The impact of leopards (*Panthera pardus*) on livestock losses and human injuries in a human-use landscape in Maharashtra, India

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There are many ways in which large carnivores and humans interact in shared spaces. In this study we provide insights into human - leopard relationships in an entirely modified, human-dominated landscape inhabited by dense populations of humans (266 per km^2), their livestock (162 per km^2) and relatively high densities of large predators (10 per 100 km^2). No human deaths were recorded, livestock losses to leopards numbered only 0.45 per km^2 per year (averaged over three years) despite the almost complete dependency of leopards on domestic animals as prey. Predation was not the major cause of livestock mortality as diseases and natural causes caused higher losses (80% of self-reported losses). We also found that ineffective night time protection and the presence of domestic dogs increased the probability of a farmer facing leopard attacks on livestock. Resident farmers faced much lower livestock losses to leopard predation in contrast to the migratory shepherds who reported much higher losses, but rarely availed of the government compensation schemes. We recommend that local wildlife managers continue to shift from reactive measures such as leopard captures after livestock attacks to proactive measures such as focusing on effective livestock protection and informing the affected communities about safety measures to be taken where leopards occur in rural landscapes. The natural causes of livestock deaths due do diseases may be better prevented by involving animal husbandry department for timely vaccinations and

treatment.

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23 **Abstract**

25 There are many ways in which large carnivores and humans interact in shared spaces.

26 In this study we provide insights into human - leopard relationships in an entirely

27 modified, human-dominated landscape inhabited by dense populations of humans (266

28 per km^2), their livestock (162 per km^2) and relatively high densities of large predators

29 (10 per 100 km^2).

30   No human deaths were recorded, livestock losses to leopards numbered only 0.45 per

31 km^2 per year (averaged over three years) despite the almost complete dependency of

32 leopards on domestic animals as prey. Predation was not the major cause of livestock

33 mortality as diseases and natural causes caused higher losses (80% of self-reported

34 losses). We also found that ineffective night time protection and the presence of

35 domestic dogs increased the probability of a farmer facing leopard attacks on livestock.

36 Resident farmers faced much lower livestock losses to leopard predation in contrast to

37 the migratory shepherds who reported much higher losses, but rarely availed of the

38 government compensation schemes.

39   We recommend that local wildlife managers continue to shift from reactive measures

40 such as leopard captures after livestock attacks to proactive measures such as focusing

41 on effective livestock protection and informing the affected communities about safety

42 measures to be taken where leopards occur in rural landscapes. The natural causes of

43 livestock deaths due do diseases may be better prevented by involving animal

44 husbandry department for timely vaccinations and treatment.

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49   **INTRODUCTION**

50   Conflicts between humans and large felids have been at the centre of attention in

51   conservation because of the impact these threatened species have on the lives and

52   livelihoods of local people (Treves & Karanth, 2003; Inskip & Zimmermann, 2009;

53   Ripple *et al.*, 2014), as well as the decline of wild felid populations which can occur due

54   to retaliatory killings (Inskip *et al.*, 2014). Livestock depredation, resulting in real or

55   perceived economic losses to individual farmers, is the most common cause of human-

56   large felid conflict (Ogada *et al.*, 2003; Katel, Pradhan & Schmidt-Vogt, 2014; Peña-

57   Mondragón *et al.*, 2017; Suryawanshi *et al.*, 2017) although some species of large felids

58   are also associated with attacks on humans (Athreya *et al.*, 2011; Kshettry, Vaidyanathan

59   & Athreya, 2017; Packer *et al.*, 2019). The prevention and mitigation of conflicts is a

60   challenging issue not only because of its urgency as many large felids are threatened,

61   but solutions have to take into account complex and locally dependent social and

62   cultural aspects (Barlow *et al.*, 2010; Dickman, 2010; Redpath *et al.*, 2013).

63

64   There is increasing evidence that poor livestock protection practices, sometimes in

65   combination with low wild prey density, lead to livestock depredation by many

66   individual large felids within a population (Athreya *et al.*, 2014; Shehzad *et al.*, 2014;

67   Suryawanshi *et al.*, 2017; Kshettry, Vaidyanathan & Athreya, 2018). Most of the

68   information on livestock depredation by large felids in tropical areas are from in, or

69   around, protected areas (Patterson *et al.*, 2004; Harihar, Pandav & Goyal, 2011;

70   Khorozyan *et al.*, 2015) where livestock are only an alternative prey. However, a number

71   of recent studies have revealed the ability of some large carnivore species to persist in

72   human-dominated landscapes (Bhatia *et al.*, 2013; Ripple *et al.*, 2014; Kshettry *et al.*,

73   2017). In such cases, predators may heavily depend on anthropogenic food resources,

74 such as domestic animals like dogs, livestock and garbage (Gehrt, Riley & Cypher, 2010;

75 Athreya *et al.*, 2014; Kshettry *et al.*, 2018). In India, reproducing populations of some

76 large carnivores species such as wolves *Canis lupus* (Jhala & Giles, 1991), Asiatic lions

77 *Panthera leo* (Banerjee *et al.*, 2013), striped hyaenas *Hyaena hyaena* (Singh, Gopalaswamy

78 & Karanth, 2010) and leopards *Panthera pardus* (Athreya *et al.*, 2013), all of which are

79 capable of attacking livestock and humans, inhabit human-dominated landscapes with

80 dense human populations. This increased spatial overlap between large carnivores and

81 people poses a challenge to conserve them in a country with an average of more than

82 380 people/km² (Census of India 2011).

83

84 Recent research within the field of human-wildlife conflicts has been increasingly

85 incorporating social science perspectives (e.g. Dickman 2010). These new perspectives

86 have tried to differentiate between the negative impacts that wildlife can have on

87 people (i.e. negative interactions between people and wildlife) from true conflicts that

88 people have about wildlife (i.e. negative interactions between different groups of people

89 about the way wildlife is managed) (Redpath *et al.*, 2013). The social science

90 perspectives have also underlined how much of the substance of a human-wildlife

91 conflict can be perceptional and may be only loosely related to actual degree of

92 economic or material impact (Dickman *et al.*, 2014). The implication is that while there is

93 a need to carefully investigate each of the different aspects of complex human-wildlife

94 interactions, there is also a need to integrate the different human perceptions when

95 deriving management recommendations. In this paper, economic losses arising due to

96 shared spaces between people and carnivores are termed 'impacts' whereas hidden

97 differences of opinions and agendas between groups of people is termed as conflict

98 (Redpath *et al.*, 2013).

99

100 Indian wildlife laws prohibit the killing of wild carnivores such as leopards and hyenas

101 (Anon 1972) and the rural communities are largely accepting of their presence (Sekar,

102 2011; Treves & Bruskotter, 2014). However, there are many examples where local

103 people either illegally kill large carnivores associated with conflicts or put pressure on

104 wildlife management authorities to remove (translocate) animals from their

105 neighbourhood (Athreya *et al.*, 2011). In these contexts, it is clear that there is a need for

106 robust knowledge of carnivore ecology and objective assessments of their impacts on

107 local livelihoods in a human-dominated landscape to guide effective conservation

108 efforts. This is especially true when misguided reactions, such as translocation, can have

109 potentially unforeseen negative effects such as increased attacks on humans by the

110 carnivores near the sites of release (Athreya *et al.*, 2011). Unfortunately, there is very

111 little such knowledge available, as wildlife research in India has almost exclusively been

112 focused on protected areas (Ghosal *et al.*, 2013). In this study, the levels of impact

113 associated with leopards in a largely rural, agricultural landscape with little wild prey,

114 but supporting high densities of domestic animals and humans was quantitatively

115 assessed. Specifically, we asked the following questions (i) what were the livestock

116 losses that people faced in the area due to leopard depredation, (ii) what factors

117 predicted livestock attacked by leopards, (iii) is compensation as a procedure evenly

118 spread among the different groups of people who report losses?

119

120 **METHODS**

121 **Study Area**

122 The study was carried out in Akole taluka (or county) of Ahmednagar district, located

123 in the western part of Maharashtra State, India (Figure 1)**.** Approximately 80% of the

124 human population in Ahmednagar district is rural and the major crops grown in the

125 area are sugarcane, millet, and vegetables. Annual rainfall is highly seasonal, and can

126   vary from 1000 to 2000 mm, although most farmers have access to irrigation from the

127   river flowing through the valley and from percolation wells widely distributed across

128   the landscape. Akole town had a human population of about 20,000 at the time of our

129   study, while the average population density of the Ahmednagar district is 266

130   people/km² (Census of India 2011) and average livestock density of Ahmednagar is 162

131   /km² (https://ahd.maharashtra.gov.in/pdf/livestock%20census/livestock_census_19th_2012.pdf

132   accessed on September 2019). Apart from the high density of various types of livestock,

133   the density of domestic dogs which are important food resources for leopards (Athreya

134   et al. 2014) is also high at 24/km². Dogs could be feral or owned but even in the latter

135   case, they are usually free roaming in the day time returning to the homes in the night.

136

137   The wild carnivores that are resident in the study area are leopard, striped hyaena,

138   golden jackal (*Canis aureus)*, Indian fox *(Vulpes bengalensis)*, jungle cat *(Felis chaus)* and

139   rusty spotted cat (*Prionailurus rubiginosus)* (Athreya *et al.*, 2013) and no wild ungulate

140   species occur. The density of leopards and hyaenas is recorded at five adults of each

141   species per 100 km² (Athreya *et al.*, 2013). Many groups of people live in this landscape,

142   the numerically dominant group in the irrigated valley is of resident farmers who own

143   both land and livestock. Migratory shepherds, who are a pastoral group, arrive each

144   dry season (September to May) with their large herds of sheep and goats to pasture on

145   the post-harvest crop residues in fields, a practice encouraged by the landowners who

146   benefit from organic manure deposited by the animals.

147

148   The study was conducted in a 647 km² area of the wider landscape surrounding the 179

149   km² intensive study area described in Athreya et al., (Athreya *et al.*, 2013, 2014) which

150   centered around the town of Akole. The nearest wildlife reserve is the Kalsubai

151 Harishchandragarh Wildlife Sanctuary (299 km^2) which is 18 km away from the western

152 edge of the study area (Figure 1).

153

154 Oral consent was obtained from the farmers who were interviewed, the reasons for

155 collecting the information was provided to them and their identities were not recorded.

156 All the necessary permissions to carry out the study were obtained from the

157 Maharashtra Forest Department, the government agency responsible for protection and

158 management of all wildlife on public and private lands in the state

159

160 **Information on livestock losses**

161 Official information on the reported number of leopard encounters with humans

162 leading to injuries and claims filed for livestock attacks caused by leopards were

163 obtained from the Maharashtra Forest Department. Based on this information, three

164 different groups of people were interviewed to obtain different kinds of information.

165 (i) Residents of randomly chosen households "**random households**" within the

166 intensive study area were interviewed to assess the level of under-reporting of livestock

167 losses. They were chosen by dividing the entire study area into grids where all houses

168 were marked and numbered using Google Earth and one house was chosen from each

169 grid using a random number generator. We enquired about the number of domestic

170 animals they owned and if the farmers had applied for livestock compensation in the

171 last five years. Information on livestock losses over five years was obtained because the

172 number of losses in one year was too few to provide meaningful information. If they

173 had not applied for compensation, they were asked to list the reasons.

174

175 (ii) People who had lost livestock recently (in the three years between 2006 and 2009)

176 and had filed for compensation and henceforth termed as "**compensation claimants**"

177 were interviewed to assess the extent of their losses and the circumstances in which

178   their livestock was lost to leopards. The farmers in this group were spread over a larger

179   landscape that surrounded the intensive study area. A wider area was sampled in order

180   to provide access to a large enough sample for statistical analysis. Information such as

181   the species, number of domestic animals owned and lost in one year, details of the

182   attack such as location (in cattle sheds, in the open, or while grazing), and location of

183   the feeding area of the animal at night (stall fed or free ranging) were obtained during

184   the interview. The quality of livestock sheds was assessed by visiting the shed where

185   the livestock were kept at night. If the sheds had an opening through which leopards

186   could get inside, or if they were fragile (made of sticks which a leopard could push

187   aside) then the quality of protection was noted as vulnerable and if the shed was

188   completely sealed it was noted as predator-resistant.

189

190   (iii) **"Migratory shepherds"** who use the valley in the dry season and are accompanied

191   by extremely large herds of sheep and goats face livestock losses to carnivores

192   (Agarwala *et al.*, 2010). Information on their domestic animal holdings, the total

193   livestock mortality in the past year and all the reasons for mortality were requested.

194

195   All interviews were semi-structured and were conducted between September 2007 and

196   September 2009. A local farmer who was part of the team was present during the

197   interviews to increase acceptance towards the research team among the locals.

198

199   **Analysis**

200   We used Generalized Linear models with a binomial error structure and our

201   inferences were based on model selection using an information theoretic approach

202   (Burnham & Anderson, 2002; Johnson & Omland, 2004) to examine the following

203   questions;

204

205 (i) We assessed the risk of small stock (almost always goats) versus large stock (calf)

206   being attacked by leopards. Each compensation claimant household that faced a

207   livestock attack was considered as a data point, the proportion of the species attacked

208   per household was considered as the response variable and the species of livestock

209   (goat or calf) was considered as the predictor variable. These two groups of animals

210   were chosen because initial analysis indicated that they were mainly predated upon by

211   leopards compared to other species.

212

213 (ii) We wanted to assess what variables influenced whether a household would face a

214   livestock predation event by leopards. A predation attempt was considered as the

215   response variable (with a binomial error structure) and the independent covariates

216   were whether the household owned a dog, the number of goats, the number of other

217   livestock apart from goats, and the quality of livestock protection. In this analysis, data

218   from both the "compensation claimants" and the "random households" was used.

219

220 All the covariates that were included in the competing models were based on a priori

221 knowledge and hypotheses. The best model was chosen based on the Akaike

222 Information Criterion (AIC) and the model with the smallest AIC was regarded as the

223 best approximating model. In the analyses, no single best model (ΔAIC > 10 from the

224 next model) was identified. Therefore, inferences were based on multiple models. In

225 such cases Akaike weights (the weight of a given model relative to other models in the

226 candidate set of models) were calculated for all models to obtain the model averaged

227 parameter estimates and confidence intervals (Burnham & Anderson, 2002). The

228 statistical software R 2010 (version 2.11.0; R development Core Team; http//www.R-

229 project.org) was used for all the analyses.

230

231 **RESULTS**

232 **Extent of livestock losses**

233 A total of 337 compensation entries of livestock depredation by leopards was reported

234 to the Forest Department between April 2006 and February 2009 over an area of 647 km²

235 (Figure 2). The total number of livestock reported as killed by leopards as per the

236 compensation records within the 179 km² intensive study area over a three-year period

237 was 242 livestock (165 goats, 61 calves, 13 sheep and 3 adult cows from a total of 224

238 households). This implies an average of 81 livestock killed each year in a landscape (or

239 45 per year per 100 km²) with a leopard and hyaena density of 10 adults per 100 km²

240 and a very high density of domestic animals (16200 heads per 100 km²). The maximum

241 number of livestock killed during one incident was 4 (reported from three households).

242

243 Despite the high density of humans and the relatively high density of leopards, no

244 human had been killed by leopards during living memory and accidental attacks

245 resulting in injury were rare in the intensive study area. During the study period (2007 -

246 2009), a boy was injured while he was cycling on a path flanked by high grass in which

247 a leopard was sitting. The leopard clawed the boy's leg but did not follow the boy even

248 though the boy was alone. In addition, just after our field work ended, in April 2009, a

249 couple was knocked off their motorbike by a leopard that was trying to cross the road at

250 the same time their bike drove past. Two more men were injured in October 2009 when

251 they were driving their motorbike at night. In this case, two leopards jumped on the

252 motorbike, bit the leg of one person and ran off into the sugarcane fields. However, it

253 was learnt later that this attack followed a provocation where another person had

254 chased one of the leopards (both were GPS-collared by us) in a jeep for nearly 500 m.

255

256 The results indicate that both sets of farmers, 'compensation claimants' and 'random

257   households', owned similar numbers of livestock (t-test, p=0.145) (Table 1). The average

258   number of goats were 2.9 per household (range = 0 - 40) and calves were 0.9 per

259   household (range = 0 - 8) whereas buffaloes and sheep occurred in smaller numbers

260   (Athreya *et al.*, 2014).

261

262   In the five-year period prior to the interviews, the 77 random households that we

263   obtained information from reported losing 1% of their livestock holdings (from a total

264   of 517) to leopards and 9% to other causes of mortality. Their losses to leopard

265   depredation were few; no buffalos, no adult cows, no calves nor sheep were killed by

266   leopards in five years with only three individuals from a total stock of 224 goats killed

267   by leopards in the five-year period. The most common causes of livestock mortality of

268   the "random households" were illness and natural causes of death (Figure 3). The only

269   exception was for domestic dogs, where leopard attacks were by far the dominant cause

270   of death (Figure 3).

271

272   In the case of the "compensation claimants" in the wider landscape, 134 of the

273   households we surveyed owned a total of 869 livestock. They reported 22% of a total of

274   480 goats and 20% of a total of 80 calves dying due to leopard predation in one year.

275   Among the compensation claimants who lost livestock due to leopard attacks, the

276   probability of a goat being attacked was twice that of a calf being attacked (GLM;

277   probability of a goat being attacked: mean = 0.364; 95% CI = 0.148-0.650; probability of a

278   calf being attacked: mean = 0.176; 95% CI = 0.106-0.266). The 31 "migratory shepherds"

279   owned a total of 4991 sheep and goats of which 813 (16%) had died in the year prior to

280   the interview. Leopards accounted for 12% of the 813 livestock deaths, the remaining

281   occurring due to natural causes.

282

283   **Patterns of livestock losses**

284   From the random households, 75% of the farmers stall-fed their livestock, 18% took

285   them out to graze, and 7% did both (N=68 provided responses to this question).

286   Seventy-six percent of the random households (N = 68 provided responses) protected

287   their smaller livestock in leopard-resistant sheds or had people sleeping near the

288   livestock at night (a traditional method of protecting their livestock), while the

289   remaining 24 % of the respondents did not have leopard-proof sheds. Dogs are usually

290   not protected and are almost always left loose outside the houses in the night, although

291   this was not quantified.

292

293   Information from the compensation claimants indicates that most leopard attacks on

294   livestock took place during the night (83%; 103 farmers responded to this question), and

295   all nighttime attacks occurred in the residential compound of the farmers (Table 2). The

296   proximity of leopard attacks to the house also allowed the farmers to intervene and in

297   55% (of the 94 farmers who responded to this question) of the cases the domestic animal

298   was retrieved. This was done for two reasons, (i) in an attempt to save the animal's life,

299   or (ii) if it was dead, they required the carcass as evidence to file for compensation from

300   the Forest Department. In none of these cases was the farmer attacked by the leopard

301   which is likely to have been in the vicinity.

302

303   Our analysis (Table 3) indicates that the important predictors of a livestock predation by

304   leopards are the presence of dogs and the quality of livestock protection, that is,

305   livestock attacks by leopards were more likely if dogs were present in the household

306   and if the livestock protection enclosure was not predator-resistant.

307

308   Among the people who had predator-resistant sheds and yet lost livestock, it was due

309   to reasons such as delaying taking the goats into the shed in the evening or failing to

310   put the livestock inside the shed for that night. Furthermore, the analysis also shows

311   that although the average number of goats was higher (5.05 goats; range = 0 to 65) in

312   houses that were visited by leopards to take livestock than in houses (2.9 goats; range =

313   0 to 40) which did not face livestock damage due to leopards, model averaged

314   coefficients (Table 4) provide poor evidence for an effect of the number of goats on the

315   probability of livestock predation by leopards.

316

317   **Compensation payment for livestock losses**

318   Over a five-year period, eight of the 77 random households lost their livestock to

319   leopards of which five households did not apply for compensation. The reasons why

320   they did not apply for compensation included, (1) they did not know how to file the

321   complaint, (2) compensation was rarely provided in time, (3) the amount paid was too

322   small and many visits had to be made to the forest officer before it was given, (4) they

323   did not have time to undertake the procedure, and (5) they had reported the loss to the

324   local forest guard but he did not take action.

325

326   Sixty eight percent of the migratory shepherds lost livestock (of the 31 interviewed) to

327   leopards in the year before the interview of which 76% of the 21 shepherds (who replied

328   to the question) did not apply for compensation. Half of the shepherds who had their

329   livestock predated upon by leopards did not know they could apply for compensation

330   (10 of 21), four shepherds said they did not have the time to file the cases, and four said

331   that the procedure was too drawn-out and cumbersome. Three mentioned that filing for

332   compensation was too expensive and two said they did not get it when they had filed

333   for it.

334

335   **DISCUSSION**

336 Previous ecological studies from this area have reported novel findings of a relatively

337 high density of leopards sharing the same space with a high density of humans

338 (Athreya *et al.*, 2013, 2014) as well as the complete dependency of leopards on domestic

339 animals (livestock and dogs contributing as much as 87% of the prey biomass) as prey

340 (Athreya *et al.*, 2014). Results from the current work indicate that the intensive study

341 area is not unique in hosting a leopard population because a much larger area of nearly

342 650 km^2 also reported leopard depredation on livestock, confirming their presence

343 across a much wider landscape. Across India, leopards are known to be responsible for

344 a large number of encounters with humans leading to casualties (Kshettry *et al.*, 2017;

345 Packer *et al.*, 2019). However, at this study site, only three human injuries caused by

346 leopards were reported during the three-year study period. In two cases they were

347 accidental incidents and the third was a provoked response. In all cases, the animals did

348 not kill the people although it would have been easy for them to do so since there were

349 no other humans in the vicinity at the time of the incidents. No respondent could recall

350 any incident of predation on humans by leopards at the study site. This is despite close

351 interactions between humans and leopards with all the night time predation on

352 livestock occurring close to houses and half of the predated livestock being retrieved by

353 the farmers by chasing the leopards off their livestock which had been attacked. Odden

354 et al. (2014) also document using GPS telemetry how close the leopards were to

355 humans both by night and day, implying that there was a constant potential for

356 aggressive encounters between leopards and people.

357

358 One would expect livestock losses to be very high because of the absence of wild

359 herbivores in this landscape (Kshettry *et al.*, 2018). However, 242 livestock killed in the

360 179 km^2 intensive study area were reported as killed by leopards over three years

361 despite extremely high densities of livestock (Athreya *et al.*, 2014), and a high density of

362 leopards (Athreya *et al.*, 2013). For the average density of 60 houses per km^2 this implied

363   a loss of 0.45 livestock per km² per year. The interview data also found that most of the

364   farmers protected their livestock effectively which is known to be a very important

365   factor in reducing livestock losses (Lichtenfeld, Trout & Kisimir, 2015; Manoa &

366   Mwaura, 2016). Therefore, the high density of livestock might not directly lead to high

367   rates of livestock depredation. It clearly also depends on other available food sources

368   (domestic dogs in this case) and how accessible the livestock is to the leopards (Athreya

369   *et al.*, 2014). Frank et al. (Frank, Woodroffe & Ogada, 2005) found that traditional

370   daytime and nighttime husbandry practices in Kenya are most effective at reducing

371   livestock losses to large predators, findings supported by many other studies (Meena *et*

372   *al.*, 2011; Hazzah *et al.*, 2014).

373   An interesting finding from our study was that the presence of dogs around farms

374   increased the risks of leopard predation on livestock. A common finding in other

375   studies has been that the presence of dogs, especially livestock guarding dogs, can deter

376   large predator attacks (Gehring *et al.*, 2010; Miller *et al.*, 2016). Dogs trained to keep

377   away predators were also used by the migratory shepherds in our study area (VA

378   personal observations) but these were largely to keep away wolves and not leopards.

379   However, the dogs used by the resident farmers were generally smaller and not bred as

380   guarding dogs and kept mostly as companions/pets. This small size, coupled with dogs

381   being an important component of leopards' diet in this landscape (Athreya *et al.*, 2014)

382   implies that not only are they not a deterrent, but are in fact an attractant. Indirectly, the

383   presence of so many vulnerable dogs is probably one of the factors that may have led to

384   the persistence of such a dense leopard population in the study area.

385

386   In the randomly sampled households (the people who had not filed for compensation)

387   the probability of experiencing a livestock loss to leopards was seen to be small but

388   among the compensation claimants, the proportion of livestock lost to depredation was

389   relatively large. As with many other studies, our results also indicate that livestock loss

390 to predators are a small fraction of the total losses farmers face. A review in 2010 of 18
391 studies of large cat predation found that usually no more than 5% of the total livestock
392 holding was lost to large cat depredation although in a few cases 12% loss was reported
393 (Loveridge *et al.*, 2010). Loveridge *et al.* (2010) reports that livestock loss from diseases
394 and theft are usually much higher than to predation by large felids. The random
395 households in our study lost one percent of their livestock over five years to leopard
396 predation and nine percent to diseases and natural causes. In the case of migratory
397 shepherds, 12% of their livestock losses were due to predation in one year but the
398 remaining 88% was lost to other causes. Although individual losses are likely to be
399 severe for marginal farmers, conservation studies dealing with conservation conflicts
400 need to take into account losses of livestock due to all reasons, including disease etc., as
401 a measure of the impact of focal carnivore species on overall livestock losses.
402
403 This does not take away from the potential impact of leopard depredation for
404 individual, marginal farmers. As a result of these impacts India, like many countries,
405 has created a compensation system which is designed to redistribute the costs of
406 protected species from the individual farmer to wider society (Gebresenbet *et al.*, 2017).
407 As well as representing a form of distributive justice, the philosophy (albeit rarely
408 demonstrated) is that compensation will reduce the antipathy of the affected farmers
409 towards the carnivore (Dhungana *et al.*, 2016). However, compensation can also lead to
410 slack herding measures because the farmer expects to get compensated in case of loss
411 (Bulte & Rondeau, 2007). For example, compensation payments were stopped in Kenya
412 because of poor financial controls and corruption (Hazzah *et al.*, 2014), which is also
413 often a problem in India. Few of these schemes are ever monitored to assess their
414 efficacy (Nyhus *et al.*, 2003).
415

416   Our results indicate that while under-reporting of loss is very low among the resident

417   farmers (eight houses in 77 did not report losses over a period of five years), it is very

418   high among the migratory shepherds (68% of 31 interviewed reported leopard

419   predation incidents in one year) and 76% of those that lost livestock to leopards did not

420   apply for compensation. The fact that some respondents in our study area cited the

421   procedure as cumbersome, resulting in low payment for too much effort, and did not

422   bother to apply for compensation is an indication of procedural problems with the

423   current system, especially in the case of the migratory shepherds. Large amounts of

424   government funds are spent on compensation each year by the state governments

425   without monitoring the delivery system or the effect of its intention (to make people

426   more tolerant to losses). Recently Maharashtra has improved the delivery system where

427   previous cash payments are now provided as electronic transfers directly into the

428   farmers' accounts.

429

430   However, although it can be argued that gains could be made through adjustments to

431   the procedures associated with compensation payments, it is also important to consider

432   whether greater gains could be made by moving away from paying for losses, and

433   instead move to a system of paying for, and assisting with prevention of livestock

434   losses. Compensation rates will always increase due to increasing costs of livestock but

435   if the same resources are used for proactive measures that aim at preventing a loss, it is

436   likely to result in improved longer term mitigation as well as reduce the drain on funds

437   and put the onus of protection on the farmer rather than the state agency that represents

438   the wild animal. More importantly, it will reduce losses to individual farmers, many of

439   whom are marginal and for whom livestock is an integral part of their livelihood

440   generation (Agarwala *et al.*, 2010). Existent livestock protection practices in the

441   landscape implies that only minor modifications are required to make them effective.

442

443 **CONCLUSION**
444
445   Carnivores are often viewed as dangerous and incompatible with human-dominated

446   landscapes. It has also been argued that there are some large cat individuals who are

447   'problem' animals and their removal will ease livestock depredations (Linnell, 2011). By

448   this definition all the leopards in our study site would be categorised as 'problem'

449   animals because they all depend at least partly on domestic animals for prey due to the

450   absence of any suitable wild prey. However, our results show that they are residing in

451   the area with an impact that is unexpectedly low considering the density of humans,

452   their livestock and leopards. Should these leopards still be termed as problem animals?

453   The term conflict is most commonly used in conservation literature while describing

454   damage incidents of livestock to predators, which are often less compared to losses due

455   to disease or illness. Conflict implies that the predator is implicated as an actor who is at

456   "fault" whereas in reality the livestock loss has occurred because of ineffective

457   protection of livestock by humans. It is important that we shift the onus of

458   responsibility to the owners of the livestock rather than on the predator who will attack

459   any herbivore/carnivore without distinguishing whether it is wild or domestic if it is

460   available. Recently several authors (Redpath *et al.*, 2013; Davidar, 2018) have called for

461   the word "conflict" to be only used for the human-human aspect of conservation

462   conflicts, preferring to reserve the word "impact" for the material and economic effects

463   of predators on people. In our study site there were relatively few social conflicts linked

464   to the leopards (Ghosal & Kjosavik, 2015), and impacts were relatively low and widely

465   dispersed across the human population. In many ways, the discourse could be even

466   more constructively switched away from impacts to one of a failure to completely adapt

467   to the presence of leopards (Carter & Linnell, 2016). However, when compared to many

468   other case studies of human-large felid interactions and the associated conflicts, the

469   situation in Akole is very close to coexistence (sensu Carter & Linnell 2016), and the

470   required adjustments to human practices are minor. Now is certainly the time to make

471   the necessary adjustments, as it is likely to be far easier to prevent escalating impacts,

472   and potential conflicts from developing than reverse them once they have appeared

473   (Miller *et al.*, 2016).

474

475

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489

490 **Declaration of conflicting interests**

491 'The Author(s) declare(s) that there is no conflict of interest'.

492

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Comparison of livestock mortality between random households and compensation claimants.

The random households provided information over five years prior to the interview as their yearly losses were too few to enumerate. The compensation claimants provided information for the year prior to the interview to avoid recall bias.

Table 1: Comparison of livestock mortality between random households and compensation claimants. The random households provided information over five years prior to the interview as their yearly losses were too few to enumerate. The compensation claimants on the other hand provided information for the year prior to the interview.

	Random households		Compensation claimants	
	Owned	Leopard kills	Owned	Leopard kills
Goats	224	3	480	107
Sheep	5	0	0	2
Calves	70	0	83	17
Adult cattle	209	0	293	1
Buffalo	9	0	13	0
Total	517	3	869	127

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8

Time and location details of livestock attacks (number of attacks) by leopards obtained from the compensation claimants. The total number of responses we got for this question was from 103 claimants.

Table 2: Time and location details of livestock attacks (number of attacks) by leopards obtained from the compensation claimants. The total number of responses we got for this question was from 103 claimants.

	Day time (0600 – 1800)	Night time (1800 – 0600)	Do not know	Total
Grazing	12	0	0	12
Outside house	1	78	0	79
Do not know	1	4	0	5
Total	14	82	7	103

2

Generalised Linear Models (binomial errors) where the response variable that was modelled was the probability of a leopard attack on livestock. The data set consists of both compensation claimants as well as random households.

Table 3: Generalised Linear Models (binomial errors) where the response variable that was modelled was the probability of a leopard attack on livestock. The data set consists of both compensation claimants as well as random households.

Model	Deviance	AICc	ΔAICc	w
Dogs present+livestock protected+dogs present: livestock protected	119.76	128.03	0.00	0.27
Dogs present + livestock protected	123.04	129.21	1.17	0.15
Dogs present + number of goats + livestock protected + dogs present: livestock protected	119.01	129.43	1.39	0.14
Dogs present + number of other livestock + number of goats + livestock protected + dogs present: livestock protected	116.96	129.55	1.52	0.13
Dogs present + number of other livestock + livestock protected	121.88	130.16	2.12	0.09
Dogs present + number of goats + livestock protected	122.07	130.35	2.31	0.09
Dogs present + number of other livestock + number of goats + livestock protected	120.64	131.06	3.03	0.06
Livestock protected	128.06	132.14	4.11	0.03
Number of goats + livestock protected	127.23	133.40	5.37	0.02
Number of other livestock + livestock protected	128.03	134.19	6.16	0.01

Model	Deviance	AICc	ΔAICc	w
Number of other livestock + number of goats + livestock protected	127.19	135.47	7.43	0.01
Dogs present + number of goats	191.08	197.25	69.21	0.00
Dogs present + number of other livestock + number of goats	190.84	199.12	71.08	0.00
Dogs present	195.85	199.93	71.90	0.00
Dogs present + number of other livestock	195.73	201.89	73.86	0.00
Number of goats	199.29	203.37	75.33	0.00
Number of goats + number of other livestock	198.98	205.15	77.11	0.00
Number of other livestock	203.15	207.24	79.20	0.00

5

Model-averaged estimate and 95% confidence interval (CI) of factors affecting the chances of leopard attacks on livestock held in farmer's pens.

Interview data from both, 'compensation claimants' and 'random households' were used. The interviews were held between September 2007 and September 2009.

Table 4. Protection related factors where the response variable modelled was the probability of a leopard attack on livestock assessed using Generalised Linear Models with binomial errors. The reported figures are: Model-averaged estimate and 95% confidence interval (CI) of parameters representing factors affecting the chances of leopard attacks on livestock held in farmer's pens. Interview data from both, 'compensation claimants' and 'random households' were used. The interviews were held between September 2007 and September 2009.

Model averaged parameters	Coefficient	Lower CI	Upper CI
Dogs present	1.93	0.0771	3.79
Number of livestock except goats	-0.0844	-0.229	0.06
Number of goats	0.101	-0.107	0.309
Protection not effective	3.85	2.48	5.22
Dogs present : Protection not effective	-1.93	-4.01	0.16

Figure 1

The Ahmednagar district is shown with the study area marked as a polygon where information on livestock losses was collected from households chosen randomly. The black dots represent the households which reported livestock loss and claimed compensation
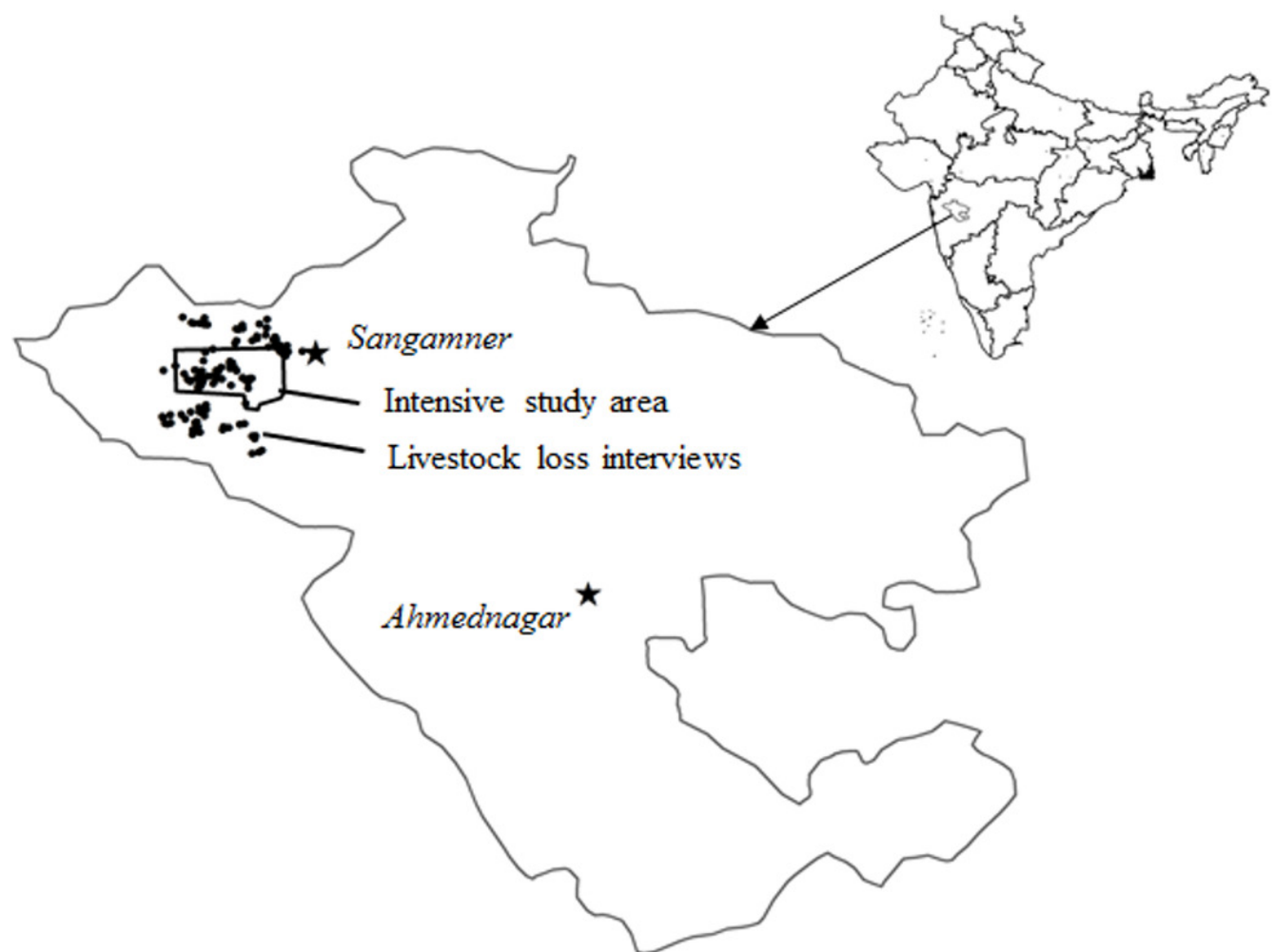
Figure 2

Seasonal distribution of the average number of livestock (with SD bars) reported preyed upon by leopards in the intensive study area (179 km^2) between April 2006 and February 2009. The information is from Forest Department records
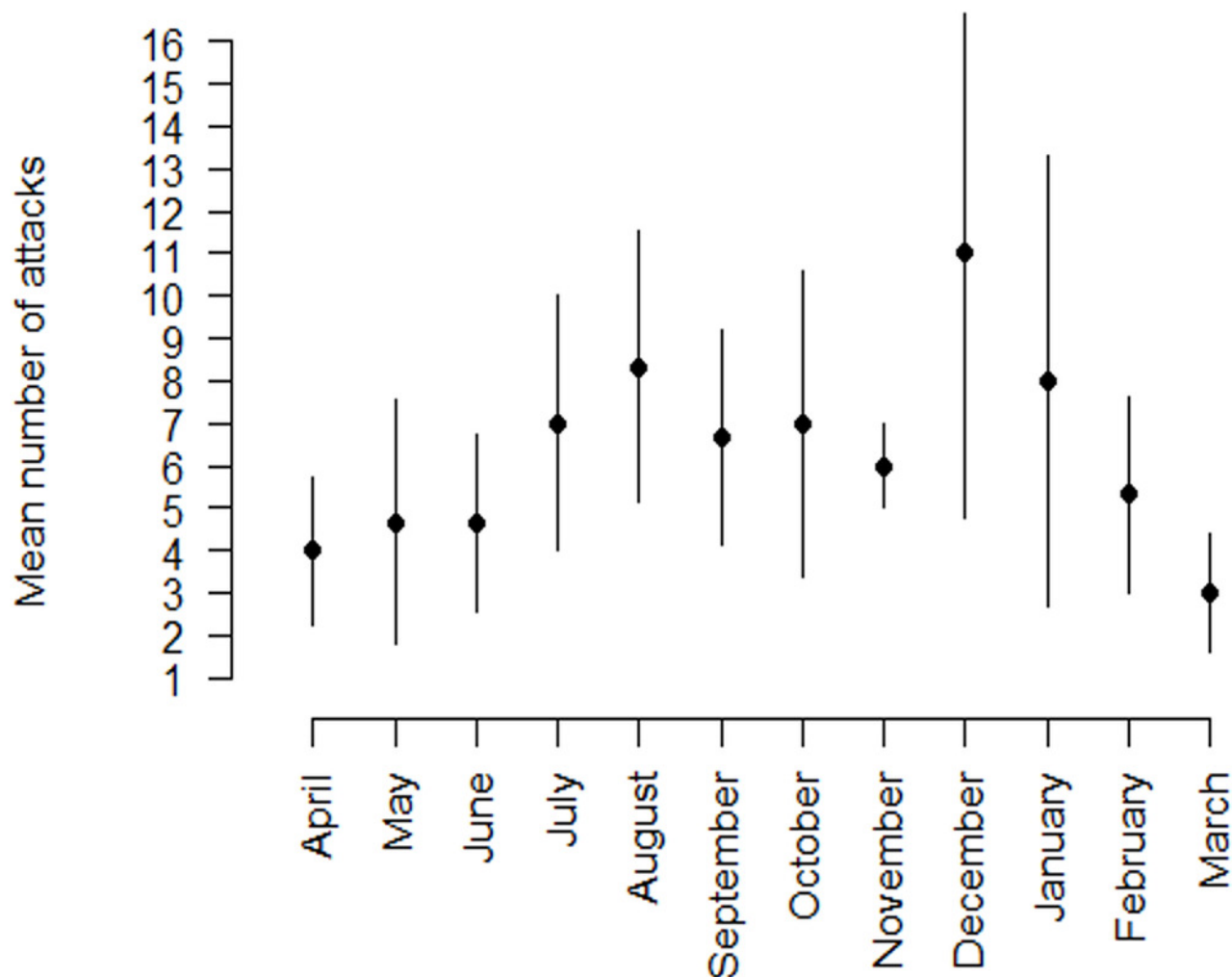
Figure 3

Causes of livestock mortality among the randomly interviewed farmers (n=77) from the intensive study area of Akole over a five year period