RESEARCH

Visitation patterns of African elephants (*Loxodonta africana*) to a rubbish dumpsite in Victoria Falls, Zimbabwe

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Abstract

Habitual crop raiding by elephants is a common cause of human–elephant conflict (HEC). While habitual raiding of rubbish dump sites by elephants is not be a typical case of HEC, it could be seen as a more indirect, passive form of conflict, caused by humans, which negatively affects both elephants and, potentially, humans. In 2016 several African elephants (*Loxodonta africana*) were found dead in a municipal dumpsite outside Victoria Falls, Zimbabwe. Others were observed consuming non-biodegradable waste from the site. In order to determine if the problem of dumpsite raiding by these wild elephants could be considered as an instance of HEC, we investigated the visitation patterns of elephants to the dumpsite and examined the presence of non-biodegradable waste in elephant dung found in the area. The results show that there was a clear trend in visitation patterns. A core group of up to 27 bull elephants habitually entered the site on a daily basis and spent several hours consuming waste from the dumpsite and drinking from the nearby sewage stabilization ponds between the early and late evening. A majority of elephant dung samples in the vicinity (71.6%) contained plastic waste. We discuss the potential negative effects this raiding has on the ecosystem and elephant health, and its potential contribution to HEC.

Résumé

La tendance des éléphants à marauder des cultures est une cause fréquente de conflit entre humains et éléphants (CHE), par les éléphants n'est pas un cas typique de CHE, il pourrait être perçu comme une forme de conflit plus indirect et passif, causée par l'homme, qui affecte négativement les éléphants et, potentiellement, les humains. En 2016, plusieurs éléphants sauvages d'Afrique (*Loxodonta africana*) ont été découverts morts dans une décharge municipale à la périphérie des chutes Victoria, au Zimbabwe. D'autres ont été observés consommant des déchets non-biodégradables sur le site. Pour déterminer si le maraudage dans les décharges par ces éléphants sauvages peut être considéré comme une problème de CHE, nous avons étudié la fréquence de visite des éléphants sauvages dans la décharge et examiné la présence de déchets non-biodégradables dans les matières fécales dans la zone. Les résultats indiquent qu'il y a des tendances nettes dans leur mode de visite, soit un groupe de 27 éléphants mâles a l'habitude de visiter le lieu tous les jours et passe plusieurs heures à consommer des déchets de la décharge et à s'abreuver dans une station d'épuration, ceci en début et fin de soirée. La majorité des déjections fécales dans le voisinage (71.6%) contenait des déchets plastiques. Nous discutons des effets négatifs potentiels de ce maraudage sur l'écosystème, sur la santé des éléphants et sur l'augmentation des risques de conflits humains-éléphants.

Introduction and background

From Human towns and settlements in less developed countries are known to have significant waste disposal problems. The less effort put into the disposal system, i.e. the more widespread the use of open rubbish dumps, the more accessible these are to local wildlife in search of food. The biodegradable waste found in these rubbish dumps can often be a vital food resource for many wildlife species (Stokes 1970; Serpell and Barrett 1995; Tortosa et al. 2002; Burns and Howard 2003).

Mammals have been recorded using rubbish dumps as regular food sources. For example, a study in Uganda found that populations of banded mongooses (*Mungos mungo*) that consumed food waste from dumps had a higher population density than those that did not interact with the rubbish sites. The authors concluded that the higher concentration of food accessible in the dumps would allow for a larger group size and higher population densities (Gilchrist and Otali 2002).

However, the food provided by rubbish dumps can affect the diet of many animal species and can also alter their health and behaviour (Newsome et al. 2014). For example, black bears (*Ursus americanus*) are important for seed dispersal and insect population control; if their natural diet is replaced with more human waste produce they will not be able to fulfill this ecological role, leading to negative effects throughout the broader ecosystem (Newsome et al. 2014). Waste-raiding black bears (*Ursus americanus*), on a more individual level, suffer more from age-related illness or death after feeding off urban rubbish than completely wild bears (Newsome et al. 2014). Loggerhead sea turtles (*Caretta caretta*) are reported to have died due to complications caused by plastic ingestion from marine waste dumping (Lazar and Gračan 2011).

There are reports of elephants foraging for biodegradable waste within rubbish dump sites, often accidentally ingesting many polythene plastic products, in both Africa and Asia (Mendis 2009; Anon 2014). The herds consisted of mixtures of males, females and calves, and elephant dung in the vicinity of dumps were found full of undigested plastic waste. While this may not be a typical case of HEC, it could be seen as a more indirect, passive form of conflict, caused by humans, which negatively affects the elephants. Mendis (2009) discusses the need to investigate elephant foraging in relation to rubbish dump raids by elephants, to help understand the extent of the problem and to assist in developing measures to address the problem.

Aims and objectives

For years, the Victoria Falls municipal rubbish dump site has been frequented by elephants in search of easy food. Gogo (2016) reported eight elephant deaths in early 2016 and it was suspected that these had been caused by the ingestion of plastic and other non-biodegradable waste from the dump. However, the municipality denied that rubbish consumption from the dumpsite was the cause of death, as there was no proof that the elephants were actually consuming the trash (Gogo 2016). Therefore, there was a critical need to establish whether there was a problem and, if so, to understand its key drivers and implement appropriate mitigation measures. We predicted that by finding a clear trend in visitation habits of the elephants to the dumpsite, we could prove that such a problem existed.

This investigation was designed to monitor the numbers of elephants visiting the site, group dynamics, and time and direction of entry/exit to the dumpsite. Using this data, statistical analysis would determine if there was a significant regular pattern of elephant visitation. The main aim was to prove that the visits by the elephants to the site were a problem that could be categorized as HEC and needed to be solved. This could be done by showing that there were numerous elephants entering the dumpsite on a daily basis to forage, and demonstrating that they were not simply passing through the site. We expected that the use of the dumpsite as a source of food by elephants would be reflected in the frequent presence of plastics in dung samples collected from the area.

Methodology

Study Area

The study was carried out between June and July 2016 (mid-dry season), at the Victoria Falls Town Municipality Dumpsite, Zimbabwe, an area of 18,000 m^2 located roughly 1 km south-east of the town's high-density suburb, Chinotimba. There are three open-air sewage stabilization ponds located approximately 30 m east of the dumpsite. It is important to note that next closest body of water is the Zambezi River, approximately 3 km away and at the bottom of a steep gorge (Fig. 1; see colour plates: page i).

The town itself is located close to the Zambezi National Park (to the west), and the dumpsite is less than 2 km from the park boundary. The town has no recycling facilities or management procedures for disposing of refuse so the dumpsite is the only place for town residents to dispose of waste. The refuse comprises of a mixture of soft plastics (shopping bags, bin liners, straws etc.), hard plastics (milk, motor oil containers), paper waste, tin cans, glass, and biodegradable food waste. Once a fortnight, a town council bulldozer enters the site to push the rubbish build-up into piles. At the time of monitoring, the rubbish piles formed a large multiple 'horseshoe' shape. The rubbish was piled between 1.5 and 2 m high. Every month the dump site is set on fire by the town council to reduce the amount of waste build-up.

Using a handheld GPS device (Garmin eTrex® 10), the boundary was mapped out by walking along the edge of the site. Elephants crossing this boundary line, which was approximately 574 m long, were recorded as having either 'entered' or 'exited' the site.

Throughout the investigation period, during daylight hours the rubbish dump site was frequented by large numbers of marabou storks (*Leptoptilos crumenifer*), chacma baboons (*Papio ursinus*), stray dogs and human scavengers. These humans and animal scavengers arrived early in the morning, just after sunrise, and left just before sunset, at approximately 17:30 each day.

Monitoring entry and exit

To determine any pattern of visitation of the elephants, we recorded four aspects of their movements into and out of the rubbish dumpsite every day: (a) the size of the groups and the overall number of individuals frequenting the dumpsite; (b) group type (male/female/calf); (c) the peak hours of elephant activity within the dumpsite; and (d) the directions of travel into and out of the dumpsite.

We set up daily observation periods, each lasting 12 hours. Initially, these periods started at 11:00 and finished at 23:00. However, after four days of preliminary observations, and based on personal accounts of numerous people scavenging waste, it was discovered that the elephants rarely enter the site before sunset. The observation timetable was then adjusted to the 12-hour period between sunset and sunrise, i.e. 18:00–06:00.

Each 12-hour period was split into intervals lasting 30 minutes. Within each interval, we recorded the number of elephants that entered/exited the dumpsite, as well as the direction of entry/exit, and classed each individual as male, female or calf aged up to 3 years old. The directions of entry/exit were recorded as the eight cardinal and inter-cardinal points of a compass, established with the compass function of the GPS device.

The first eight intervals, i.e. 18:00–22:00, were monitored visually with the aid of binoculars (Canon 15×20 IS UD 4.5°), and spotlight (Coleman 5360 series), with a red filter to prevent interference with the elephants. The remainder of the time intervals, i.e. 22:00–06:00, were monitored automatically by infrared camera traps (Bushnell Model 119436), strategically placed to capture the entry and exit points of dumpsite. The camera traps were set up at 18:00 and removed at 06:00.

Statistical analysis

Data were plotted and analysed using Microsoft Excel 2016 and R Studio v1.0.136. The total numbers of elephants that entered the site each day were plotted as a histogram to show the daily data. In order to look at group dynamics, we compared the daily ratios of each category (male/female/calf).

To test for time effects on the pattern of elephant visits to the site, we first plotted elephant entrances per time interval into a time series graph and performed a Ljung–Box test to check for autocorrelation. This would show us if a pattern over time existed. We then repeated this for elephant exits per time interval. To examine visit duration (how long the average elephant spent in the dump site) we performed a cross-correlation with lags between the two time series graphs. Finally, we calculated the percentages of directions of entry and exit and used rose charts to illustrate the results.

Faecal analysis

To identify if the elephants were ingesting plastic and non-biodegradable wastes, the entire area within a 700 m radius of the dumpsite was explored and every separate pile of elephant dung encountered was recorded as a ‘poo point’. Poo points included fresh and older piles of dung. We visually determined the presence and type of non-biodegradable waste in each dung bolus was and calculated the percentages of plastic-containing points.

Results

Elephant visitation patterns

As expected, it was observed that there was a significant pattern of elephant visitation. On an average day, 15–16 individuals entered the dumpsite (mean value 15.5, range 10–27, interquartile range [IQR] 11–19; Fig. 2). Upon entering the site, elephants would arrive in groups, averaging six to seven individuals. They would leave the site in much smaller groups, averaging three individuals.

During the study all (100%) of the elephants that visited the dumpsite were adult males. No adult females or calves were recorded.

On average over the study period, the highest number of elephant entries occurred during the second interval, between 18:30–18:59 (Fig. 3). The number of entries decreased significantly thereafter, with fewer than five individuals entering per interval after the fifth interval (20:00–20:29). After the fourteenth interval (00:30–00:59), very few elephants entered the dumpsite. On two occasions, there were already a couple of elephants within the dumpsite when we arrived at 17:30 to set up the equipment, whose visits were assigned to the first interval (18:00–18:29). Exits peaked during the sixth interval (20:30–20:59), and most elephants had exited by midnight (Fig. 4).

The maximum number of elephants entering the site together was much higher than the maximum number of elephants exiting together. The longer ‘whiskers’ of Fig. 4 show that there was a higher variation in numbers of individuals exiting during any particular interval than in number of individuals entering. While elephants consistently entered the site in larger herds (of up to 21 individuals), they exited in smaller groups of varying sizes, usually of 1–4 individuals but with the largest group consisting of 10 elephants.

There was a significant autocorrelation for time of entry to the dump site (Ljung–Box tests: x-squared = 8.6176, df = 1, p-value = 0.003329), with a marked peak in activity between 18:00 and 19:59 (intervals 1–4). There was also a significant autocorrelation in times of departure (x-squared = 44.741, df = 1, p-value

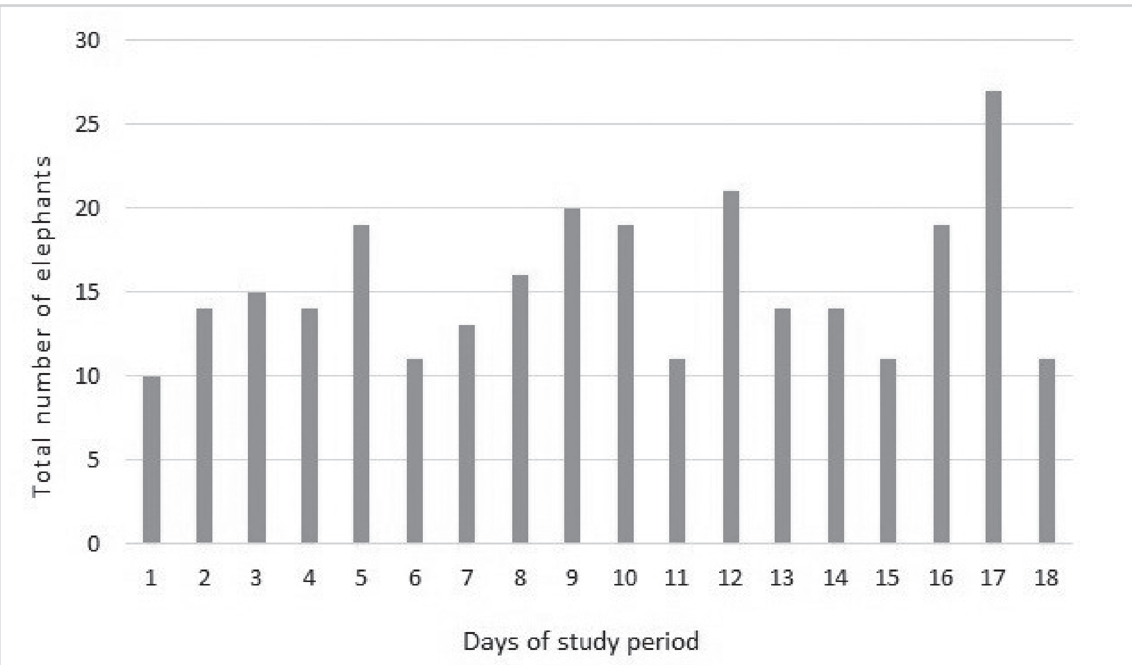

Figure 2. Numbers of elephants that visited the dumpsite each day.

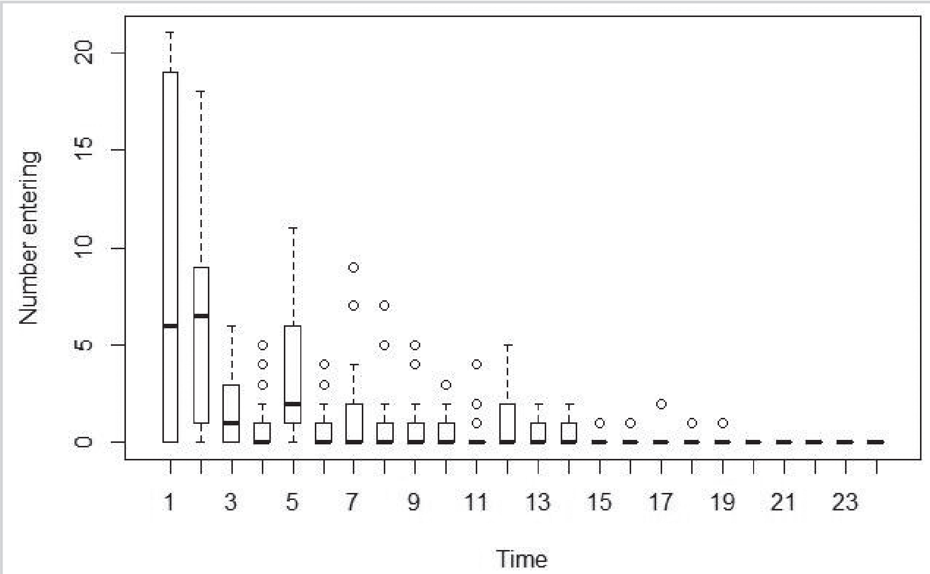

Figure 3. Numbers of elephants entering the dumpsite over time. Each number on the x-axis represents one 30-minute interval during the period 18:00–06:00). The box-and-whisker plot shows the mean number of arrivals for each period during the 18 days of the study period (solid line), the inter-quartile range (box), the extreme values that still fit the pattern (dashed lines) and outliers (open circles).

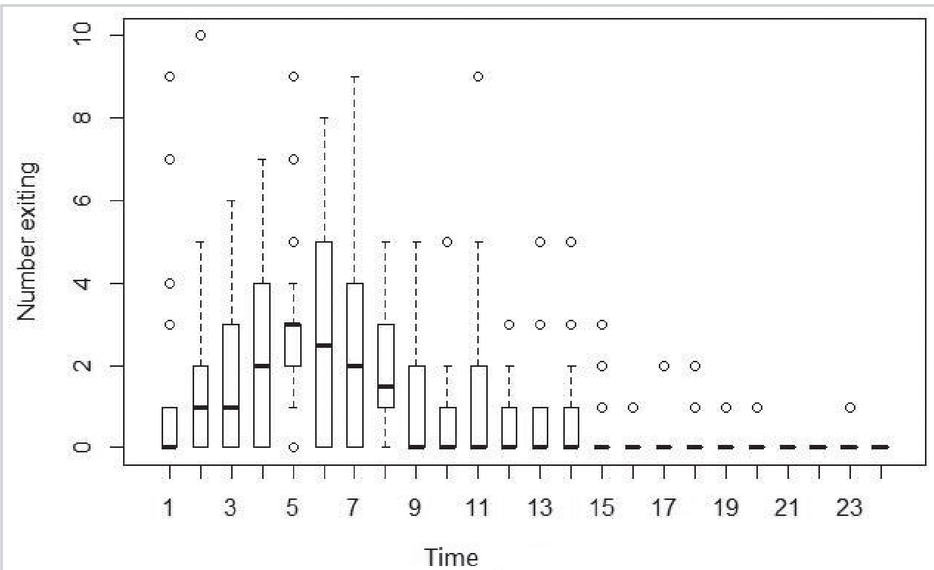

Figure 4. Numbers of elephants exiting the dumpsite over time. Each number on the x-axis represents one 30-minute interval during the period 18:00–06:00. For interpretation of box-and-whisker diagram, see Fig. 3 legend.

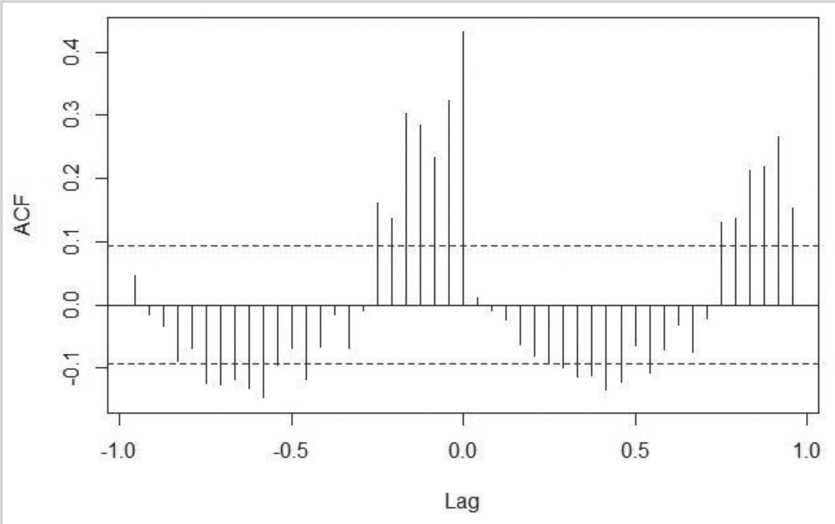

Figure 5. Cross-correlation of entry to exit time series, where each line represents a 30-minute time interval. Intervals extending past the dotted lines shows significant correlation (either positive or negative) between entry/exit times. The middle 'peak' shows 7 intervals that positively correlate entry time to exit time, although they are in a negative lag (i.e. <0). Therefore, movement in entry will correlate positively with a movement in exit up to 7 intervals later (i.e. 2 ½ hours). ACF = autocorrelation function.

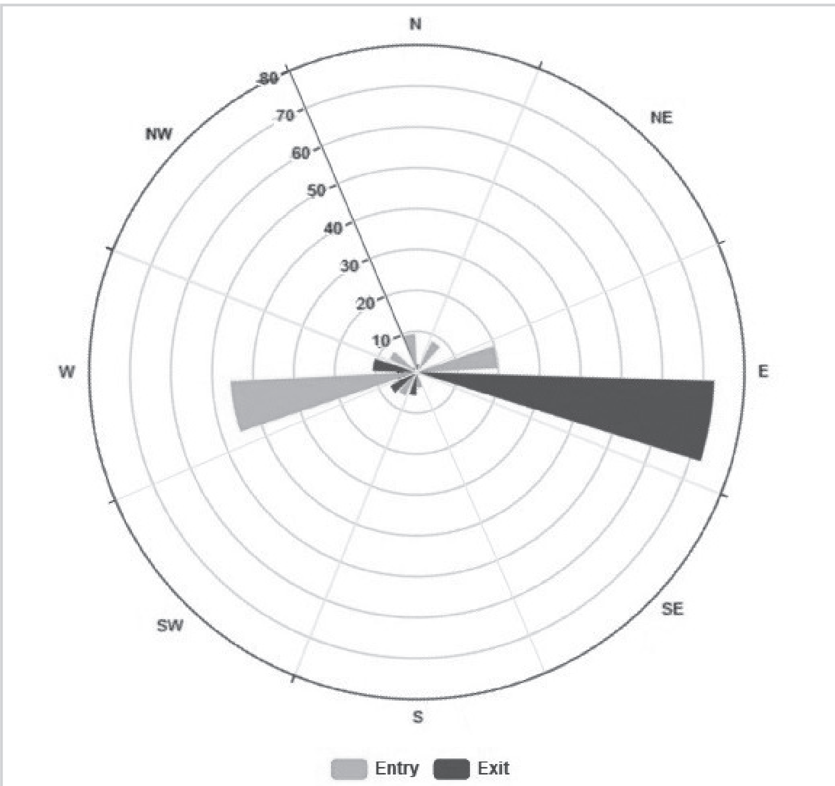

Figure 6. Directions of entry and exit shown in percentages.

$= 2.25 \times 10^{-11}$), with a marked peak in activity between 18:30 and 21:29 (intervals 2–7). These tests prove that there is a daily pattern of elephant visitation to the site, with a peak activity between 18:00 and 21:29. The cross-correlation between entry and exit times showed a significant time lag between entry and exit of the elephants (Fig. 5), of up to 7 time intervals (2 ½ hours). This showed that the elephants were not just passing through the dumpsite.

The directions of entry/exit provide clues as to where the elephants came from before the site, and where they were headed to after leaving. The results show that just under half of the number of entries came from the west (Fig. 6), while 20% came from the east. We can also see that the clear majority (72%) of exits from the site were to the east, while exits to the west were only 11%. There were very few exits in other directions. An interesting observation was that several individuals habitually entered the dumpsite, spent approximately 2–3 hours consuming waste, then exited the dumpsite to the east, and returned from the east with wet trunks and occasionally wet bodies. This suggested that they were utilizing the nearby open-air sewage stabilization ponds to consume water, before returning to the dumpsite to forage for another couple of hours. Upon further investigation, it was then confirmed visually that some individuals were immersing themselves in the sewage ponds and drinking from them.

Faecal analysis

In total, 222 piles of elephant dung were observed and recorded as 'poo points' within the vicinity of the rubbish dumpsite. We recorded presence vs. absence of non-biodegradable waste in the piles of elephant dung. We found that 71.6% of elephant dung in the vicinity of the site contained plastic waste (Figs. 7a & 7b; see colour plates: page i), proving that the elephants were consuming waste from the site. We also visually observed the consumption of non-biodegradable waste (Fig. 7b; see colour plates: page i).

Discussion

Elephant visitation patterns

To summarize the results, approximately 15–16 adult male elephants would enter the site shortly after sundown in groups, averaging six or seven at a time, most commonly from a westerly direction and spend approximately 2½ hours within the dumpsite, before exiting to the east in smaller groups of three. The peak times of activity were between 18:30 and 21:59.

The highest number of individuals recorded within the site at the same time was 27 elephants. The population of elephants raiding the dumpsite represents a small minority of the population of approximately 1,800 individuals within this region of Zimbabwe (the Matesti Complex, north-west Matebeleland) (Dunham et al. 2007).

However, it is quite likely that more elephants utilized the site than were observed during the investigation. Chiyo (2010) showed that the number of elephants that occasionally crop raid is much larger than the number than habitually crop raid. If the same pattern holds in this case, there may be a core group of habitual dump raiders and a larger population of occasional raiders. Since this study did not identifying individual elephants, it was not possible to determine the total number of bulls that utilized the dumpsite during the study period. This would have required individually identifying animals and undertaking a mark–recapture analysis, which we were not able to do because of low light levels during the investigation. That being said, the results indicate that there are certainly enough of them for their behaviour to be considered a problem.

The nature of the visitation pattern observed could potentially be explained by the degree of stress the elephants encountered on arriving at the dumpsite. Elephants entered the site in groups of six to seven individuals and it was observed they would always enter hurriedly and displaying a degree of nervousness. If they felt an element of anxiety in traveling to the site, arriving in larger groups would provide greater safety. Once within the boundary of the dumpsite, they slowed down and casually started foraging throughout the litter piles. When they left, it was in smaller groups of one to four individuals.

A likely reason for the nervousness displayed by the elephants is the proximity of the site to the edge of the town. Humans can pose a threat to elephants, and the closer the elephants are to the town border, the greater is the chance of coming into contact with humans. This would also explain the group dynamics. Not a single female or calf was observed at the dumpsite. Female elephants are very protective of their offspring, and most commonly travel in natal family herds, most of which contain several calves at any given time (Wilson and Mittermeier 2011). Making the trip from within the National Park to the dumpsite poses danger for calves by increasing the chance of human contact, and so would most likely be avoided by females with offspring.

The route from the National Park boundary to the dumpsite crosses the main highway into the town, which the elephants visiting the dumpsite would have to cross daily. High volumes of traffic during the daylight hours can make the road an impenetrable barrier for any elephant, especially cows with calves. When traffic dies down in the late afternoon/early evening, the road becomes easier to cross. This, together with the fact that the dumpsite is constantly filled with human scavengers and people dumping their rubbish throughout the day, makes it unsurprising that the bull elephants only enter the site after sundown.

Once within the dumpsite, it appeared that the elephants were comfortable with where they were. The average time each elephant spent in the dumpsite was 2½ hours, though some would spend up to 7 hours there, foraging for food amongst the waste. Most elephants exited the site to the east (72.6%), going directly to the sewage treatment ponds in smaller groups of only a couple of individuals at a time. Some elephants were observed re-entering the site from the East with wet trunks and bodies. It was observed that some, but not all, of the elephants would drink the water from the stabilization ponds, and occasionally swim in them.

The waste system in Victoria Falls does not separate biodegradable human food-waste from non-biodegradable waste, meaning the dumpsite is full of high-calory food scraps, replenished daily. The rubbish dumpsite and stabilization ponds therefore provide a consistent food and water supply, which may be especially important in the dry season when these resources become scarce within the National Park. While female elephants with calves may not be willing to take the risk, bull elephants are more often inclined to forage in high-risk areas. This is consistent with elephant crop-raiding patterns, where males are much more likely to risk raiding crops than females. Chiyo (2010) briefly discusses how sexual selection could drive bull elephants to adopt riskier foraging strategies, in order to increase nutrient gains and therefore reproductive success.

Effects of plastic waste ingestion

The results of the faecal analysis show that within a 700 m radius of the site, a large majority (71.6%) of droppings contained some sort of non-biodegradable, man-made waste. The types of waste observed within the faecal matter included everything from soft plastic bags to metal bottle caps and shards of broken glass.

Elephant digestive transit has been estimated at 18–24 hours (Wilson and Mittermeier 2011) but is strongly affected by kind of the food consumed. The concentration of plastic waste in faecal matter close to the dumpsite suggests that at least some elephants ingested waste from the site over the course of several days. This fits with elephant behaviour patterns elsewhere, where elephants use the same area in the same way for a few days before moving on (Moss et al. 2011).

Therefore, it is likely that a population of elephants would spend a few days consuming plastic waste from the dumpsite and then move on, roaming throughout the rest of the Zambezi National Park and unintentionally 'littering' by depositing the non-biodegradable waste found in their faecal matter. This could cause issues for a variety of other animal species, such as strangulation or colic.

Apart from its effects on the broader ecosystem, frequent plastic ingestion could be harmful to the elephants themselves, especially the habitual dumpsite raiders. Elephants spend around 70% of their day foraging for food, and if on average these elephants spent 2–3 hours within the dumpsite foraging, we can estimate that approximately 20–40% of their diet is found on a rubbish dumpsite. The digestive system of elephants is non-ruminant, meaning they only have one stomach, which is of considerable size, being used mostly as storage for food. Due to the high fibre content of their normal diet, only about 44% of their food is properly digested (Wilson and Mittermeier 2011). Therefore, with an increase in plastic and non-biodegradable waste consumption, there is a potentially massive decrease in quantity of food properly digested, which can lead to malnourishment and other digestive-related health problems, such as colic and colonic blockage, which can have fatal consequences (Koehl 2016). This might provide a partial explanation of the elephant deaths recorded around Victoria Falls in the early months of 2016 (Gogo, 2016).

There are other dangers associated with consuming human waste products, which could have contributed to these deaths. A study done in 1972 shows that *Salmonella enteriditis* can infect and be fatal to elephants (Windsor and Ashford 1972). This can be transmitted through certain human foods, and especially when in mixed waste and left to rot, i.e. in the unhygienic conditions typical of those found in mixed waste dumpsites.

Another possibility is that the elephant deaths recorded around the dumpsite were caused not by the ingestion of plastics and waste from the municipal dumpsite, but instead from drinking water from the adjacent stabilization ponds. As mentioned above, some elephants were observed to drink from the ponds on a nightly basis. Numerous toxic heavy metals and other organic pollutants are associated with waste water from sewage systems (ICON 2001). However, the cause of death of these elephants was never determined.

Besides possible effects on elephant health and mortality, another major concern is that there are up to 27 wild bull elephants frequenting the outskirts of a human settlement. While elephants do not usually engage with humans, it would only take one bull elephant to be in musth or to be startled to cause a human death. If a human being was killed by a wild elephant, the National Parks Rangers would have to euthanize the elephant. The chances of this happening are greatly increased by daily visitation to the dumpsite.

Conclusion

We have shown that elephants frequented the dumpsite on a regular basis during the study period, giving rise to many potential health complications and an increased chance of human–elephant conflict. Open rubbish dumps are a common problem throughout many regions of southern Africa, so this may not be an isolated case.

It is important to note that since the time of investigation, the Victoria Falls Green Fund/ Environment Africa, the Victoria Falls Anti Poaching Unit (VFAPU) and the Victoria Falls Wildlife Trust have collaborated to set up The Elefence Project. The aim was to set up an electric fence around the municipal rubbish dumpsite, specifically to prevent the entry of elephants into the dumpsite. This fence was completed early November 2016. While this has been a good temporary solution that has for the most part kept elephants out, its upkeep is costly. A more long-term solution would involve separating biodegradable and non-biodegradable waste at source and having separate disposal areas. This could prevent attracting wild elephants to the dumpsite, and thus avoid many of the issues discussed.

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