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Mortality records (1979–2011) shed light on threats to Asian Elephants *Elephas maximus* Linnaeus, 1758 (Mammalia: Proboscidea: Elephantidae) in Nilgiris, southern India

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Abstract: We compiled records of 291 elephant deaths over a 33-year period (1979–2011) from the Mudumalai Tiger Reserve and the reserved forests of Nilgiri North and South divisions of southern India from the databases of the Tamil Nadu Forest Department, the Wildlife Protection Society of India and the Nilgiri Wildlife and Environment Association. We tested the null hypothesis that the causes of elephant deaths would not differ with time, by gender and with level of protection. We classified records by gender and age: adults (≥15 years), sub adults (5–15 years), juveniles (>1–<5) and calves (≤ 1). We organised records over 3-decade periods. The database consisted of 209 adults (≥15 years), 27 sub adults (5–15 years), 33 juveniles (>1–<5) and 22 calves (≤ 1). MTR had the maximum records (148) followed by NND (138) and NSD (4). The median age of death was 20 years for adult males and 30 years for adult females. Mean survival time for adult males was 22.45 years, and 31.84 for females. Poaching was responsible for the majority of deaths (40%), particularly of male elephants (82%), and unknown causes (31%) for the majority of female deaths (66%). Human-caused deaths, which included poaching and some accidents, averaged 72% between 1979 and 2000 and decreased to 22% during 2001–2011. Deaths due to unknown causes and diseases increased from 28% in 1979-1989 to 69% in 2001–2011. Relative to estimated population size, deaths attributed to poaching was higher in NND (47%) than in MTR (34%). The causes of death differed by region. In conclusion, the elephant population in the Nilgiris is at risk and needs stringent protection; the mortality database should be systematised; forensic capabilities upgraded, and detection of carcasses improved.

Keywords: Asian Elephant, endangered species, India, ivory poaching, Mudumalai Tiger Reserve, Nilgiri Biosphere Reserve, Nilgiri North Division, wildlife forensics.

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INTRODUCTION

The Asian Elephant *Elephas maximus* is under threat of extinction from habitat loss and poaching (Lomolino & Channell 1995; Choudhury et al. 2008) and now survives in fragmented habitats which decrease its long-term viability (Leimgruber et al. 2003). India is estimated to host approximately 60% of all Asian Elephants (Riddle 2010). The largest population, estimated to be around 6000 elephants, is in the Nilgiris-Eastern Ghats (NEG) region of southern India, which is around 15000km^2 in area (Baskaran 2013).

Ivory poaching, habitat loss and fragmentation are major threats to elephant populations in India (Leimgruber et al. 2003; Choudhury et al. 2008), and while ivory poaching has recently declined, its impact on sex ratios still lingers (Baskaran 2013). Armbruster et al. (1999) showed that there is a lag period before a slowly-declining species such as the Asian Elephant can be driven to extinction. Therefore, it is crucial to identify and ameliorate threats before they become serious. In this study we examined mortality records of 291 Asian elephants from the Mudumalai Tiger Reserve (MTR), the Nilgiri North Division (NND) and Nilgiri South Division (NSD), which are contiguous forests and form part of the Nilgiris-Eastern Ghats elephant range in southern India. The database covered a period of 33 years (1979–2011), which included a period of intensive ivory poaching in the 80s, 90s and early 2000s (Daniel et al. 1987; Prasad 2000), probably causing about 45–68 % of male elephant (tusker) deaths in Tamil Nadu (Sukumar 1989).

Illegal killings for the ivory trade are a source of elephant mortality, and the MIKE program (Monitoring the Illegal Killing of Elephants) was established to assess trends in illegal killings in range states to help CITES (Convention on International Trade in Endangered Species, (http://www.cites.org) policy on ivory trade (Burn et al. 2011). Moreover this data being from forests contiguous to two MIKE sites (Burn et al. 2011) could augment understanding threats to this population.

We looked at: (1) patterns and causes of elephant mortality over time, by age class, gender and across areas with different levels of protection; and (2) human-caused deaths over time and in reserves with differing levels of protection. We tested the null hypothesis that causes of death would not differ over time, with age, gender, and levels of protection.

MATERIALS AND METHODS

Study area

The databases were from the contiguous forests of the Mudumalai Tiger Reserve (321km^2), the Nilgiri North Division (448km^2) and the Nilgiri South Division (199km^2), which together cover an area of 968km^2 (Fig. 1). MTR being a Tiger Reserve falls under IUCN category II (National Park), whereas NND and NSD consist of Reserved Forests (Indian Forest Act 1927, http://envfor.nic.in/legis/forest/forest4.html) which come under IUCN category V (protected landscape) if they are buffer zones of protected areas (http://www.iucn.org/about/work/programmes/gpap_home/gpap_quality/gpap_pacategories, viewed 26 January 2015).

MTR is located along the west of the Nilgiris District, and is contiguous with the Reserved Forests (RF) of NND towards the east and the northern slopes of the upper Nilgiri Plateau and has an average elevation of ~950m. The higher altitude RFs (> 2000m) towards the west and south such as Upper Bhavani, Korakundah, Kundah, and Naduvattam fall under the NSD and have a matrix of montane evergreen forests, grasslands and plantations (Fig. 1).

The database

We compiled the database from the regional offices of the Tamil Nadu Forest Department (TNFD, http://www.forests.tn.nic.in/WildBiodiversity/np_mnp.html); the Wildlife Protection Society of India, New Delhi (WPSI, http://www.wpsi-india.org/wpsi/index.php) and the Nilgiri Wildlife and Environment Association (NWEA, http://en.wikipedia.org/wiki/Nilgiri_Wildlife_and_Environment_Association). There were 183 records from TNFD, 82 from WPSI and nine from NWEA. Seventeen records were common to TNFD and WPSI.

The records included information on the date when the animal was discovered, its sex, estimated age and age category (adult, sub adult, juvenile or calf), the range/beat/division in which it was found, and possible causes of death. For some sites verification was done using range office records.

The causes of death were described in official records as 'one female elephant of 32 years died at this place suffered injuries. Post-mortem done. Death due to internal haemorrhage. Bullet found' etc. In 248 instances, the records noted the case as 'wildlife offense' and listed as 'poaching', 'disease', 'electrocution', 'hit by vehicle', 'others', 'unknown' and minor categories such as 'fell off rock', 'injured'. From the wildlife offense listed and the reason for the death as per official veterinarian

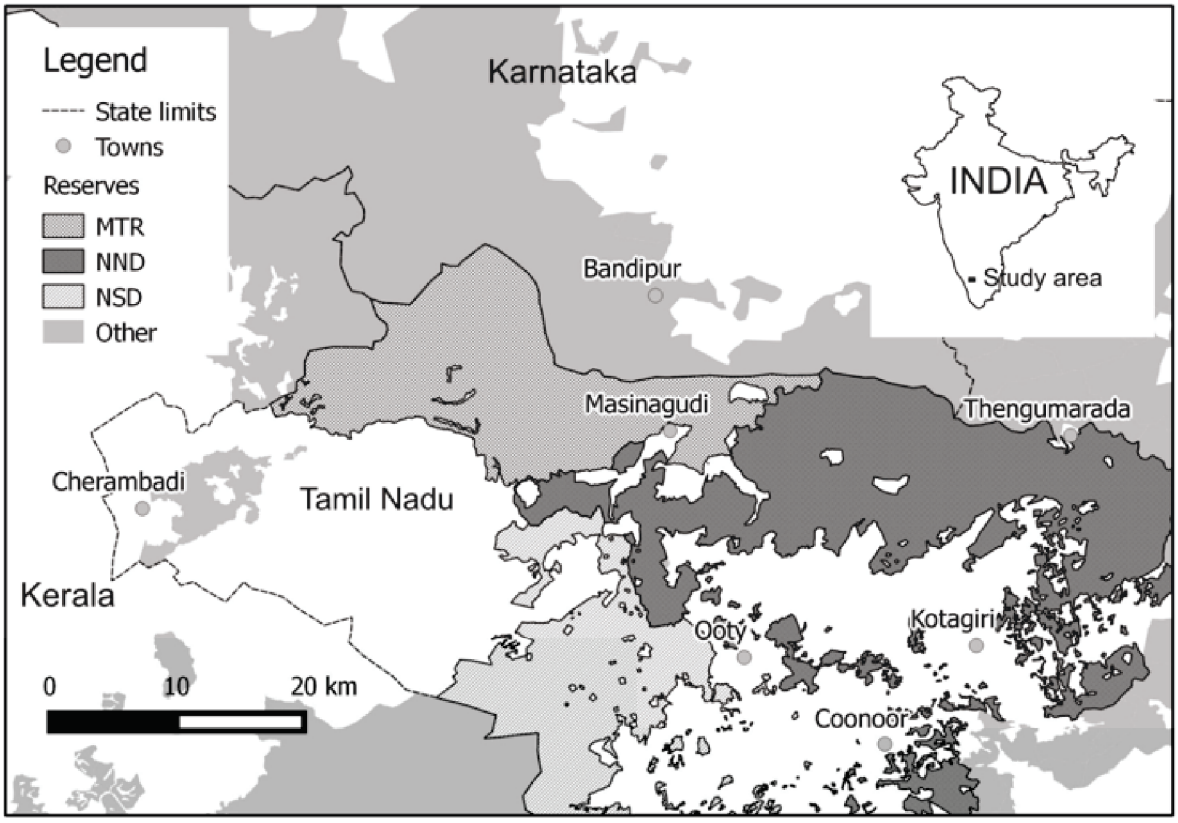

Figure 1. Map of the study area indicating the different protected areas.

report, we deduced the cause of death and grouped the records into six categories: 'poaching', 'accident', 'attack by wild male', 'disease', 'other' and 'unknown'. Accidental deaths were caused by vehicle hits, electrocution, falling down when negotiating steep slopes. In some cases the wildlife offense under which the death was categorized differed from the reason for the death. Comparing both sources of information we shifted 15 cases from wildlife offense category 'unknown' and 'others' to disease, six cases from 'attack by wild male', 'others' and 'unknown' to poaching since the elephants had been noted as having been shot or tusks removed, six cases from unknown' and 'others' to 'accident' since the animals had been electrocuted or suffered shock, hemorrhage and had collapsed. For instance, in many cases of death by trauma or disease, the wildlife offense was left blank or listed as 'other', in which case we placed these either under 'disease' or 'accident'. In the case of an obvious disease, it was noted as such, and in the case of trauma such as hemorrhage and internal wounds, it was marked as 'accident'. Cases of possible death due to colon compaction and caecal impaction was left blank or listed as 'unknown' in the wildlife offense category, and was placed under 'disease' in our database. The category 'other' included old elephants, females that died while calving, and calves that had lost their mothers or had been abandoned.

Patterns of mortality over time

The data were arranged in chronological order from the earliest to the latest record and grouped into 11-year intervals: 1979–1989, 1990–2000 and 2001–2011 called 'decades' for simple usage. Based on the information given each record was classified as that of a calf (≤1 year), juvenile (>1 to <5 years), sub adult (5-15 years) and adult (≥15 years), (after Sukumar & Santiapillai 1993). We assessed whether the number of deaths, and their reported causes had changed over the three decades.

Comparison of mortality in male and female elephants

We compared the causes of deaths between adult male and female elephants. Where estimated age was noted, we assessed the median age of death and conducted a survivorship analysis.

Comparison of mortality with levels of protection.

We tested whether patterns of mortality and the

reported causes differed between MTR and NND over the three decades. We compared the following regions: 1. Mudumalai Tiger Reserve, 2. the Gudalur region, 3. the Masinagudi-Mavinhalla-Chemanatham belt, 4. Bokkapuram-Singara, 5. Nilgiris south, 6. Sigur-Anaikatti, 7. Coonoor-Kallar, to see whether they differed with regard to causes of death. We did not use data from NSD due to paucity of records.

Patterns of human caused deaths over the years

All poaching cases and 13 of the accidents such as electrocution, and hit by vehicles came under 'human caused deaths'. We assessed whether the proportion of human caused deaths had changed over time.

Data analyses

The data were analysed using non-parametric statistics. Categories with fewer than five samples were not included in the analysis. We used the survival analysis to assess mean age of death for adult males and females. All analyses were conducted using SYSTAT (SPSS 2000).

RESULTS

General patterns

The majority of records were of adults (209, 72%), followed by juveniles (33, 11%), sub adults (27, 9%) and calves (22, 8%). Of 151 records with estimates of age, 70 (46%) were adults, 43 were calves and juveniles (<5 years) and the rest were sub adults (Fig. 2). Among adults mortality was highest between 20–30 years of age with a decrease after around 35 years (Fig. 2).

The deaths were attributed to poaching (117, 40%), unknown causes (91, 31%), diseases (38, 13 %), accidents (35, 12%) and other minor categories (Table 1). In the 'unknown' category 14 carcasses were found in highly decomposed state and therefore a cause could not be attributed. There were significant differences in the causes of mortality by age categories (Non parametric ANOVA (Friedman two-way analysis =8.38, df=3, p =0.038, Table 1), with adults succumbing disproportionately to poaching (45%).

Patterns of mortality over time

Overall, elephant deaths increased over time, from 57 in 1979–1989 to 120 in 1990–2000 and 113 in 2001–2011. Deaths due to poaching were highest in 1990 to 2000 (65%) and decreased to 10% in 2001–2011, whereas those due to unknown causes increased significantly from 26% in 1979-1989 to 44% in 2001–2011 (χ^2 = 37.56, df=2, p<0.0001), and diseases increased from 2% in 1979-89 to 25% in 2001–2011 (Table 2). The maximum age reported in the records did not significantly increase

Table 1. Non parametric (Friedman two-way non-parametric ANOVA =8.38, df=3, p =0.038) indicates significant differences in the causes of mortality by age categories. Categories with samples <5 were not included in the statistical analysis

Causes	Years				Total
	Adult (≥15)	Sub adult (>5 to <15)	Juvenile (>1 to <5)	Calf (<1)	
Accident	20	5	6	4	35
Attack by wild elephant	4	0	0	0	4
Disease	26	4	5	4	39
Other	2	0	0	1	3
Poaching	98	7	12	0	117
Unknown	59	11	10	13	93
Total	209	27	33	22	291

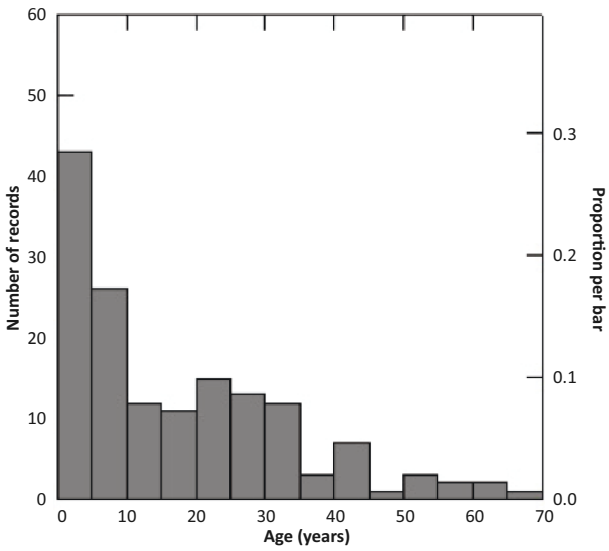

Figure 2. Distribution of elephant deaths by estimated age (n=151)

Table 2. Differences between female and male elephants in reported causes of death over the three decades.

Causes	1979–1989		1990–2000		2001–2011		Total
	M	F	M	F	M	F	
Accident	1	0	5	5	10	9	30
Disease	0	1	4	3	10	19	37
Poaching	29	9	50	9	8	1	106
Unknown	4	9	10	22	13	21	79
Total	34	19	69	39	41	50	252

Table 3. Total records of elephant deaths in Mudumalai Tiger Reserve, and the Reserved Forests of the Nilgiri North and South Divisions over 33 years (1979-2011), with population estimates from literature (Davidar et al. ms) and the percentage of deaths attributed to poaching in MTR and NND.

Forest Sector	Area (km²)	Estimated population size N	Total deaths	Deaths attributed to poaching	% poached
Mudumalai Tiger Reserve	321	~643 (Baskaran 2013)	148	50	34
Nilgiri North Division	448	~419 (Baskaran 2013)	138	65	47
Nilgiri South Division	199	Not known	4	1	-
Total	968	~1000	290	116	40

Table 4. Regional differences in causes of death among wild elephants in the Mudumalai Tiger Reserve (MTR), and Reserved Forests (RF) of the Nilgiris (χ2=19-49, df=3, p = 0.0002). Attack by wild elephants and 'other' causes were not included in the chi square analysis.

Causes	Bokkapuram-Singara	Coonoor-Kallar	Gudalur	MTR	Masinagudi-Mavinhalla	Nilgiris south	Sigur-Anaikatti	Total
Accident	2	6	5	10	7	3	2	35
Attack wild elephant	0	0	0	2	0	0	2	4
Disease	0	1	1	26	7	0	3	38
Other	0	0	2	3	1	0	0	6
Poaching	2	5	16	50	8	1	34	116
Unknown	7	2	2	57	11	0	12	91
Total	11	14	26	148	34	4	53	290

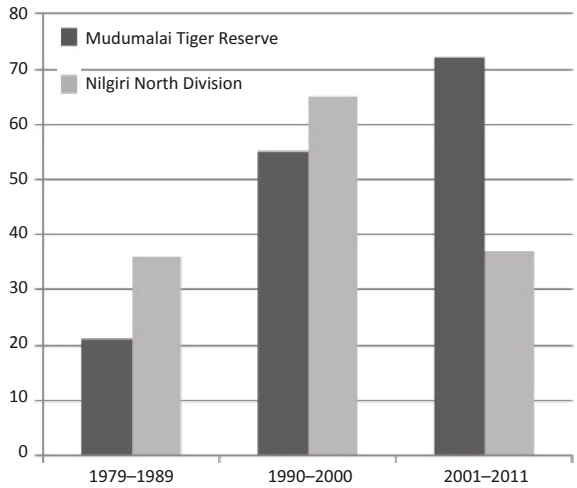

Figure 3. Elephant death records over three decades from Mudumalai Tiger Reserve (MTR), Nilgiri North Division (NND) and Nilgiri South Division (NSD) forests. The number of records differed significantly between MTR and NND (χ2=15.69, df=2, p = 0.0004).

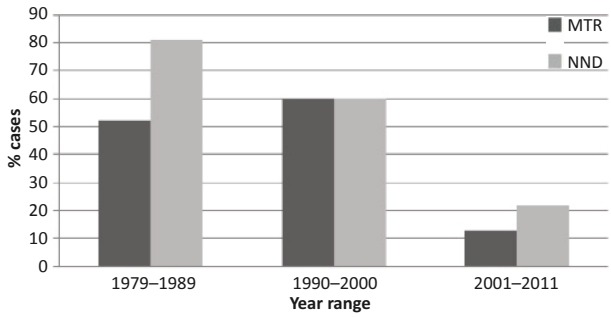

Figure 4. Comparison of human caused deaths over the years (χ2=61.41, df=2, p <0.0001) and between MTR and NND (χ2=5.05, df=2, p=0.079).

over the years (χ2=0.27, df=1, ns). Between 2001 and 2011, 52% of young adults around 20–40 years of age died due to unknown causes, and 24% succumbed to caecal and colon impaction.

Comparison of mortality in male and female elephants

The estimated ages of adult males and females differed significantly (Mann Whitney U test = 692, p = 0.003), median age of adult male was 20 years (95% CI 19 to 25.9, n=20) and maximum age recorded was 40 years. The median age of death for adult females was 30 years (95% CI 28.2 to 35.5, n=50) and maximum age recorded was 65 years. NND had no records of adults >35 years of age. Mean survival time for adult males was 22.45 and adult females 31.84 years.

Deaths due to poaching (χ2=43.62, df=1, p<0.0001) and unknown causes (χ2= 7.72, df=1, p=0.005) differed significantly between males and females. About 82% of the males were poached compared with 18% of females, whereas 66% of the females died of unknown

causes (Table 2). Both sexes were equally susceptible to accidents ($\chi2$= 0.13, df=1, ns) and diseases ($\chi2$= 1.68, df=1, ns).

Comparison of PAs with differing levels of protection

The number of records over the decades significantly differed between MTR and NND ($\chi2$=15.69, df=2, p = 0.0004). Deaths increased in MTR over time and peaked in NND between 1990 and 2000 (Fig. 3). Adult deaths did not significantly differ between MTR and NND ($\chi2$=0.31, df=1, ns), although NND supported fewer elephants (Table 3). Levels of poaching deaths were significantly higher in NND than MTR ($\chi2$ = 7.45, df=1, p = 0.006, Table 3). There were regional differences in the causes of mortality with unknown causes and poaching dominating in MTR, poaching in Gudalur and the Sigur plateau and accidents/poaching in Coonoor/Kallar ($\chi2$=19-49, df=3, p = 0.0002, Table 4).

Patterns of human caused deaths over the years

Overall human-caused deaths significantly declined from around 71% in 1979–2000, to 22% in 2001–2011 ($\chi2$=61.41, df=2, p <0.0001). The overall proportion of human-caused deaths was 42% in MTR and 54% in NND, but differed only marginally when the three decades were compared ($\chi2$=5.05, df=2, p=0.079, Fig. 4).

DISCUSSION

Our study suggests that elephant populations in these reserves are still at risk despite decreases in the levels of poaching and human-caused deaths over the years. Overall, survivorship is low: more so for adult males than females, and the recently assessed sex ratios of adults is still skewed towards females, a legacy of the ivory poaching in the past (Baskaran 2013). The proportion of illegal killings (0.22) is higher than that reported for Asian Elephants (0.15; Burn et al. 2011), which might increase further if the causes for the majority of recent deaths could be established. The adult females in the population despite facing less threat from humans have lower survivorship than female timber elephants in Myanmar (Clubb et al. 2008).

The Nilgiris-Eastern Ghats region holds the largest population of Asian Elephants in the wild, and is critical for the long term survival of the species. This range lies within a matrix of human dominated landscapes where high human densities, expansion of settlements and intensive agriculture are serious threats. Maintaining the viability of this population in the midst of inhospitable landscapes is a challenge for conservation.

The reserved forests of the NND have proportionately higher number of human-caused deaths probably because of higher intensity of anthropogenic pressures (Silori & Mishra 2001; Davidar et al. 2007, 2010; Baskaran et al. 2012) and lower levels of protection. These forests which connect the Western and Eastern Ghats, and provide a passage to higher elevation ecosystems, are important range lands for elephants (Davidar et al. 2012). Radio collared elephants used MTR as well as the reserved forests as part of their range (Desai 1991; Desai & Baskaran 1996), and are seasonal visitors in higher elevation montane shola forests and grasslands of the NSD and the Mukurthi National Park (Davidar et al. 2012). Therefore, these habitats need to be protected stringently and connectivity ensured.

Ivory poaching remains a general and widespread threat to elephants in India (Wildlife Protection Society of India: http://www.wpsi-india.org/projects/elephant_poaching.php, viewed 21 July 2013) and vigilance is required see that it does not recur in this region. Other threats could be cryptic and difficult to detect, such as poisoning of wildlife which is widespread in India (Richards 2011), and ingestion of plastic waste. In the recent decade 24% of elephant deaths were attributed to intestinal compaction. Plastics are ubiquitous in the Nilgiri District despite a ban, and are widely dispersed by tourists and tourism operators (What ails the Nilgiris, http://www.keralatourismwatch.org/node/130, viewed 23 July 2013). Plastics cause digestive impaction in livestock (Remi-Adewunmi et al. 2004), and wildlife (Beck & Barros 1991; Moser & Lee 1992; Jacobsen et al. 2010; Kumar & Dhar 2013).

The limitations of the study were that the analyses were confined to recorded deaths whereas many deaths particularly those of younger elephants, and deaths in more remote areas, would not have been detected. Similarly, difficulties in ageing elephants could bias survivorship. In conclusion, detection of deaths need to be improved through regular patrols throughout the reserves; database on elephant deaths should be systematised; forensic capabilities upgraded and elephant populations monitored.

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