

1 **Patterns and determinants of Elephant attacks on humans in Nepal**

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13 **Abstract**

14 Attacks on humans by Asian elephant (*Elephas maximus*) is an extreme form of Human-elephant
15 conflict. It is a serious issue in southern lowland Nepal where elephants kill more humans than any
16 other wildlife. Detailed understanding of elephant attacks on humans in Nepal is still lacking which
17 affected in devising appropriate strategies and actions for human elephant conflict mitigation. This
18 study documented spatio-temporal pattern of elephant attacks on humans, factors associated with
19 the attacks and human/elephant behaviour contributing to deaths of victims when attacked. We
20 compiled all the documented incidences of elephant attacks on humans in Nepal for last 20 years
21 across Terai and Siwalik region of Nepal. We also visited and interviewed 412 victim families (274
22 fatalities and 138 injuries) on elephant attacks. Majority of the victims were males (87.86%) and had
23 low level of education. One fourth of the elephant attacks occurred while chasing the elephants.
24 Solitary bulls or group of sub-adult males were involved in most of the attack. We found higher
25 number of attacks outside the protected area. People who were drunk and chasing elephants using
26 fire-crackers were more vulnerable to the fatalities. In contrast, chasing elephants using fire was
27 negatively associated to the fatalities. Elephant attacks were concentrated in proximity of forests
28 primarily affecting the socio-economically marginalized communities. Integrated settlement, safe
29 housing for marginalized community and community grain house in the settlement should be
30 promoted to reduce the confrontation between elephants and humans. Conservation of elephant
31 should be carried out in entire landscape, extending beyond the boundary of protected areas to
32 reduce threats of elephant extinction.

33

34 **Key words:** Asian elephant, Attacks on humans, Spatio-temporal pattern, Terai-Siwalik landscape

35 **1. Introduction**

36 Asian elephant (*Elephas maximus*, referred to as 'elephant' hereafter) is a globally endangered
37 megaherbivore (Williams et al., 2020) It is an umbrella species in tropical and subtropical forests of
38 Asia, and has a strong cultural role in various Asian societies (Menon et al., 1996; Sukumar, 2003;
39 Jadhav & Barua, 2012; Vasudev et al., 2020). Once widely distributed in the Asia, elephants are now
40 confined to ca. 5% of their historical range in highly fragmented landscapes (Sukumar, 2006). In
41 addition, the rapid development of linear-infrastructures including railways, highways, electric
42 transmission lines and irrigation canals cause further obstruction to elephant movement. Elephants
43 require large areas for their survival with long distance seasonal movements (Leimgruber et al.,
44 2003; Goswami, 2017). However, increasing habitat fragmentation brings them in frequent
45 confrontation with humans. As a result, human elephant conflict (HEC) is worsening and has become
46 a prominent cause of elephant population decline (Sukumar, 2006). Attack on humans is the
47 extreme form of HEC. Other effects upon local people from HEC includes loss of crops, damage to
48 property, and safety threats (Dickman, 2010); and a large number of elephants are also killed in
49 retaliation.

50 Nepal is a typical example of an elephant range country with a small but growing population of
51 about 230 elephants in highly fragmented landscape (Ram & Acharya, 2020). Increasing
52 encroachment and forest conversion in the lowlands of the Terai and Chure hills (Himalayan
53 foothills) have destroyed the traditional migratory routes of the elephants. Whereas some
54 residential solitary bulls living in protected areas have become habituated to visiting agricultural
55 areas for a higher quality diet causing a high amount of damage (Koirala et al., 2016). Elephants
56 cause the highest number of human deaths among the wildlife species in Nepal. Thus, HEC is a
57 serious issue throughout the lowland Nepal (Acharya et al., 2016).

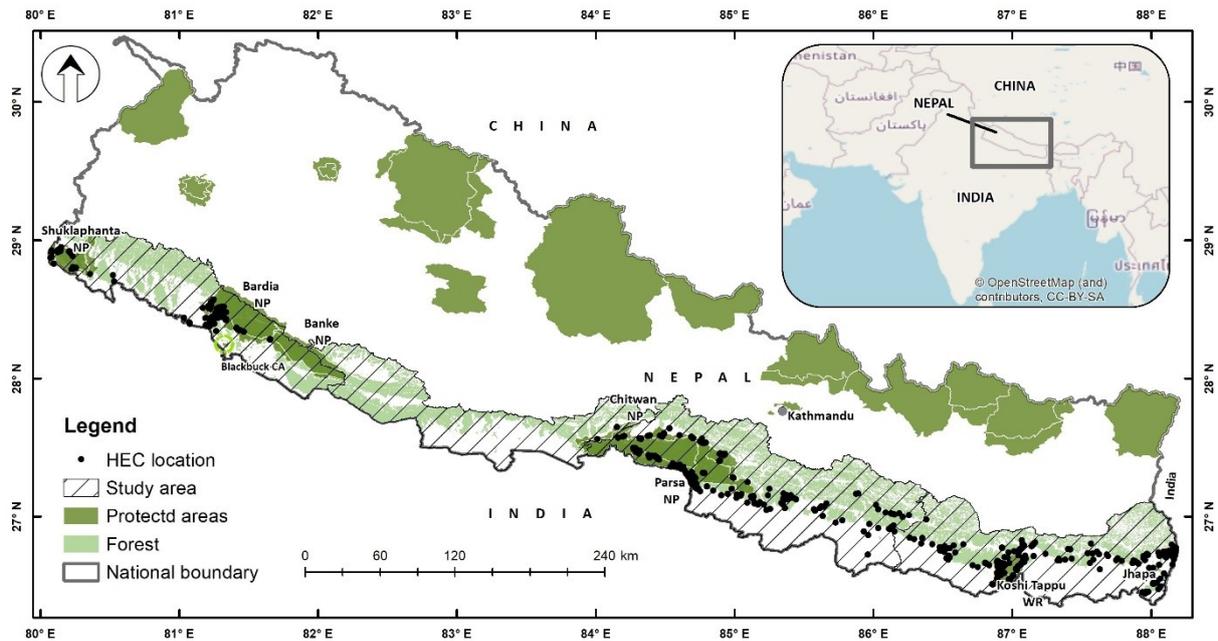
58 Few studies on human-elephant conflict have been carried out in Nepal primarily focusing on crop
59 and property damage (Neupane et al., 2013; Graham et al., 2016; Pant et al., 2016). However,
60 detailed studies of elephant attacks on humans are still lacking. This study attempts to document
61 spatio-temporal pattern of elephant attacks on humans in Nepal, characteristics of the victims and
62 attacking elephants, determine factors associated with the attacks, and identify human and elephant
63 behaviour contributing to deaths of victims when attacked. We tested hypothesis 1) human activities
64 are responsible for elephant attacks on humans; 2) elephant attacks are higher in the close proximity
65 to forest; and 3) majority of the attacks on humans is caused by solitary bull elephants. The study
66 results have long term implications for the conservation and management of elephants in the human
67 dominated landscape of Nepal and beyond.

68 **2. Material and Methods**

69 **2.1 Study area**

70 The study was conducted across the Terai and Siwalik region of Nepal covering ca. 46,000 km² of
71 elephant range in 24 districts (Figure 1). The Terai and Siwalik region of Nepal is densely populated
72 with 391.5 persons/km² (CBS, 2014). About 51% of total population of Nepal reside in the region
73 with agriculture and livestock husbandry as the primary occupation. About 42% of the study area is
74 forested providing habitats and migration corridors for the Asian elephant (DFRS, 2015). Major cities,
75 industrial areas and major highways fragment the forested areas. The region was intact till 1950s but
76 afterwards it is under continuous human pressure from expansion of agriculture, settlements and
77 built-up areas.

78 The study area comprises various habitats including highly productive alluvial floodplain grasslands,
79 riverine forests and climax (*Shorea robusta*) forest supporting many rare and globally threatened
80 species including tiger (*Panthera tigris*), dhole (*Cuon alpinus*), greater one-horned rhinoceros
81 (*Rhinoceros unicornis*). The study area has a sub-tropical climate characterized by hot and humid
82 summers (mid-March/mid-June), intense monsoons (mid-June/mid-September), and dry
83 autumns/winters (mid-September/mid-March) (Lamichhane, Persoon, et al., 2018; Lamichhane,
84 Subedi, et al., 2018). The maximum temperature on varies from 35–40°C during summer and 14–16
85 °C in winter (Jackson, 1994) . The mean annual rainfall ranges between 1138 and 2680 mm, with
86 over 80% of the rain occurring during the 3 monsoon months (Lamichhane, Persoon, et al., 2018) -.
87 Elephants in Nepal are found in four population clusters i.e. eastern (Koshi to Jhapa), Central
88 (Chitwan to Mahottari), Western (Bardia to Dang), and Far Western (Kanchanpur & Kailali). Out of
89 four population clusters of elephants, higher number of attacks on humans were recorded in
90 eastern, central and western clusters. They frequently migrate through the Nepal-India
91 transboundary forest connectivity in the East (Northern part of West Bengal), West (Uttrakhand) and
92 some places in the South (Bihar and Uttar Pradesh).



93
 94 Figure 1. Study area location, forest cover, protected areas and locations of elephant attacks on
 95 humans in Nepal.

96 **2.2. Elephant attacks data collection**

97 We compiled all available data of elephant attacks on humans (death and injury) from the Divisional
 98 Forest Offices (DFO) and Protected Area (PA) offices across the study area for the period 2000 to
 99 2020. We also conducted 30 stakeholder consultation meetings to gather information on human
 100 killings, livelihoods, elephant visiting patterns and people's perception towards the elephants. We
 101 also collected/verified the information on human killings by elephants from annual reports of parks,
 102 wildlife reserves, divisional forest offices, regional forest directorates, Department of National Parks
 103 & Wildlife conservation (DNPWC) and Department of Forests (DOF).

104 **2.3. Victim household questionnaire survey**

105 We conducted structured questionnaire surveys of all affected households (n=412) in the study area.
 106 On consent, either the head of the household or another adult member was interviewed. GPS
 107 location of each household was recorded. The questionnaire included demographic background of
 108 the interviewee and the victim, socio-economic status, victim behaviour and activity during attack,
 109 methods used for driving elephants off, characteristics of attacking elephant, and habitat
 110 characteristics (Table 1). We also collected information on relief to the victim or family (Annex I).

112 **2.4. Data analysis**

113 We entered all the questionnaire survey data in MS Excel and prepared descriptive summaries using
 114 pivot table function (Dan Clark, 2020). We then performed data analyses in the R statistical package

115 v. 4.0.2 (R Development Core Team 2020). We used chi-square test of independence for comparing
 116 the frequency of attacks (death and injury) between seasons, months, ethnicity, age group, sex and
 117 major occupation of people (Lamichhane, Persoon, et al., 2018). We categorized victims into five
 118 categories based on ethnicity, upper cast Hindus including Brahmin Chhetri Thakuri (BCT), Dalit or
 119 underprivileged group, Janajati (ethnic groups such as *Gurung, Magar, Newar, Tamang, Rai, Limbu,*
 120 *Tharu, Bote, Darai, Rajbansi* etc.), Madhesi, and Muslim. Similarly, we grouped the victims into five
 121 age categories i.e. <15, 15–24, 25–44, 45–64, 65+ years following (United Nations, 1982) . Education
 122 level of the victims was categorized into illiterate (who cannot read and write), literate (who can
 123 read/write but have not attended formal school), Primary (completed primary school), and
 124 Secondary or above. Housing of the victim was categorized into cemented house, CGI roof house,
 125 tiled roof house, and thatched house.

126 We carried out binomial logistic regression by constructing a Generalized Linear Mixed Model
 127 (GLMM) (Zuur et al., 2010) to determine the factors associated with fatalities in elephant attacks. In
 128 the GLMM, fatalities on elephant attack were used as dependent variable by coding the human
 129 fatality–1 and injury–0. Fourteen explanatory variables representing elephant characteristics, human
 130 characteristics and site characteristics were defined (Table 1). Elephant behaviour included social
 131 characteristics (solitary bulls or herd elephant) and the elephant was in musth. The human
 132 characteristics included age and sex of the victim, education, activities of the victim during elephant
 133 attack, location of attack, type of house of victims. Human behaviour or response towards elephants
 134 (chasing with fire, explosives, or gun) was also included. Site characteristics included place of attack,
 135 migration route of elephants, and proximity to forest. We extracted the victim location’s habitat and
 136 environmental variables (Naha et al., 2019) (Table 1) using Google earth engine platform (Gorelick et
 137 al., 2017; Buchholtz et al., 2020) and Arc-GIS v 10.5 (ESRI, 2016; Wang et al., 2018) .

138 We ranked models by the small-sampled corrected Akaike’s Information Criteria (AICc, lower AICc
 139 value indicates higher model ranking) using multi-model inference in ‘MuMIn’ package in R (Barton,
 140 2020) . The final model was obtained by averaging the top candidate models supporting the data
 141 equally well ($AICc \leq 2$, (Burnham & Anderson, 2001).

142 Table 1. Variables used in binomial logistic regression and their type/source. The human casualty in
 143 elephant attack was the dependent variable and the independent variables included elephant
 144 characteristics, human characteristics, and environmental and habitat characteristics.

145

Variables	Type of variable	Categories/values	Data source
Elephant characteristics			

Herd type/size	Categorical	Solitary adult bulls, Sub-adult male, Sub-adult male group, Herd without calves, Female with calves	Questionnaire survey
Musth	Binomial	1, 0, NA (1 - Yes, 0 - No, NA - Don't know)	Questionnaire survey
Human characteristics			
Response to elephant	Categorical	Shouting, Fire cracker, stones,	Questionnaire survey
Alcohol use	Binomial	1,0, NA (1 - Drunk, 0 - not drunk, NA - Don't know)	Questionnaire survey
Victim age and sex	Categorical	Sex (Male, Female) Age (<15, 15 - 24, 25 - 44, 45 - 64, 65+),	Questionnaire survey
Victim ethnicity	Categorical	1. BCT (Brahmin, Chhetri and Thakuri); 2. Janjati (Ethnic communities of hills & Terai like Gurung, Magar, Tamang, Newar etc.); 3. Indigenous Terai (Tharu, Bote, Darai, Mushahar); 4. Dalit (under-privileged casts of Kami, Damai, Sarki etc.); 5. Madhesi and 6. Mushlim	Questionnaire survey
Education	Categorical	Illiterate, literate, primary, Secondary or above	Questionnaire survey
Activity of the victim at the time of incident	Categorical	Chasing elephants, resting at home, guarding crops, travelling on foot,	Questionnaire survey
House type	Categorical	Concrete, GI sheet, tile house, thatch house	Questionnaire survey
Environmental and habitat characteristics			
Proximity to forest	Numeric		GIS & questionnaire survey
Season	Categorical	Winter, Summer, Monsoon	Questionnaire survey
Land use type	Categorical	Farmland, settlements, forests/grassland	GIS

147 **3. Results**

148 **3.1. Victim characteristics**

149 There were 412 records (274 fatalities and 138 injuries) of elephant attacks on humans. Males were
150 attacked more frequently than females. Most of the victims (87.86%) had low level of education
151 (illiterate or primary level). Ethnic people or *Janajati* were the most affected group followed by BCT,
152 *Dalit*, *Madhesi* and Muslim. Age of the victims on elephant attacks range from infant (7 months) to
153 80 years old but most of them (71%) were adults of the age 24 - 64 years (Table 1). A quarter of
154 elephant attacks occurred while people were chasing elephants and half took place around
155 settlements or homes (Table 2). Most of the people attacked (88.8%) had low level of education
156 (illiterate or primary education only) and the two third of the victims of elephant attacks were living
157 in the thatched house.

158 Table 2. Characteristics of victims attacked by elephants in Nepal's Terai and Chure region of Nepal
159 between 2000 and 2020.

Victim characteristics	Incident type		Total
	Death	Injury	
Sex			
Female	116	38	154
Male	158	100	258
Caste/ethnicity			
BCT	74	49	123
Dalit	46	20	66
Janajati	115	50	165
Madhesi	36	15	51
Muslim	3	4	7
Age			
<15	19	7	26
15-24	39	23	62
25-44	101	61	162
45-64	92	39	131
65+	23	8	31
Education			
Illiterate	141	63	204
Literate	44	36	80
Primary	55	27	82

Secondary or above	34	12	46
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Housing			
Cemented house	28	22	50
CGI roof house	31	27	58
Tiled roof house	28	9	37
Thatched house	187	80	267
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Total	274	138	412
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160

161 Table 3. Victim activity and location of elephant attacks in the Terai and Chure region of Nepal during
162 2000-2020.

Activity of the victim	Location of attack			Total
	Crop field	Forest	Home/ settlement	
Chasing elephants	11	22	70	103
Travelling	1	30	50	81
Sleeping or working at home	-	-	66	66
Fetching forest products	-	65	-	65
Guarding crops	36	1	2	39
Livestock grazing	2	23	1	26
Open defecation	-	-	21	21
Other	1	7	3	11
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Total	51	148	213	412
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163

164 3.2. Elephant characteristics

165 Most of the elephant attacks on humans (85.2%, n=412) were caused by solitary adult bulls or group
166 of sub-adult males. Attacking elephants were mostly tusked in musth (Table 34). Only 6.8% and
167 4.6% of the attacks were caused by the elephants in herd and females separated from the herd
168 respectively.

169 Table 4. Characteristics of the elephants involved in attacks on humans in Nepal's Terai and Chure
170 region between 2000 and 2020.

Elephant characteristics	Attacks on humans		
	Death	Injury	Total
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Group type			
Adult males	213	103	316

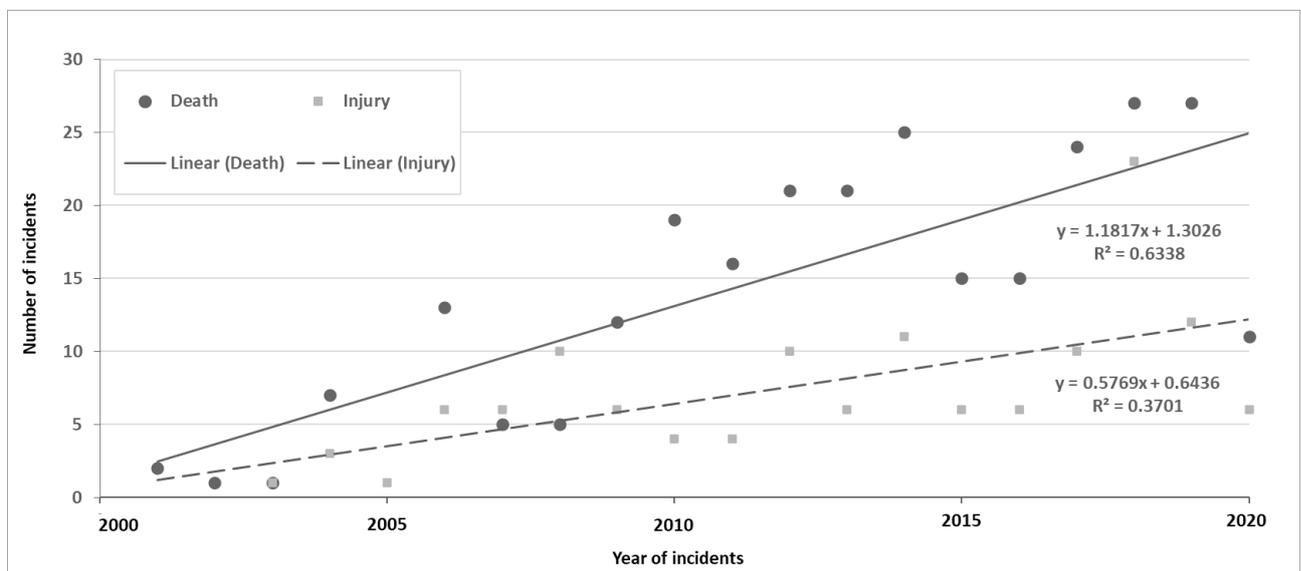
Adult females	6	13	19
Mixed group herd	17	11	28
Sub-adult male group	27	8	35
Unknown	11	3	14
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Adult/sub-adult bull elephant			
Yes	240	111	351
No	24	24	48
Don't know	10	3	13
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Elephant in musth			
Yes	131	76	207
No	71	36	107
Don't know	72	26	98
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Total	274	138	412

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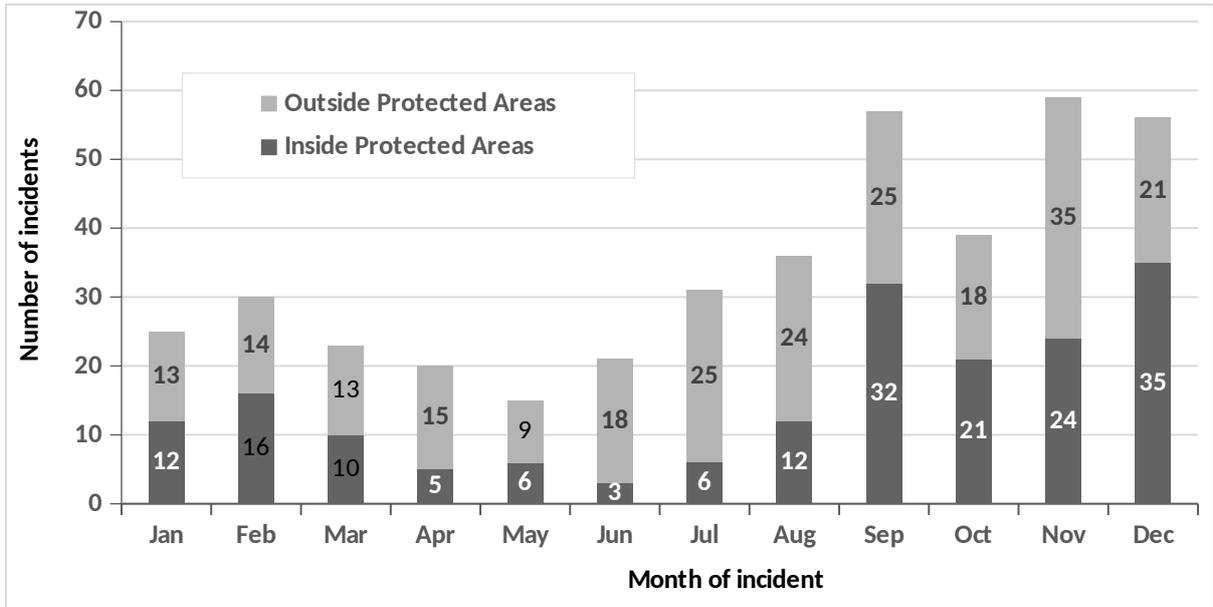
172 3.3. Temporal and spatial distribution of elephant attacks on humans

173 Elephant attacks on humans varied significantly across months ($\chi^2 = 76.272$, $df = 11$, $p < 0.001$) with
 174 peak in post-monsoon season (September to December). Number of attacks were higher outside
 175 protected areas (Table 4) but the difference was not significant ($t = -1.0751$, $df = 19.296$, $p = 0.2956$).

176 Linear regression showed a gradual increase of attacks between 2000 and 2020 (Figure).



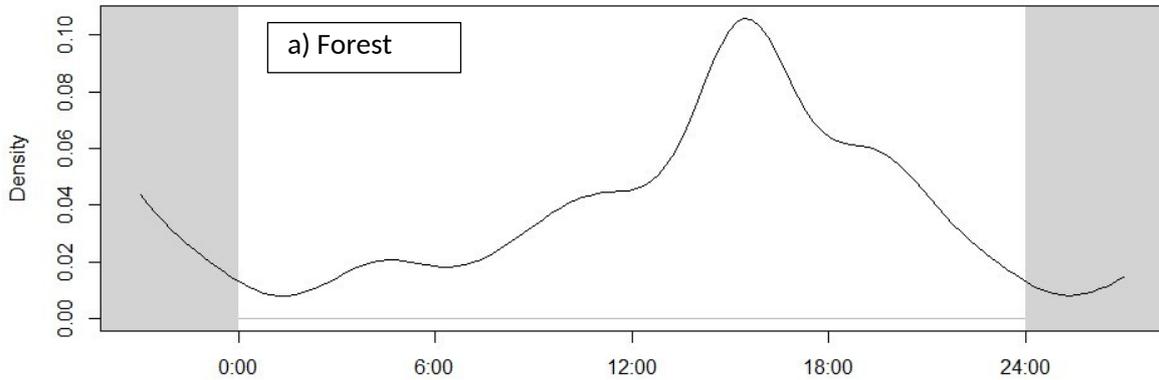
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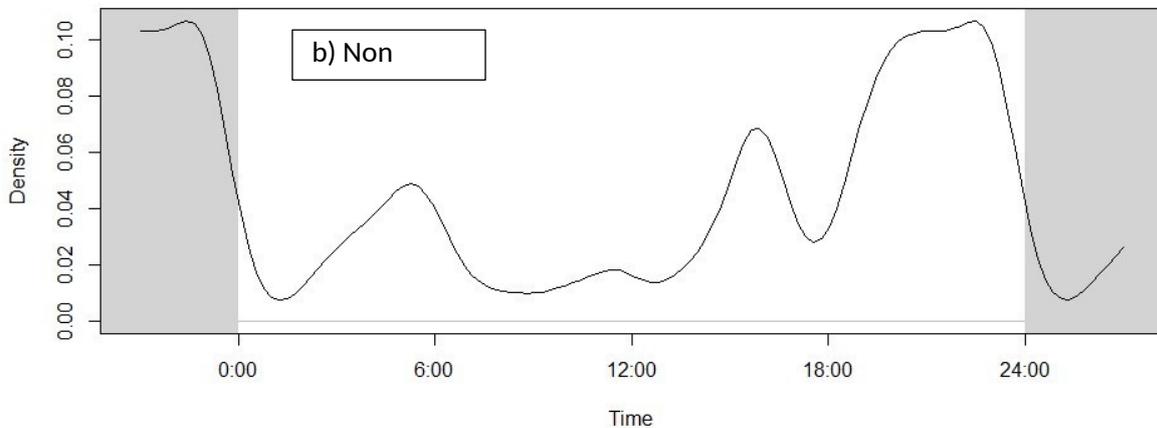
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179 Figure 2. Temporal distribution of elephant attacks on humans (death and injuries) in Nepal during
 180 2000 and 2020 a) over the years, b) over the different month.

181 Two peaks of the attacks on humans by elephants was observed, 1) afternoon (4-5 pm), and 2)
 182 evening (7-9 pm). In the forested areas, elephant attacks on humans are at peak in the afternoon,
 183 whereas, in settlement areas, elephant attacks peaked in the evening (Fig. 3).



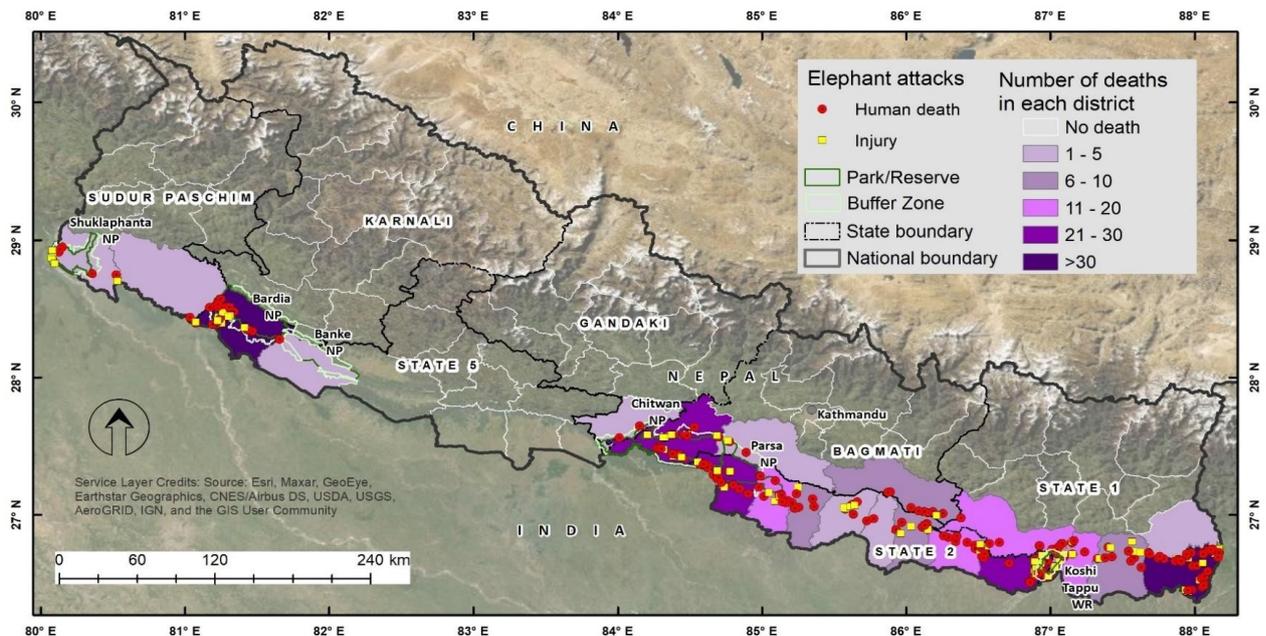
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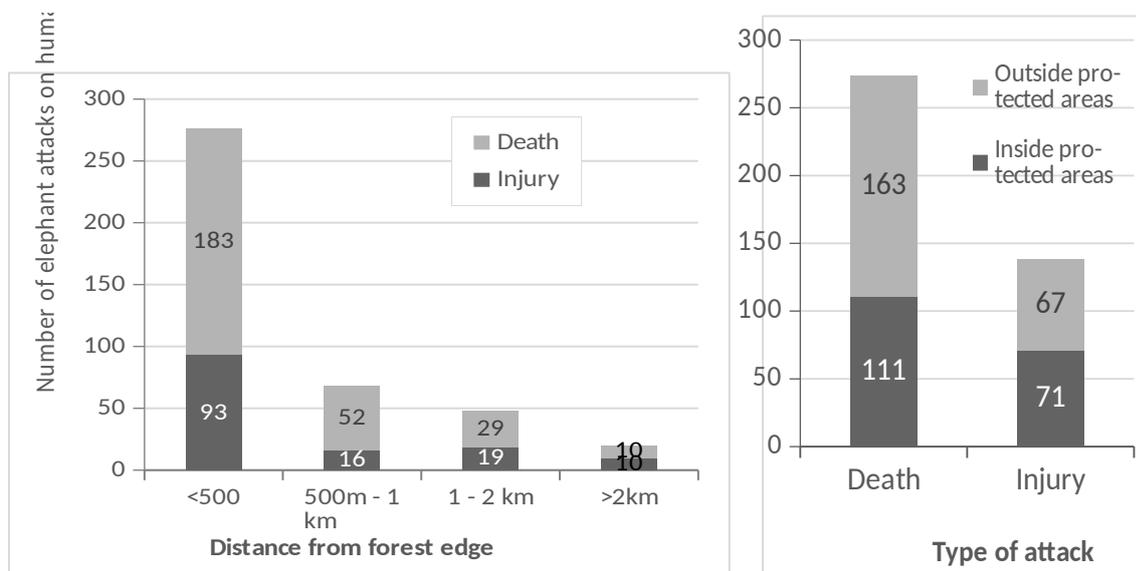
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186 Figure 3. Elephant attacks on humans at the different time of day in a) forested areas and b)
 187 settlement and agriculture areas outside forests.

188 The number of attacks on humans varied significantly among the districts ($\chi^2=338.49$, $df = 19$, p -value
 189 < 0.01) with the highest number of incidents ($n=66$) from Jhapa and Bardia districts in the eastern
 190 and the western Nepal respectively (Figure). The majority of elephant attacks (67%) occurred within
 191 500 m from the forest edge (Figure5).



192
 193 Figure 4. Spatial distribution of elephant attacks on humans in Nepal.



194
 195 Figure 5. Spatial distribution of elephant attacks on humans in Nepal with respect to distance from
 196 forest edge (left) and inside/outside of the protected areas (right).

197 **3.4. Factors associated with human fatality**

198 Based on the averaged value of the top candidate models, people who were drunk and
 199 chasing elephants using fire crackers were more vulnerable to fatalities. In contrast, chasing
 200 elephants using fire was negatively associated to fatalities (Table 5).

201 *Table 5. Factors associated with human fatality.*

Parameters	Estimate	Std. Error	Adjusted SE	z value	Pr(> z)	Significance
(Intercept)	0.652	0.795	0.798	0.81	0.413	
Crackers_Drums	1.095	0.508	0.511	2.14	0.032	*
Drunk	1.124	0.380	0.382	2.93	0.003	**
Fire_chasing	-1.715	0.576	0.579	2.96	0.003	**
House_typeCGI	0.063	0.588	0.592	0.10	0.915	
House_typethatched	0.795	0.504	0.508	1.56	0.117	
House_typediled	1.585	0.828	0.833	1.90	0.057	.
Place_attackForest	-0.914	0.530	0.533	1.71	0.086	.
Place_attackHome/ settlement	-0.272	0.522	0.526	0.51	0.605	
prox_forest	-0.001	0.000	0.000	1.91	0.055	.
Age	0.013	0.010	0.010	1.21	0.223	
Ele_Musth	-0.294	0.358	0.360	0.81	0.414	

202
 203 Significance codes: <0.001 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
 204

205 **4. Discussion**

206 Our study presents the most comprehensive analysis of the elephant attacks on humans in Nepal.
207 Elephants attacked an average of 20 humans per year with two thirds resulting into fatalities in the
208 Terai and Chure region. We documented the increasing trend of Elephant attacks on humans over
209 the years. All three of our hypotheses were found true. Human response towards elephants was a
210 major factor resulting in elephant attacks, supporting our first hypothesis. Higher number of attacks
211 by elephants on humans was recorded outside the protected areas, mostly in proximity of the forest
212 (66.99 % attacks in <500m from forest edge) supporting our second hypothesis. Over 76% of the
213 attacks on humans were caused by the solitary bulls (third hypothesis).

214 **4.1. Characteristics of the victims of elephant attack**

215 Elephants attacked males more frequently than females which can be associated with the high
216 mobility of males and their involvement in chasing the elephants (Sarker et al., 2015). For instance,
217 majority of the males were attacked while chasing elephants or travelling whereas females were
218 attacked more frequently while fetching forest products or working at home. Most of the attacks on
219 humans occurred close to forests where socio-economically marginalized people reside (Pant et al.,
220 2015; Neupane, Johnson, et al., 2017). Most of the attacked persons were illiterate, living in
221 thatched house, an indicator of poor social and economic condition (Neupane et al., 2013). People
222 living in thatched house often keep their grain storage close to where they sleep due to limited
223 space in the house. It increases the chances of elephant damage in their house and risks of elephant
224 attack (Naha et al. 2019). Neupane et al. (2013) documented low level of education and awareness
225 about elephants as an important determinant of the elephant attacks on humans. High proportion of
226 attacks on *Janajati* (ethnic) people can be associated with their involvement in local liquor
227 production, consumption and selling for their livelihood (Parajuli, 2015; Lamichhane et al., 2018b).
228 Such liquor also attracts elephants (Naha et al., 2019), primarily the solitary bulls, increases the
229 chances of encounter with humans. Thus, marginalized people living in the settlements near to the
230 forest edge, especially on the elephant migration routes are vulnerable to elephant attacks (ten
231 Velde, 1997; Jadhav & Barua, 2012).

232 **4.2. Characteristics of elephants attacking humans**

233 Mixed herd elephants rarely attacked humans (<5% of the incidents) although they are involved in
234 crop raiding during migration through agriculture areas or settlements (Naha et al., 2020). Solitary
235 adult bull elephants were responsible for majority (76.7%) of attacks on humans in Nepal (Acharya et
236 al., 2016). Attacks on humans were highly varied among elephant individuals. In our observation, a
237 few individual bulls, who repeatedly visited human settlements and agriculture areas, were involved

238 in the majority of the attacks. Similar findings of attacks on humans by solitary bulls is reported from
239 some parts of Bangladesh(Sarker et al., 2015) . With frequent interaction with humans, these bulls
240 become familiar with the human behaviour and lose the natural fear. However, they are also
241 harassed by people most of the time while raiding crops or grain stores. These irritating actions of
242 humans make them more aggressive resulting in violent attacks. We identified 37 such bulls causing
243 three quarters of all attacks on humans in the last twenty years. Out of 37 identified bulls, 19 were
244 involved in more than five incidences and some caused a disproportionately higher number of
245 attacks (up to 36). Such individuals can be termed “problem individuals” (Lamichhane et al., 2017;
246 Swan et al. 2018). Thus, human-elephant conflict management should prioritise managing such
247 problem elephants.

248 **4.3. Temporal patterns of elephant attacks**

249 Documented records of elephant attacks on humans in Nepal goes back to the 1970s (Upreti 2020,
250 Pers. Comm.) with sporadic records until the late 1990s. In our study, we only included data
251 between 2000 and 2020 (June). Elephant attacks on humans increased over the years from an
252 average annual 11 (± 8.5 SD) attacks during 2000–2010 to 29 attacks (± 11.2 SD) during 2011–2020.
253 The wild elephant population has gradually increased in Nepal from 52–53 individuals during the
254 1990s to 107–145 individuals in 2007 and 227 individuals in 2020 (Smith & Ishra, 1992; ten Velde,
255 1997; DNPWC, 2009; Ram & Acharya, 2020). Elephant movement is also increasing with escalating
256 elephant population. Human population growth rate in the Terai and Siwalik region (1.72%) is also
257 higher compared to the national average (1.35%; CBS, 2014). Consequently, the deforestation rate
258 is also higher in this region especially in the Siwaliks (0.18% annually) (DFRS, 2015). The remaining
259 forests are also becoming increasingly fragmented with planned and ongoing large-scale
260 infrastructure development such as roads, railways, canals, industries, airports and urban areas
261 forming barriers to elephant migration (MOFSC, 2015). Overlap in forest use by elephants and
262 humans is increasing, resulting a high human–elephant interaction (Acharya et al. 2017; Lamichhane
263 et al., 2018a; Mariki et al., 2015; Mukeka et al., 2019).

264 Elephant attacks on humans occurred throughout the year but peaked during September–December
265 coinciding with the rice harvesting season. Lamichhane et al. (2018a) also shows that elephants use
266 both forested and human-dominated areas but use of human-dominated areas varies seasonally
267 with peak in the autumn. Pre-monsoon (March–June) had the lowest level of attacks as agriculture
268 areas are devoid of crops and elephants are concentrated primarily in the forests feeding on
269 climbers, tree barks and new grass (Koirala et al., 2016; Lamichhane et al., 2018a).

270 Most of elephant attacks occurred between 15:00 – 22:00 hours with two peaks at ~16:00 and
271 ~20:00. Elephant attacks in forested areas peaked during the afternoon (~16:00) when human
272 activity, mainly cattle grazing, and fodder and forest resource collection, is high inside the forests.
273 The elephants generally rest during the mid-day hot period and start become active with decreasing
274 temperature in the afternoon (after 15:00). This increases the chance of interaction between
275 elephants and humans. Close to the time of sunset (~18:00), most of the people are returning home
276 from the forest while elephants remain inside forest so decreasing the chances of interaction
277 between them. Elephant attacks again increase in the evening (19:00–21:00) when elephants enter
278 the settlements or agricultural fields and people come in direct confrontation while chasing
279 elephants away.

280 **4.4. Spatial pattern of elephant attacks**

281 Two-thirds of elephant attacks on humans occurred within 500 -meters from the forest edge. Similar
282 finding was also documented in previous studies (Neupane et al., 2018; Ruda et al., 2018; Pant et al.
283 2016). People living in proximity of forests are vulnerable to elephant attacks because 1) chances of
284 encountering elephants is high at close distance to forest, 2) generally marginalized communities live
285 in these areas with lack of proper housing (thatched houses), and 3) low level of education and
286 awareness. Similar finding of a higher number of attacks by wildlife close to forest or park boundary
287 (<1 km) and an inverse relationship between the distance from the forest edge and wildlife attacks is
288 reported in other studies (Gurung et al., 2008; Lamichhane et al., 2018b; Pant et al., 2016).

289 A higher number of elephant attacks outside protected areas (59.5%) in our study is consistent to
290 Acharya et al. (2016). Similar results with higher conflict incidents outside protected areas has been
291 reported from north-east India (Choudhury, 2004a) Elephants require large areas to fulfil their needs
292 of large quantity of forage, water, and also finding mates. Their home ranges surpass the protected
293 area. People living close to protected areas are more aware about elephant behaviour and respond
294 accordingly (Lamichhane et al., 2019). Beyond protected areas, human response towards elephants
295 is more aggressive resulting in a high number of human casualties as well as retaliatory killing of
296 elephants (25 out of 33 retaliatory killing in past 20 years, unpublished data compiled by the first
297 author).

298 The elephant attacks on humans were concentrated in four pockets, Jhapa, Koshi, Chitwan Parsa,
299 and Bardiya. Despite the smaller population of elephants (~35) in eastern Nepal, the number of
300 attacks on humans is proportionately higher (43% of total attacks in Nepal). The reason for such a
301 high casualty in eastern Nepal especially in Jhapa district of south-eastern border of Nepal is because
302 of 1) the highly fragmented habitats outside of the protected areas, 2) historical migration route of

303 elephants from West Bengal, India straddling the national boundary, 3) low level of awareness on
304 elephant behaviour, and 4) provoking human actions towards elephants. Historically, ~100 elephants
305 used to migrate annually from West Bengal (India) entering Nepal from the eastern border during
306 September–October and May–June (Mallick, 2012). While migrating, they often come in
307 confrontation with people as they are forced to travel through settlements and agricultural land,
308 with a large part of their historic migration route encroached by people (Choudhury, 2004b) . A
309 fence installed in Bahundangi area (Jhapa district) at the Eastern border of Nepal have contributed in
310 reducing human-elephant conflict in the fenced areas. However, the elephant continue their
311 movement in Nepal from south of the fenced area (Jyamiregadhi and Jalthal) (Naha et al., 2019;
312 NTNC, 2019). Some elephants, especially males, break the fence and continue their movement up to
313 Koshi Tappu WR and westwards.

314 About one quarter (24%) of all elephant attacks on humans in Nepal occurred in Koshi Tappu WR and
315 its periphery. Koshi Tappu WR acts as a stepping stone for the elephant population in eastern Nepal.
316 Koshi Tappu WR (173 km²) is much smaller than the home range of elephants (188 – 400 km²,
317 Williams et al., 2008; Alfred et al., 2012; Williams, Krausman and Asir, 2015). With the high
318 dependency of communities on the reserve for grazing, fodder, firewood and fishing, elephants and
319 people come in frequent confrontation. The situation is further aggravated in the densely populated
320 agrarian areas in the periphery of the reserve.

321 Human casualty was recorded throughout Central (upto Nawalparasi East) and Eastern Terai. In the
322 Chitwan-Parsa Complex in central Nepal, 27.4% of the elephant attacks were recorded, mostly from
323 Chitwan, Parsa and Bara districts. There is a gap in elephant distribution between the central
324 population (Nawalparasi East) and the western population (Bardia) with only a sporadic presence in
325 Banke, Dang and Kapilvastu districts (Lamichhane et al. 2018a). The largest elephant population
326 (>100) in Nepal exists primarily in Bardia NP in western Nepal where 16.7% of total elephant attacks
327 on humans occurred. Elephants in the western population also migrate through the Chure-Siwalik
328 foothills West of Bardia reaching up to Shuklaphanta NP causing some incidents of attacks on
329 humans (ten Velde, 1997).

330 **4.5. Factors associated with the human fatality**

331 Our results of two third of elephant attacks resulting in the fatality is consistent with Acharya et al.
332 (2016). Human behaviour and responses towards elephants were the major factors to cause
333 elephant attacks on humans. Aggressive human behaviour towards elephant with intolerance was
334 the major determinant of human fatality in elephant attack (Nelson et al., 2003). People were killed
335 mostly while chasing wild elephants using fire crackers and other high sound and light objects. Drunk

336 people were more vulnerable to deaths if elephant attacked (Neupane, Kunwar, et al., 2017).
337 Negative association of fatalities while chasing elephants using fire torch indicates it as a safe and
338 effective method for pushing elephants outside of the village.

339 **5. Conclusions**

340 Human casualties from elephants have been increasing with its multifaced impact on human-
341 elephant coexistence in Nepal. Elephant attacks were concentrated in proximity of forests primarily
342 affecting the socio-economically marginalized communities. Most of the attacks on humans were
343 caused by solitary bull elephants. Human response towards elephant was a major factor associated
344 with the elephant attacks on humans. Chances of elephant attacks and human fatalities increases
345 when drunk people are chasing elephant. This urgently requires a human elephant conflict (HEC)
346 mitigation strategy to combat this issue. Local people as well as the Government of Nepal (GON)
347 have adopted various preventive and curative measures such as fences in hotspots, problem animal
348 management, and relief support for victims/families to reduce both human casualties and elephant
349 retaliation. These measures should be continued and additional activities such as integrated
350 settlement, safe housing for marginalized community and community grain house in the settlement
351 should be promoted to reduce the confrontation between elephants and humans. Conservation of
352 elephant should be carried out in entire landscape, extending beyond the boundary of protected
353 areas to reduce threats of elephant extinction. Conservation awareness campaign should be carried
354 out throughout the landscape and involve community for elephant conservation.

355 **Acknowledgements**

356 We thank Wildlife Institute of India, Ministry of Forests and Environment (Nepal), Department of
357 National Parks and Wildlife Conservation (DNPWC), National Trust for Nature Conservation (NTNC),
358 ZSL Nepal, WWF Nepal for supporting at different stages of the study. Ms. Carol Inskipp and Dr.
359 Narendra Man Babu Pradhan reviewed and provided crucial feedback on earlier version of the
360 manuscript. We acknowledge the contribution of field assistants Mr. Suman Acharya, Mr. Dinesh
361 Ghimire, Mr. Badri Chaudhary, Mr. Buddhi Binod Acharya and Shankar Luitel. We are indebted to the
362 support of Director General of DNPWC, National Park/Wildlife Reserve wardens and Divisional Forest
363 Officers of the Terai region during this study. The study would not be possible without the funding
364 support of Rufford Small Grants Foundation, International Elephant Foundation, USAID – Hariyo Ban
365 Program through WWF Nepal and ZSL Nepal.

366 **Author contributions**

367 AKR, NS, SM & BP designed the study; AKR conducted the fieldwork; AKR, BR & RA analysed the
368 data; AKR & BR wrote the first draft of the manuscript; HSB, NLN and all authors revised the
369 manuscript.

370

371 **Data Accessibility**

372 Data and outputs including the Rcodes will be available after article is published. These files are
373 deposited in Dryad (<https://doi.org/10.5061/dryad.f7m0cfxvp>).

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503

504

505 Supplementary Information S1. Sex of victim and their activity while attacked by elephant.

506

Activity of the victim	Death		Injury		Total
	female	male	female	male	
Chasing elephants	14	51	13	25	103
Fetching forest products	23	20	14	8	65
Guarding crops	7	23	3	6	39
Livestock grazing	5	12	4	5	26
Open defecation	6	5	4	6	21
Other	1	7	1	2	11
Sleeping/working at home	27	22	5	12	66
Travelling	16	35	10	20	81
Grand Total	99	175	54	84	412

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508