanth et al., 2013; Karanth & Kudalkar, 2017). We did not assess the relative effectiveness of individual mitigation measures as we relied primarily upon recall data for our conflict surveys. Proximity to water bodies and density of forest cover were expected to have a strong positive association with crop loss and livestock depredation (Bhattarai & Fischer, 2014; Gadd, 2005; Karanth et al., 2012). We expected a positive association between grazing of livestock on communal forest lands and livestock depredation and a negative association between household size and livestock depredation (Karanth et al., 2017; Ogra, 2009).

Given that our response variables were binary, we constructed logistic regression models to assess the predictive power of our covariates. Then, we calculated Akaike's information criterion adjusted for a small sample size (AICc). This criterion uses parsimony to find the best set of models to explain trends in data (Burnham & Anderson, 2002). Based on a priori predictions, we tested eight models for crop raiding, eight models for livestock depredation, four models for socioeconomic factors influencing attitudes toward conservation, three models for the effects of HWC and conflict-inducing behaviors on attitudes toward wildlife conservation, and four models for the self-reported interactions with conservation officers and policies. The top models (cumulative AICc weights > 0.95) were selected with the aim of optimizing parsimony and goodness-of-fit (Burnham & Anderson, 2002).

Results

History, Demographics, and Land Ownership

At the time of our study, only 40% of survey respondents cultivated their land, which went against the stipulations placed on land ownership in Thengumarahada by the government (Jayachandran, personal communication, 2013). The average landholding size was 2.3 acres (ranging from zero to nine acres) with 68% of the respondents born in STR-MTR. Other sociodemographic details of these households are shown in Table 2.

Table 2. Characteristics of Surveyed Households in Thengumarahada.

Number of households sampled	421
Number of people in household (avg.)	4
Gender	43% Female, 57% Male
Literacy (avg.)	67%
Born at Sathyamangalam	68%
Avg. landholding size	2.29 acres (0.93 hectares)
Landowners	48%
Agriculture as primary source of income	39.91%

Agricultural Practices and Reported Crop Loss

Twenty-four crops were grown in STR, including lentils and pulses, oilseeds, cereals, and vegetables. The most commonly cultivated crops were groundnut (35% of total farmed crops), rice (32%), soya (30%), and banana (27%). Three crops—rice (50%), groundnut (35%), and marigold (13%)—experienced declines in production between 2004 and 2014. A majority of HWC cases (34%) in the settlement were attributed to crop loss by wild pigs (71%) and elephants (44%). Families reporting crop loss faced monetary losses of almost INR 7,450 (US$ 108), ranging from INR 0 to INR 2,00,000 (US$ 0–US$ 2,900). Peak crop damage by wildlife occurred between November and January.

We modeled factors associated with household-level crop loss and generated three top-ranked models (cumulative AIC weight > 0.95, Table 4). As predicted, households were more likely to lose crops if they cultivated rice ($\beta = 0.38 \pm 0.10$ SEM) and were located closer to the forest ($\beta = -0.62 \pm 0.24$). Banana cultivators were less likely to lose their yield ($\beta = -0.90 \pm 0.40$). Larger households were seen to be positively associated with crop damage, unlike our prediction ($\beta = 0.20 \pm 0.11$).

Commonly used crop-related mitigation measures in the study site were fencing (37%), night-time crop vigilance (33%), and improved lighting (17%, Figure 2). People were most likely to use fencing (76%), followed by trenches (61%) and lighting (57%), as suggested mitigation techniques. However, there was no association found between the number of mitigation measures used or individual mitigation measures with preventing crop damage.

Livestock Ownership and Depredation

At the time of the survey, 87% of village-owned livestock were grazed in the buffer zone of STR-MTR, while 13% of livestock were stall-fed, when compared with all livestock being grazed in the forest a decade

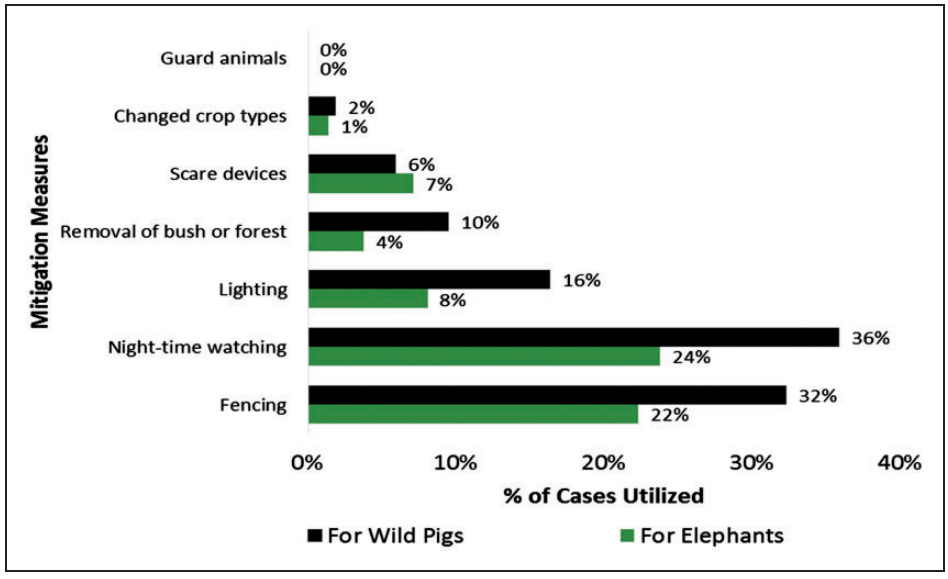

Figure 2. Mitigation measures used to prevent crop loss in Thengumarahada.

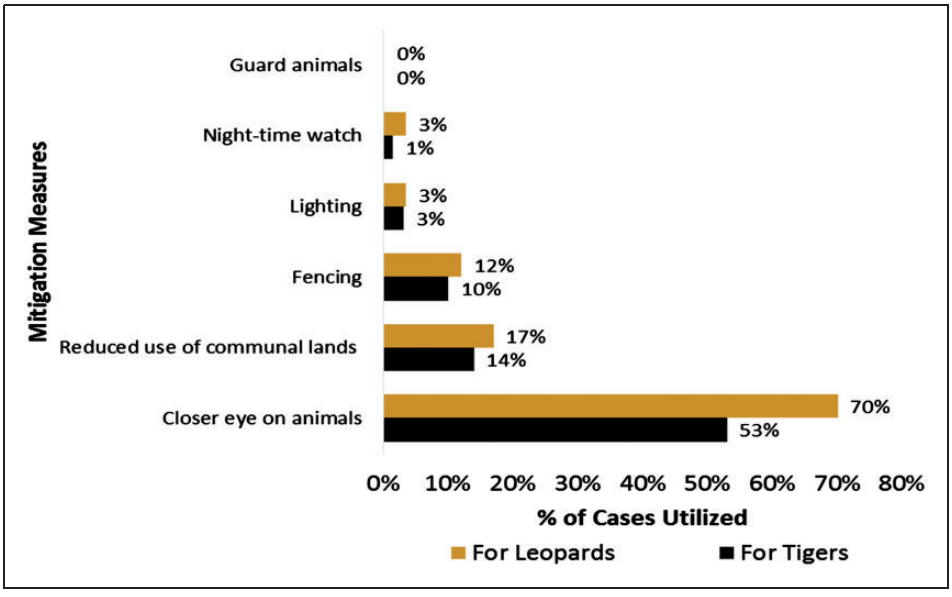

Figure 3. Mitigation measures used to prevent livestock predation in Thengumarahada.

ago. On average, respondents grazed livestock for 154 days in the year inside the reserved forests. Of the 40% of respondents reporting conflict, 10% reported livestock depredation, with cases primarily attributed to leopards (19%), tigers (11%), and jackals (10%). Most cases of depredation by big cats were reported from November to January. Families facing livestock depredation reported monetary losses of about INR 2,360 (US$ 35), ranging from INR 0 to INR 1,20,000 (US$ 0–US$ 1,741). The majority (82%) of respondents do not use mitigation for livestock depredation (Figure 3).

We then modeled self-reported livestock loss by households in Thengumarahada and its associated hamlets and generated two top-ranked models (cumulative AIC weight >0.95, Table 4). As predicted, households grazing livestock in the forest were more likely to face livestock depredation ($\beta = 2.88 \pm 0.45$). Other variables were not significant predictors of livestock predation.

Conflict and Compensation

HWC was reported by 40% of respondents (Table 3). Crop loss was the most common type of conflict (34%),

Table 3. Characteristics of Human–Wildlife Conflict as Reported by Households in Thengumarahada.

Households reporting crop loss	34%
Avg. income loss from crop raiding in INR (range)	7,447 (1,000–2,00,000)
Top crop raiding species	Wild pig (71%), elephant (44%)
Top crop loss mitigation measures	Fencing (37%), night-watching (33%), lighting (17%), removal of forest/bush (10%)
Top months for crop raiding	November–January
Households reporting livestock predation	10%
Avg. income loss from livestock predation in INR (range)	2,359 (3,000–1,20,000)
Top carnivores	Leopard (19%), tiger (11%), jackal (10%)
Top livestock predation mitigation measures	Watching animals (11%), reduced use of communal lands (2%), fencing (2%)
Top months for livestock predation	November–January
Households reporting losses to authorities	39%
% Aware about government compensation	29%
% Receiving government compensation	3%

followed by livestock predation (10%), and human injury (3%). There were no reported cases of human death during our study period. More people were afraid of damage to assets (including crops, livestock, property, and quality of life) from herbivores (48%) than from carnivores (17%). Apart from specific mitigation measures to protect individual land holdings and livestock from wildlife, 39% of respondents said that members of their household participate in communal activities for mitigating HWC, where communal meetings were the major activity (28%).

Tamil Nadu Forest Department officials visited sites of conflict within 24 hr of a reported conflict incident in 52% of conflict cases. Despite this, few (29%) people were aware of government compensation programs for crop loss. Tamil Nadu has a fairly comprehensive policy for compensation and paid INR 32 million (US$ 465,960) for HWC cases in 2012–2013 (Karanth et al., 2018).

Perceptions and Attitude of Locals Toward Wildlife and PAs

STR and MTR are integral to the livelihoods of people residing in these settlements. The majority of respondents (97%) identified climate regulation and the provision of clean water as the top benefits of living in the reserved forest. Many respondents (84%) believed that these forests should be protected for the future, and wildlife is best protected by restricting forest use (73%). They also believed that PAs were created to prevent poaching (71%), and government played a major role in restricting forest use by placing protection on the forests (53%).

We assessed perceptions of government conservation efforts and associated restrictions on forest use in Thengumarahada and found two best-ranked models (cumulative AIC weight >0.95, Table 4). Families owning larger plots of land were more likely to view conservation efforts in the region in a negative light ($\beta = -1.05 \pm 0.29$), contrary to what we hypothesized. Larger households (with more than four people) were more likely to view conservation efforts positively ($\beta = 0.24 \pm 0.13$). Most respondents (64%) were willing to change their perceptions of wildlife and encourage wildlife conservation (58%) in the absence of crop and livestock damage.

We examined forest resource use by residents of Thengumarahada. Many respondents (76%) supported the ongoing conservation efforts in the PAs and the wildlife within it, stating that restrictions on forest use were necessary to preserve the forests and wildlife for future generations. Most respondents collected water (90%) and dead trees (86%) from the PA, with 43% also harvesting fish from the Moyar River. People also grazed livestock within the PAs (26%) and collected nontimber forest products (17%). Many (79%) respondents stated that women were disproportionately affected by conflict. Conflict was primarily said to impact the time women dedicated toward household chores (47%). The tasks most hindered by HWC were the time spent doing home duties (90%) and the gathering of fuelwood (79%). However, this result is at odds with the overall positive attitude seen in female respondents toward conservation of the PAs ($\beta = 1.09 \pm 0.15$).

Discussion

Household-level surveys provide insights about how people live and interact with the surrounding forest and wildlife (Banerjee, Jhala, Chauhan, & Dave, 2013; Barua et al., 2013; Dhanwatey et al., 2013). In Thengumarahada,

Table 4. Top-Ranked Models (Cumulative Weight > 0.95) and Beta Coefficients for Predicting Household-Level Support for Conservation Efforts in STR-MTR.

	Crop loss		Livestock predation	Perceptions of conservation	
Variables	Land size + rice + banana + groundnut	Land size + number of crop raiding mitigation methods + distance to water + household size + grazing + forest cover + soya + rice + groundnut + banana + marigold	Grazing	Land size + household size	Gender + age + household size + literacy + land size
AICc	530.70	535.27	233.423	442.977	446.394
Delta AIC	1	0.67	0	0	3.417
AIC weight	0.55	0.37	0.901	0.79	0.143
Intercept (*SE*)	–0.57 (0.13)	–0.33 (0.24)	–3.81 (0.41)	1.04 (0.15)	1.09 (0.15)
Coefficients					
Land size	–0.006 (0.13)	0.07 (0.16)	NA	–1.05 (0.29)	–0.96 (0.29)
Rice	0.38 (0.10)	0.13 (0.40)	NA	–	NA
Groundnut	–0.04 (0.36)	–0.13 (0.40)	NA	–	NA
Banana	–0.901 (0.40)	–0.89 (0.42)	NA	–	NA
Soya	–	–0.30 (0.42)	NA	–	NA
Number of crops	–	–	NA	–	NA
Marigold	–	0.19 (0.44)	NA	–	NA
Forest cover	–	–0.615 (0.24)	–	–	NA
Distance to water	–	–0.11 (0.12)	–	–	NA
Number of household members	–	0.20 (0.11)	NA	0.24 (0.13)	0.24 (0.13)
Number of crop mitigation methods	–	–0.10 (0.14)	NA	–	–
Grazing	–	0.56 (0.23)	2.87 (0.45)	–	NA
Number of large livestock	NA	NA	–	–	NA
Number of small livestock	NA	NA	–	–	NA
Total number of livestock	NA	NA	–	–	NA
Number of livestock protection mitigation methods	NA	NA	–	–	–
Gender	NA	NA	NA	–	1.09 (0.15)
Literacy	NA	NA	NA	–	–0.10 0.12
Age	NA	NA	NA	–	–0.08 0.12
Do STR-MTR exist to protect wildlife?	NA	NA	NA	–	–
Do STR-MTR benefit you?	NA	NA	NA	–	–
Conflict with FD?	NA	NA	NA	–	–
Benefits from FD?	NA	NA	NA	–	–
Resource extraction from forest?	NA	NA	NA	–	–
Have conservation efforts worsened your livelihood?	NA	NA	NA	–	–
Has government visited post-conflict incident?	NA	NA	NA	–	–
Total income loss	NA	NA	NA	–	–
Have you experienced HWC?	NA	NA	NA	–	–

Note. AIC = Akaike's information criterion; AICc = Akaike's information criterion adjusted for a small sample size; STR-MTR = Sathyamangalam and Mudumalai Tiger Reserves; HWC = human–wildlife conflict; FD=Forest Department.

crop loss was species-dependent, with wild pigs and elephants responsible for the damage of large swaths of crops compared with deer and primates. Overall, we found that conflict losses were lower in Thengumarahada compared with settlements on the periphery of other previously studied PAs in India (Karanth et al., 2013, 2017; Karanth & Kudalkar, 2017; Karanth & Surendra, 2018). In Thengumarahada, average monetary losses due to crop damage estimated at INR 7,450 (US$ 108) were far lower than the average losses to households outside PAs such as

Bhadra Tiger Reserve (INR 24,687; US$ 360), Nagarahole Tiger Reserve (INR 21,646; US$ 315), Bandipur Tiger Reserve (INR 22,015; US$ 320), and Biligiri Ranganathaswamy Temple Tiger Reserve (INR 17,144; US$ 250) in neighboring Karnataka (Karanth & Kudalkar, 2017).

Although located deep within the forest, many households (39%) farmed for a living. Factors such as land size and crops grown were associated with crop loss similar to previous studies (Chhangani, Robbins, & Mohnot, 2008; Karanth et al., 2012; Karanth & Kudalkar, 2017; Sitati et al., 2005). We found a positive association between family size and crop raiding corroborating other studies that linked larger family size to increased vigilance and thus lower crop loss (Agarwal, 2000; Chhangani et al., 2008; Madhusudan, 2003; Sitati et al., 2005). In Thengumarahada, the proximity to forest was negatively associated with crop loss, which may be due to these villages being located within dense forest and not at the forest edge, unlike in other PAs (Karanth et al., 2013; Sitati et al., 2005). In Thengumarahada, we found lower than average usage of crop loss mitigation (33%), compared with usage in other PAs such as Bandipur (58%), Biligiri Rangaswamy Temple (57%), Kumbhalgarh (55%), Dandeli-Anshi (55%), Kanha (49%), and Tadoba-Andhari Tiger Reserve (TATR, 37%; Karanth et al., 2013; Karanth & Surendra, 2018).

The practice of free-grazing livestock by people living in and adjacent to PAs is common across India (Karanth & Kudalkar, 2017; Karanth & Surendra, 2018; Mishra et al., 2003; Ogra & Badola, 2008). Yet, livestock predation was less frequently reported than crop loss across PAs in India (Karanth et al., 2017, 2018). In Thengumarahada, majority of the livestock (87%) are still grazed inside the forests, accounting for the comparatively high rate of livestock depredation. We also found that people were less likely to protect livestock than crops. This practice increases the likelihood of livestock depredation, even when herds are watched (Dhanwatey et al., 2013; Harihar et al., 2014; Karanth et al., 2017; Mishra et al., 2003). Prior studies in Kanha (Central India) have households that faced high frequencies of predation in association with intensive grazing of livestock inside the PA (Karanth & Kudalkar, 2017). Unfortunately, it is difficult to regulate or restrict these practices, especially with often marginalized forest-dwelling communities (Banerjee et al., 2013; Harihar et al., 2014; Karanth et al., 2012). Stall-feeding and use of guard animals may reduce fatal encounters with carnivores, thus reducing losses to households in these PAs (Karanth & Kudalkar, 2017; Mishra et al., 2003; Treves & Karanth, 2003).

Monetary losses due to livestock predation in Thengumarahada averaged INR 2,360 (US$ 34) were similar to losses incurred by households surveyed in the periphery of other PAs in Karnataka and Rajasthan (Karanth & Kudalkar, 2017). In contrast, PAs in Central India, such as Melghat Tiger Reserve, face higher losses due to livestock predation by tigers, amounting to INR 31 crore (US$ 45,300) per annum in regions of high tiger occupancy (Harihar et al., 2014). We expected greater monetary losses for Thengumarahada households, but this may be attributed to the smaller sample size in our study in STR-MTR and thus less loss overall. Another possible explanation is the comparatively higher number of families owning goats and sheep when compared with large livestock such as cattle and buffaloes, thus resulting in lowered cost for losing small livestock (Margulies & Karanth, 2018).

Shrinking spaces for wildlife in India increases interaction between people and wildlife and associated losses (Karanth et al., 2018). With an increase in negative interactions, it is imperative that current policy focuses on tangible solutions targeting these conflict scenarios and building tolerance toward wildlife by local residents. Currently, 18 out of India's 29 states process compensation requests for cases of property damage, 22 states process cases of crop loss, 26 states process cases of livestock depredation, and 28 states compensate families for human injury and death due to wildlife conflict (Karanth et al., 2018). The Indian government advocates compensation for HWC, but the eligibility criteria, application procedures, and implementation and payment procedures vary from state to state. Tamil Nadu states compensation policy provides reimbursements of up to INR 25,000 per acre (US$ 376 per acre) for crop damage, up to INR 10,000 (US$ 150) for the loss of milch cattle or bullocks, up to INR 30,000 (US$ 451) for human injury, and up to INR 3,00,000 (US$ 4,513) for human death (Government of Tamil Nadu, 2010).

Previous research has found that rural communities were not adequately aware about government compensation programs and their eligibility for various compensation packages, highlighting an urgent need to streamline and regulate this procedure (Karanth et al., 2012; Karanth & Kudalkar, 2017). Wildlife-associated losses were reported to government officials by 39% of respondents, while 29% respondents were aware of existing government compensation schemes. Only 3% of people reporting conflict were provided compensation by the government. This reporting of losses is similar to Central India and Rajasthan but significantly lower than other PAs in the Western Ghats (Karanth et al., 2017; Karanth & Kudalkar, 2017). This may affect the perception of the magnitude of losses incurred by people due to wildlife, impeding conservation efforts in STR and MTR (Agarwala, Kumar, Treves, & Naughton-Treves, 2010; Karanth & Nepal, 2012; Megaze, Balakrishnan, & Belay, 2017). Compensation

payments are higher across most of the country than seen in STR-MTR, with government officials preferring to address claims by people residing in the administrative buffer of PAs (Karanth et al., 2012, 2013; Karanth & Kudalkar, 2017). In this case, the villages fall within the overlapping buffers of MTR and STR, but due to efforts to relocate villages from the buffer zones of these PAs, compensation for losses inside the reserved forest is minimal (Jayachandran, personal communication, 2013).

Scenarios and repercussions of HWC faced in Thengumarahada are similar to those seen in other forest-dwelling communities across India. Studies from Bhadra Tiger Reserve, prior to the resettlement of families to the PA's periphery, indicate high frequency and severity of encounters with wildlife and a dependence upon collection of forest produce for livelihoods (Karanth, Curran, & Reuning-Scherer, 2006; Madhusudan, 2003). Forest-dwelling communities were seen to have high impacts upon forest health and ecology, leading to government incentivizing and implementing voluntary resettlement of these villages outside the PA (Harihar et al., 2014; Karanth, 2007; Karanth et al., 2006). However, in the case of TATR, which also hosts villages inside the PA boundaries, forest health was less impacted by villages within the PA, whereas villages on the periphery of TATR contributed far more to fragmentation and loss of forest cover (Nagendra et al., 2010; Vaidyanathan et al., 2010). However, it is worth keeping in mind that the peripheral villages of TATR have a larger population overall than those within the PA, which could play a major influence on the impacts of settlements on the health of the PA (Nagendra, Pareeth, & Ghate, 2006; Vaidyanathan et al., 2010). In addition, unlike Thengumarahada, a majority of people living within the PA boundaries are employed by the forest department (Nagendra et al., 2010). These interior villages also depend heavily upon forest produce for subsistence as well as cash income, unlike in Thengumarahada, and those villages that are deep inside the forest have a lack of amenities and poor access to infrastructure, something that we came across in our study site as well (Nagendra et al., 2010).

The forests of STR-MTR play an important role in the livelihood security of people, due to their heavy dependence on forest resources. While 76% of the respondents said they believed that the ongoing conservation of PAs and their wildlife was important, we noted that the daily forest-use practices of respondents still went against restrictions placed on forest use by the Forest Conservation Act (1980). Families listed various ways in which they used the forests for their benefits, as seen in TATR and Melghat (Harihar et al., 2014; Nagendra et al., 2010). It is important to recognize that at the time of our study, these villages were exempted from the stipulations of forest and wildlife laws by virtue of their tribal status and due to the original agreement between the Thengumarahada Farming Society and the Madras Government (Jayachandran, personal communication, 2013). These stipulations impede the mandate of the forest department—to render forest spaces inviolate for wildlife—by invalidating their ability to place restrictions upon forest dwellers or to relocate villages from within the forest to the outskirts (Ogra, 2009).

Despite restrictions, many respondents (79%) expressed happiness that their village was located within the reserved forest, and many (75%) recognized the importance of protecting areas for wildlife and prioritized the existence value of endemic species (62%). This provides the groundwork for future dialogue regarding forest usage and possible relocation of these villages from inside the forest. This also points toward the importance of the history and culture of local forest dwellers in determining the attitudes of local people toward conservation. A study conducted by Talukdar and Gupta (2017) in villages around Chakrashila Wildlife Sanctuary in Assam found that most families believed that humans and wildlife could coexist with ease and that families settled within the forest believed they were not suited to a lifestyle outside of the PA. This was seen in Thengumarahada where free resource availability (28%), and tradition and familiarity (29%) were cited as incentives to remain in the forest hamlets. This points to the necessity to study families' perceptions and needs on resettlement at the individual PA level (Megaze et al., 2017; Talukdar & Gupta, 2017).

We also explored the relationship between gender and the effects of HWC. Women (primarily responsible for the collection of forest produce) were more exposed to inherent risks and are thus disproportionately affected by HWC. Therefore, women may hold negative perceptions of the forest department and conservation efforts within the PA (Agarwal, 2000; Dickman, 2010). Research by Badola and Hussain (2003) in and around certain Himalayan National Parks found that many women who used forests for their livelihoods viewed forest patrols as basic infringements on their rights as tribals and also had an overall negative view of PA management due to a lack of rights and negative experiences with forest guards. Many studies around PAs have also recorded an overall bias toward women, both directly and indirectly, in cases of HWC (Agarwal, 2000; Barua et al., 2013; Ogra, 2009).

Implications for Conservation

Attitudes of local communities play an important role in the preservation of forests and wildlife in India (Harihar

et al., 2014; Karanth et al., 2017; Nagendra et al., 2010; Ogra, 2009). PA-specific studies can highlight specific scenarios and leading to nuanced management interventions that are relevant, timely, and effective (Karanth & Kudalkar, 2017; White & Ward, 2011). The forests of STR-MTR are valuable source sites for a variety of charismatic and endangered fauna including tiger, Asian elephant, leopard, gaur, and vultures (Government of Tamil Nadu, 2010; Reddy et al., 2012). Conserving these landscapes are of paramount importance to ongoing conservation efforts in the states of Tamil Nadu, Karnataka, and Kerala, which together form the largest contiguous elephant corridor and are home to the largest subpopulation of the tiger in India (Goswami, Vasudev, et al., 2014; Karanth et al., 2013).

Ongoing discussions in STR and MTR suggest a proposed plan to relocate Thengumarahada and its associated villages outside the PA (Government of Tamil Nadu, 2010; Jayachandran, personal communication, 2013). Voluntary relocation of villages has been successfully carried out in other PAs in India, including Bhadra, Kudremukh, Nagarahole, TATR, Melghat, Sariska, and so forth (Dickman, 2010; Karanth, 2007; Karanth et al., 2013; Sekhar, 1998). The lack of facilities and educational opportunities, as well as declining forest productivity, were often cited reasons for voluntary relocation, as seen in Melghat Tiger Reserve (Gooch, 2009; Harihar et al., 2014). In the case of STR and MTR, we asked respondents if they would be willing to voluntarily relocate and resettle outside. We found that 34% of families were willing to relocate at the time of the study, despite a comprehensive relocation package and better prospects outside the reserved forest. This presents both an opportunity and challenge to work with both willing and unwilling people to build consensus and people's well-being living in or outside the PA. This mirrors many resettlement efforts in India where there is ongoing debate about need for setting aside inviolate spaces for wildlife versus the livelihoods and cultural ties of people who have lived on that same land for generations (Harihar et al., 2014; Talukdar & Gupta, 2017; Treves & Karanth, 2003).

The residents of Thengumarahada following our study, as of 2014, agreed to relocate in exchange for better amenities and opportunities (Jayachandran, personal communication, 2014; Oppili, 2014). The panchayat claimed that the establishment of STR created issues in the accessibility of transport, education, and other material goods and services. In addition, residents faced heavy crop losses due to monsoon failure, and continued HWC pushed households in this settlement to take the decision to relocate (Oppili, 2014). Provided that relocation is implemented equitably and following due process for people willing to move voluntarily, this may lead to changes in attitude and improved equations with the PA management and prove to be a rare win-win for people and wildlife (Harihar, Pandav, & Goyal, 2009; Jayachandran, personal communication, 2013).

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