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Impact of Electric Shock and Electrocution on Populations of Four Monkey Species in the Suburban Town of Diani, Kenya

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Abstract
Electric shock and electrocution affect at least 31 primate species, but studies of how electrical infrastructure affects primate populations are rare. We investigated 320 cases of electric shock and electrocution in four sympatric monkey species in Diani, Kenya, 1998–2019: Peters's Angola colobus (*Colobus angolensis palliatus*), Zanzibar Sykes's monkey (*Cercopithecus mitis albogularis*), Hilgert's vervet (*Chlorocebus pygerythrus hilgerti),* and the Southern yellow baboon (*Papio cynocephalus cynocephalus*). These represent 16% of the total welfare cases reported to a local conservation organization. Deaths occurred in 73% of cases. The number of cases did not increase through the study period, presumably because mitigations implemented by the power distribution company and a local conservation organization offset the risks associated with the electrical infrastructure expansion. Colobus accounted for 80% (N = 256) of cases, representing *ca*. 4.6% of the population annually, which is likely unsustainable. Adult male colobus were shocked or electrocuted more than expected, while all other age–sex classes were involved in proportion to the population structure. The number of cases was low for Sykes's monkey (13%, $N = 42$), vervets (5%, $N = 16$), and baboons (2%, $N = 6$). Our findings show that electrical infrastructure affects species differentially; larger arboreal species with individuals ≥8 kg are at higher risk of injury and death than smaller arboreal species and terrestrial species. Other organizations can estimate risks in their areas based on the factors we reviewed. Further understanding of how body mass impacts risk will have implications for designing electrical infrastructure as part of conservation planning.

Keywords *Colobus angolensis palliatus* · Electrical infrastructure · Electric shock · Electrocution · Monkey · Power lines · Primate · Urban environment

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Introduction

Urbanization is a major cause of wildlife extinction (McKinney 2006). Although many species of wildlife have adapted to urban habitats (Hulme-Beaman *et al*. 2016), they are exposed to novel threats in doing so (Beamish and O'Riain 2014; Sol *et al*. 2013). One of these threats results from the electrical infrastructure (Dwyer *et al*. 2014; Katsis *et al*. 2018), as some species use electricity cables, poles, and transformers as aerial pathways due to limited tree coverage (Rodrigues and Martinez 2014). This enables them to remain arboreal while accessing food resources and sleeping sites, searching for mates, and dispersing (Ram *et al*. 2015).

The likelihood of wildlife surviving electrical injuries is low because the unique pathophysiology affects the whole body (Schulze *et al*. 2016). In severe cases, these injuries present as tissue burns where the current enters and exits the body, respiratory paralysis, cardiac arrest, muscle necrosis, systemic infections, and organ damage (Fish and Geddes 2009; Koumbourlis 2002). The severity of an injury varies with voltage, type of current and amperage, and duration of exposure. Secondary trauma often occurs when the individual falls from the infrastructure (Fish and Geddes 2009; Koumbourlis 2002; Kumar and Kumar 2015).

The literature records injuries and deaths from electrical infrastructure in 10 families and 31 species of primates. Social media, especially the YouTube platform, and websites of conservation organizations, document species injured or killed by the electrical infrastructure undescribed in the scientific literature. Published reports typically note that the electrical infrastructure is a threat to a species (Boinski *et al*. 1998; Kumara *et al*. 2006; Nowak *et al*. 2017) or report a small number of cases (Goulart *et al*. 2010; Lokschin *et al*. 2007; Montilla *et al*. 2020; Moore *et al*. 2010; Printes *et al*. 2010). Some studies found that electrical infrastructure is a major source of injury and death for arboreal primates (Al-Razi *et al*. 2019; Ampuero and Sá Lilian 2012; Montilla *et al*. 2020), while other studies found that electrical infrastructure had a considerable impact on terrestrial species (chacma baboons *Papio ursinus*: Beamish 2009 and Hanuman langur, *Semnopithecus entellus*: Ram *et al*. 2015). One study of the spatio-temporal location of incidents within an electrical infrastructure grid found that injuries and deaths occurred on specific sections in a suburban area, and these remained relatively constant over time and across seasons (Katsis *et al*. 2018). Several other studies also showed that particular sections of the infrastructure caused most cases (Printes 1999; Ram *et al*. 2015).

Four species of monkeys occur sympatrically in the oceanside suburban town of Diani, in southeast Kenya: Peters's Angola colobus (*Colobus angolensis palliatus*), Zanzibar Sykes's monkey (*Cercopithecus mitis albogularis*), Hilgert's vervet (*Chlorocebus pygerythrus hilgerti*), and the Southern yellow baboon (*Papio cynocephalus cynocephalus*). Colobus Conservation is a local primate conservation organization that investigates primate welfare cases reported by members of the community, offering an opportunity to study electric shock and electrocution trends at one site across species varying in behavioral and morphological attributes. We analyzed 22 years of records for injuries from electric shock and deaths from electrocution (1998–2019) and investigated the impact on the populations of these species using annual population census data. We combined cases of electric shock, which occurs when an organism serves as a pathway for electric current but is not killed by that current, and electrocution, which occurs when the organism is killed by that current.

Although electrical infrastructure related injuries and deaths affect a broad range of primate species, little is known about its impact on the populations. To gauge the severity of the problem in Diani, we first examined the percentage of shock and electrocution cases compared to the total reported cases and the percentage of reported cases that resulted in the death of the monkey. We then tested several hypotheses and predictions: 1) If the expansion of the electrical infrastructure increases the risk of electric shock and electrocution cases, we predict that the number of annual cases reported would increase through the study period concurrently with Diani's growth. 2) If arboreal and terrestrial species experience different risks, we predict more cases involving the arboreal colobus and Sykes's monkeys than the terrestrial vervets and baboons. 3) If large individuals are more likely to be affected because they can contact multiple elements of the electrical infrastructure simultaneously, creating a short circuit, we predict more cases involving individuals with higher body masses; particularly adults and especially adult males. Finally, we explored the relationship between the number of electric shock and electrocution cases with rainfall.

Methods

Study Site

We conducted our study in Diani, an oceanside suburban town in southeastern Kenya between Southern Palms Beach Resort (−4.267569°, 39.595537°) and KFI Supermarket (−4.342196°, 39.563738°), an area of *ca*. 6.5 km^2 (Fig. 1). Diani is a linear development lying parallel to the Indian Ocean coastline, with an economy based on beach tourism. Phytogeographically, this area lies within the Zanzibar–Inhambane Undifferentiated floristic region, which historically extended from southern Somalia to the Limpopo River in Mozambique (White 1983). Diani retains original forest trees and fragments interspersed with exotic vegetation planted among the houses, hotels, and shopping areas.

Kenya Power & Lighting Company is responsible for transmitting and distributing electricity in Kenya. In Diani, the company positioned the medium voltage distribution line alongside Beach Road, which bisects the town from north to south. Along some sections of the road, the company placed the powerline within the roadside vegetation. Older utility poles are wood, while more recently installed poles are concrete. These poles route either two, three or four cables, or a combination. The cables are placed vertically or horizontally towards the top of the poles. Transformers with uninsulated terminals step down the voltage from medium to low voltage distribution lines, connecting the utility to the consumer. The cables are uninsulated except where Kenya Power & Lighting Company and Colobus Conservation have jointly added insulation to mitigate the risk of primate electrocutions.

Diani's climate is hot and humid, influenced by the sea-level altitude and the monsoon winds from the Indian Ocean. Although variable, typically, there are two dry seasons and two rainy seasons annually. The long rains occur from April to June, and the short rains occur from October to November. The dry seasons occur from July to September and December to March (J. Beakbane, *unpubl. data*).

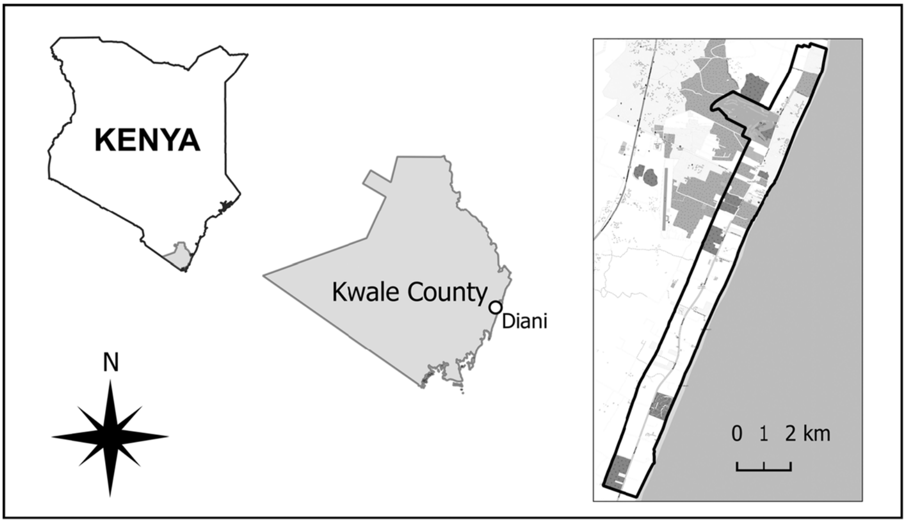

Fig. 1 The study area within the oceanside suburban town of Diani, located in Kwale County, southeastern Kenya (Cunneyworth and Duke 2020).

Study Species

The four species of monkey in Diani vary in habitat use, social organization, and morphology, and are all sexually dimorphic.

Peters's Angola colobus (colobus) is a medium-sized primate; adult female body mass is 9 kg, and adult male body mass is 11 kg (Harvey *et al*. 1987). They are highly arboreal and folivorous (Davies and Oates 1994; Dunham 2017). Groups typically consist of six individuals; a single adult male, multiple adult females, and offspring (Anderson 2005).

Zanzibar Sykes's monkey (Sykes's monkey) and Hilgert's vervet (vervet) are both guenons. In Sykes's monkeys, adult female body mass is 4 kg, and adult male body mass is 8 kg. In vervets, adult female body mass is 3 kg, and adult male body mass is 5 kg (Harvey *et al*. 1987). Molecular studies propose that Sykes's monkeys and vervets belong to different phylogenetic clades; Sykes's monkeys are in the arboreal clade, and vervets are in the terrestrial clade (Xing *et al*. 2007). Both species are omnivorous. Sykes's monkeys live in one-male, multifemale groups, and vervets live in multimale, multifemale groups (Mugatha *et al*. 2007; Struhsaker 1967).

The Southern yellow baboon (baboon) is the largest primate in Diani; adult female body mass is 15 kg, and adult male body mass is 20 kg (Harvey *et al*. 1987). Baboons are omnivorous, primarily terrestrial, and live in multimale, multifemale groups (Altmann *et al*. 1993).

Data Collection

Members of the community report primate welfare cases to Colobus Conservation. This local conservation organization operates an emergency rescue service for injured and ill primates. The staff follow up on each report in the field and provide veterinary care when appropriate or collect the carcass if the individual is dead. The staff inputs each case into a database as part of the organization's internal reporting. The information recorded includes species, date, cause and description of the incident, age class, sex, body mass, the clinical presentation of the individual, and case outcome (alive not captured, treated and released, dead on arrival, died under treatment, euthanized, not found, or unknown). The veterinarian or field assistant categorizes electric shocks and electrocutions at the time of the incident by physical presentation of the monkey and/or proximity of the injured or dead individual to electricity cables, poles, or transformers.

We used previously published population census data for each species (Cunneyworth and Duke 2020). These data were available for 2004–2006 and 2010–2019. We delineated the census study area, then reviewed the location information in each case report and created a subset of cases in the census area for analysis.

A Diani resident provided rainfall data collected at *ca*. 09:00 h daily for the entire study period. A standard rainfall gauge measured the rainfall in mm. The rainfall gauge was 1.7 km south of the study area (−4.3556°, 39.5615°).

Statistical Analysis

We analyzed data using IBM SPSS version 23. For all tests, the probability level of significance was 0.05. We tested assumptions and used Shapiro–Wilk's test to test for normally distributed data and the Levene's test to test for homogeneity of variance.

We analyzed 22 years of the organization's records from January 1998 to December 2019. We calculated 1) the number of electric shock and electrocution reports for all species of monkeys as a percentage of the total number of welfare reports of monkeys for the same area and time frame, 2) the mean and standard deviation for the number of monthly electric shock and electrocution reports ($N = 264$ mo), and 3) the percentage of each category of case outcome for the monkey (alive not captured, treated and released, dead on arrival, died under treatment, euthanized, not found, or unknown).

We used a Pearson's correlation to test for an association between study year and the number of reported cases. We chose a one-tailed test, as we predicted that the number of reported cases would increase over time as Diani's electrical infrastructure expanded.

We investigated the impact of electric shocks and electrocutions on the population of each species using the annual census data. We calculated the number of cases annually as a percentage of the population size in that year. We used a Kruskal–Wallis test to determine whether the distributions of annual percentage of the population that were shocked or electrocuted differed across species. As this test was significant, we used a Mann–Whitney U test to carry out planned pairwise comparisons. We determined which pairs of species were statistically different and reported the results of the adjusted α level ($0.05/6 = 0.008$) using the Bonferroni correction for multiple tests to protect against type I error.

We tested if the age–sex classes were shocked or electrocuted in proportion to their occurrence in the population. We carried this test out only for colobus due to the low number of cases for the other species. We first established the population's structure by determining the proportion of the population for each age class (infant, juvenile, subadult, and adult) for each census year (2004–2006, 2010–2019), and then calculated a mean across the years. We assumed an equal number of females and males in each age class (Bronikowski *et al.* 2016). Using the chi-square goodness of fit test, we tested if the proportion of each age–sex class involved in electric shock and electrocution cases differed from its mean proportion in the population. As this test was significant, we carried out planned *post hoc* tests to calculate the *z*-scores based on the adjusted residuals and used a one-tailed test with a Bonferroni adjusted α level (0.05/8 = 0.006).

For colobus, we compared the distribution of body mass (kg) in cases of electric shock and electrocution with that for all other colobus welfare cases (i.e., vehicle–monkey collisions, abuse, dog attacks, illness, and injuries) ($N_{\text{shocks and electrocutions}} = 144$; $N_{\text{other causes}} = 243$). We then compared the body mass (kg) of colobus females and males involved in electrical infrastructure related incidents ($N_{\text{females}} = 51$; $N_{\text{males}} = 93$). We used Mann–Whitney *U* tests for both tests.

Lastly, we used a two-tailed Spearman's ρ correlation for all the cases to test whether the monthly number of electric shock and electrocution cases ($N = 264$ mo) was associated with the monthly rainfall (mm). We used the monthly values because we could not attribute a specific day to the incident for half of the cases given that individuals that receive electric shock often live with their injuries for some time before being reported.

Ethical Note

Our study adhered to the legal requirements of Kenya with permission from the Kenya Wildlife Service. NACOSTI granted this research permission through permit number NACOSTI/P/16/10434/11346. The University of Bristol ethics committee approved the protocols. The authors have no conflicts of interest or competing financial interests to declare.

Data Availability Supporting data are provided as Electronic Supplementary Material.

Results

Within the study area, members of the community reported 2017 welfare cases involving monkeys from January 1998 to December 2019. Of these, 320 cases (16%) were either electric shock injuries or electrocutions. The mean number of cases reported was 1.2 per month (range = 0–6, $N = 264$ mo, SD = 1.3). The case outcomes show low survival: only 25% ($N = 79$) of the shocked or electrocuted individuals were alive and not captured or treated and released. Death occurred in 73% of cases ($N = 233$), and of those cases, 149 died at the time of the incident, 31 died under veterinary care, and 53 were euthanized because of extensive injuries. The team did not find the monkey in the field in six cases and did not note the case conclusion in two cases.

The annual number of electric shock and electrocution cases ranged 6–23 ($\overline{X} = 15$, SD = 4) (Fig. 2) and did not increase over the study period (one-tailed Pearson's correlation = −0.005, $N = 22$ yr, $P = 0.49$).

The number of incidents reported by members of the community varied by species: colobus, $N = 256$ (80%), Sykes's monkeys, $N = 42$ (13%), vervets, $N = 16$ (5%), and

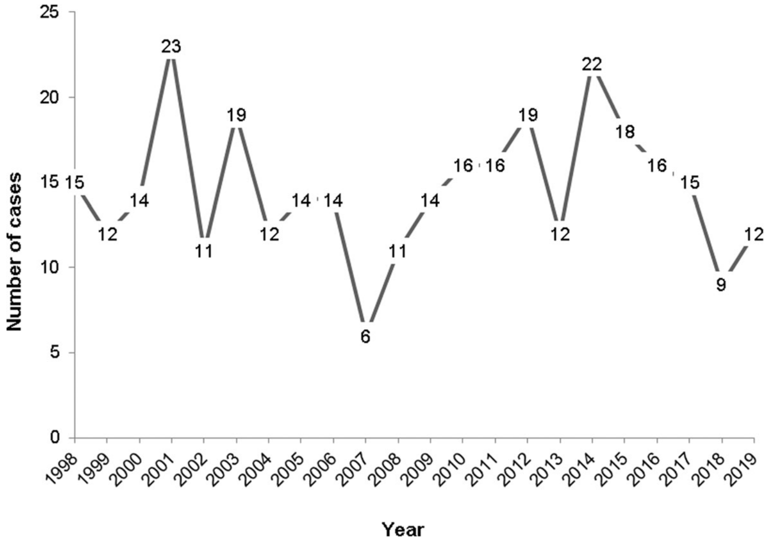

Fig. 2 The number of electric shock and electrocution cases reported by members of the community in Diani, Kenya, 1998–2019 (N = 22 yr), in four monkey species combined (colobus, Sykes's monkey, vervet, and baboon).

baboons, N = 6 (2%). We found significant differences between the four species in the percentage of the annual population involved in electric shock and electrocution incidents ($\chi^2 = 32.2, N = 52$; df = 3, $P < 0.001$) (Fig. 3). In planned pairwise comparisons (Table I), the annual percentage of the colobus population shocked or electrocuted was significantly higher than that for the other species, while the percentages of the population involved were similar for Sykes's monkeys, vervets, and baboons.

We reviewed the number of cases by age–sex class for all four species (Fig. 4); however, we carried out the age–sex class and body mass analyses only for colobus, as the number of electric shock and electrocution cases was low for the other species. For colobus, the proportion of each age–sex class affected differed significantly from the proportion of each age–sex class in the population ($\chi^2 = 15.9$, $N = 227$, df = 7, $P = 0.03$). *Post hoc* tests show that colobus adult males were affected significantly more than expected given their presence in the population. The proportion of all other colobus age–sex classes shocked or electrocuted did not differ significantly from the population structure (Table II) after applying the adjusted α level for multiple tests.

Colobus individuals involved in electrical infrastructure related cases were larger than those involved in other welfare incident types (Mann–Whitney U = 12,095, $P <$ 0.001, Fig. 5). The percentage of reports that recorded a body mass was similar in shock and electrocution cases (56%) and other causes (58%). There were significant differences in body mass between colobus males and females who were shocked or electrocuted (U = 3638, N = 144, P < 0.001), with females showing a population distribution and males being larger (Fig. 6).

Monthly rainfall and the monthly number of electric shock and electrocution cases were significantly negatively correlated ($r = -0.16$, N = 264 mo, N = 320 cases, P = 0.009). In months with lower rainfall, there were more electric shock and electrocution cases (Fig. 7).

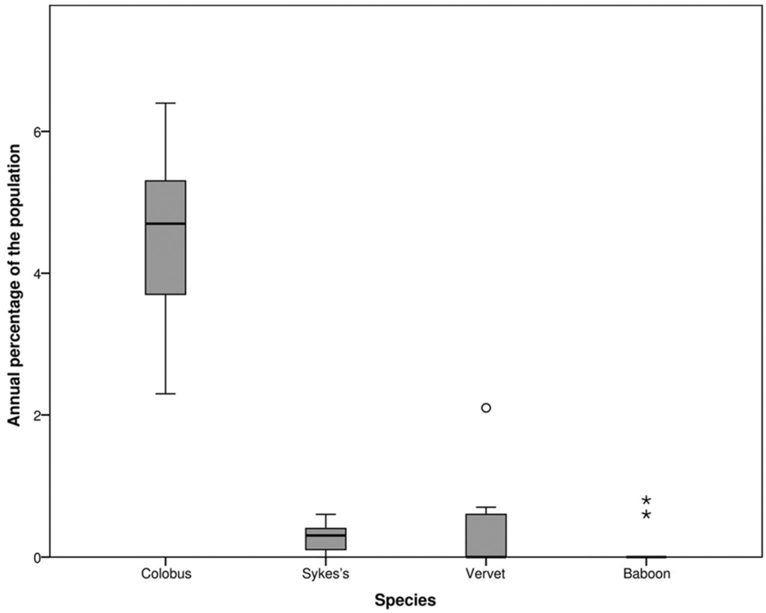

Fig. 3 Annual percentage of the population reported as electric shock or electrocution cases in four species of monkey in Diani, Kenya, 2004–2006, 2010–2019 (*N* = 13 yr). Boxes represent 50% of the dataset, with the line indicating the median value. The whiskers represent the top and bottom quartiles. The circle indicates an outlier, and asterisks indicate extreme outliers.

Discussion

Of the 2017 welfare incidents reported to the conservation organization in 1998–2019, 16% were electric shock or electrocution cases, considerably fewer than the 34% of vehicle–monkey collision cases reported for the same study area (Cunneyworth and Duke 2020). The number of cases of electric shock and electrocution of monkeys was consistent across the years but more community reports occurred in months with rainfall ≤50 mm than in other months. Almost three-quarters of cases resulted in death. This is not surprising, because of the delay between the incident and its reporting by

Table I Results of pairwise Mann–Whitney tests comparing the annual percentage of the population involved in electric shock or electrocution cases in four species of monkey in Diani, Kenya, 2004–2006, 2010–2019 (*N* = 13 yr)

Species	χ^2	*N*	Df	*P*
Colobus–Sykes's	22.0	13	1	0.001**
Colobus–vervet	25.4	13	1	<0.001**
Colobus–baboon	30.6	13	1	<0.001**
Sykes's–vervet	3.5	13	1	1.00
Sykes's–baboon	8.7	13	1	0.82
Vervet–baboon	5.2	13	1	1.00

Asterisks indicate highly significant results.

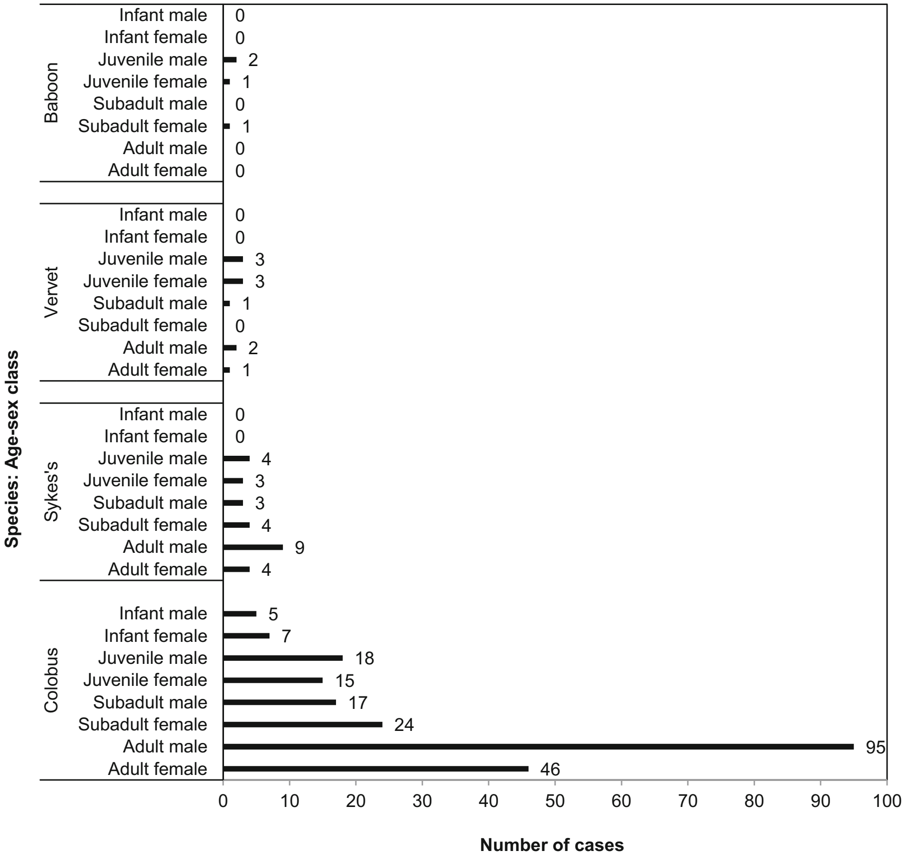

Fig. 4 Number of cases of electric shock and electrocution reported by age–sex class in four species of monkey in Diani, Kenya, 1998–2019 ($N = 22$ yr). Only cases with recorded age–sex class are included ($N = 268$).

members of the community (Kumar and Kumar 2015). We found species differences, and of the two arboreal species in Diani (colobus and Sykes's monkeys), colobus made

Table II Results of *post hoc* tests comparing the observed proportion of each colobus age–sex class involved in electric shock and electrocution cases with that expected from the mean proportion of the colobus population represented by that age–sex class, in Diani, Kenya, 2004–2006, 2010–2019 ($N = 13$ yr)

	Female				Male			
Age class	Exp.	Obs.	*z*-Score	*P*	Exp.	Obs.	*z*-Score	*P*
Infant	0.06	0.03	−1.5	0.07	0.06	0.02	−2.41	0.01
Juvenile	0.08	0.07	−0.71	0.24	0.08	0.08	−0.07	0.47
Subadult	0.10	0.11	0.10	0.46	0.10	0.07	−1.54	0.06
Adult	0.26	0.20	−2.33	0.01	0.26	0.42	8.00	<0.001**
Total	0.50	0.41			0.50	0.59		

Asterisks indicate highly significant results.

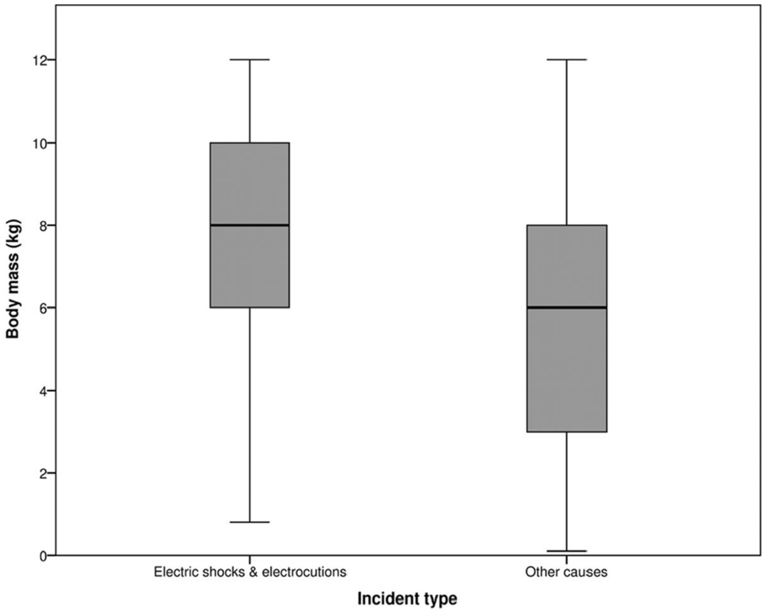

Fig. 5 Body mass of colobus individuals involved in electric shock and electrocution cases (N = 144) compared with all other colobus welfare causes (N = 243), 1998–2019. Boxes represent 50% of the dataset, with the line indicating the median value. The whiskers represent the top and bottom quartiles

up most cases, with *ca*. 4.6% of the colobus population involved annually. Cases involving Sykes's monkeys, vervets, and baboons were low, and the percentage of the

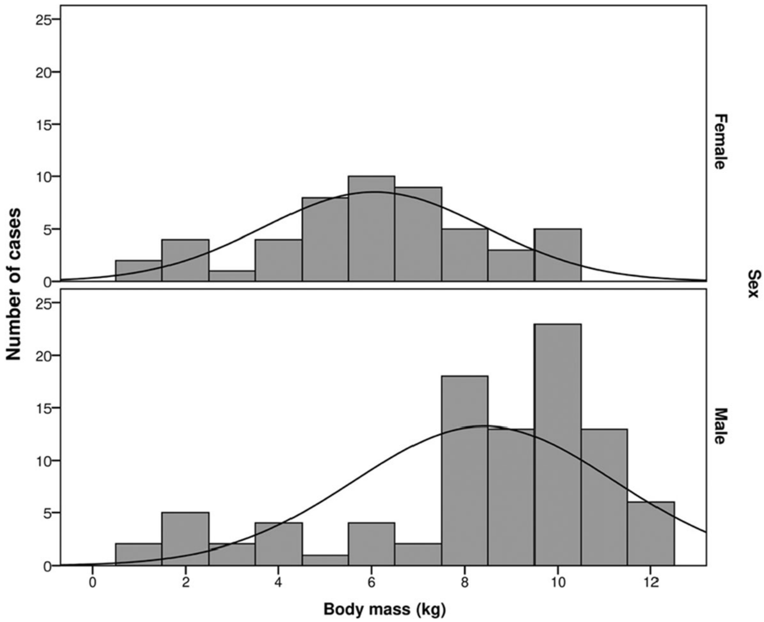

Fig. 6 Number of electric shock and electrocution cases for colobus body mass categories and indicating the normal curve, for females (N = 51) and males (N = 93) in Diani, Kenya, 1998–2019 (N = 22 yr).

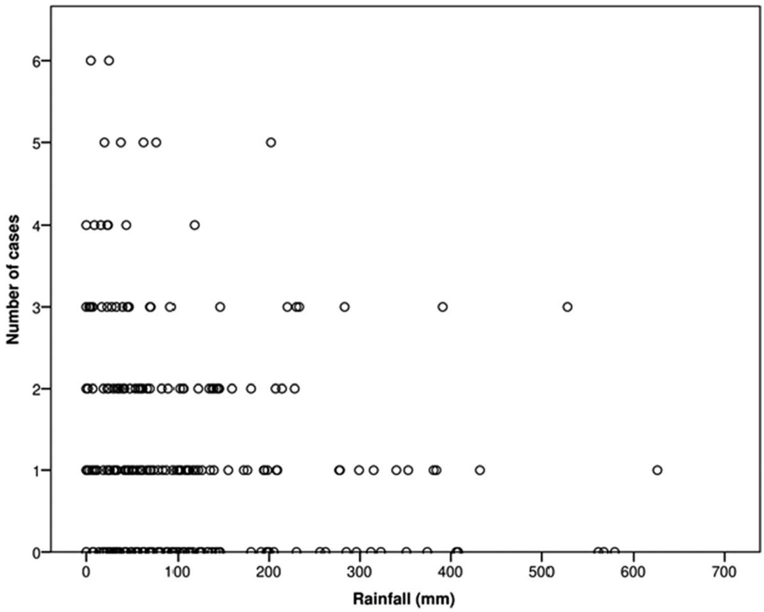

Fig. 7 The number of electric shock and electrocution cases by month ($N = 320$ cases) compared to monthly rainfall in Diani, Kenya, 1998–2019 ($N = 264$ mo) in four species of monkeys combined (colobus, Sykes's monkey, vervet, and baboon).

population involved annually was low. For colobus, the body mass of the individuals involved in shock and electrocution cases was higher than that of colobus involved in other causes of welfare incidents. Of all the colobus age–sex classes, only adult males were involved more than expected given their proportion in the population. This was reflected in the higher body mass of colobus males involved than colobus females.

Reports of injuries and deaths due to the electrical infrastructure did not increase over time as we predicted given Diani's growth during the study years. We attribute this to the mitigation strategies that the power distribution company and the conservation organization implemented to reduce such cases. Since 2002, these organizations, in partnership, have trimmed vegetation growing around electricity cables, poles, and transformers. The amount trimmed has varied by month and by year, but typically, the teams cut *ca*. 500 m twice a month. In 2010, long-term mitigations began by insulating electricity cables and moving transformers known to cause electric shocks and electrocutions. While the efficacy of these tree-trimming and insulation mitigations remains to be tested in detail, our findings suggest that they may contribute to reducing injuries and deaths, as cases have not increased over time, although the electrical infrastructure has expanded.

We suspect that electric shock cases are underrepresented in our dataset. A study of 3 colobus groups in our study area with 21 study subjects found 5 electrical infrastructure related incidents occurred in 336 study days (N. Dunham, *unpubl. data*). These cases included one electrocution case (an adult male) and four electric shock cases (two adult males, one adult female, one juvenile female). In the electric shock cases, the individuals sustained burn injuries but the incidents were not reported by members of the community. If electric shock cases are as frequent as those observations suggest, this presents substantial welfare concerns regarding the installation of uninsulated electrical infrastructure in primate areas (Printes *et al.* 2010).

We found that species of monkeys differ in their risk of electric shock and electrocution. Of the four species of monkeys that live sympatrically in Diani, Kenya, three—Sykes's monkeys, vervets, and baboons—experienced injuries and deaths infrequently, indicating that the electrical infrastructure is a negligible conservation threat to these populations. However, the reports of colobus injured or killed consistently exceeded 4% of the annual population, which is the upper limit of sustainable mortality for primates (Robinson and Bodmer 1999). The annual censuses of colobus in Diani indicate that their numbers are decreasing (Cunneyworth and Duke 2020). The Diani colobus are the second largest population in Kenya (Anderson 2005), making electrical infrastructure an ongoing conservation threat to this Vulnerable species (Cunneyworth *et al.* 2020; De Jong *et al.* 2020).

We hypothesized that stratum use—arboreal vs. terrestrial—influenced species risk from the electrical infrastructure, where arboreal species are at high risk of involvement in electrical infrastructure incidents and terrestrial species are at low risk of involvement. Our results support the prediction that terrestrial species are at low risk of electric shock and electrocution, as there were no cases for either vervets or baboons in many study years. In years with cases, the annual percentage of the population affected was well within the range of sustainable mortality (Robinson and Bodmer 1999). However, the data do not entirely support the prediction that arboreal species are at high risk of electric shock and electrocution, as the annual percentage of the Sykes's monkey population reported to be involved was similar to that of the terrestrial species. This result is surprising, as both colobus and Sykes's monkeys are primarily arboreal (*ca.* 1% and *ca.* 6% terrestrial, respectively) (Coleman and Hill 2014; Dunham 2017), and their distributions overlap extensively in Diani due to the compact nature of suitable habitat in the town. This difference between colobus and Sykes's monkeys indicates that stratum use is not the only factor determining electrical infrastructure risk for arboreal species. Differences in habitat use are an unlikely explanation as the Diani hotspots of electric shock and electrocution of these two species are strongly correlated (Katsis *et al.* 2018), presumably because they negotiate the suburban environment in similar ways. In addition, differences in the size of the home range and daily path length are also unlikely explanations as colobus are folivores and rest for 50–70% of the day (Wijtten *et al.* 2012), meaning that they should be at lower risk of shock and electrocution due to less time spent moving and consequently less time in potential contact with the electrical infrastructure than Sykes's monkeys.

We suspect that body mass is an important factor in understanding electrical infrastructure risk. The distribution of cases across age–sex classes follow the same pattern for colobus and Sykes's monkey, with adult males more often shocked or electrocuted. Both species are sexually dimorphic, suggesting that larger individuals are at greater risk of electric shock and electrocution than smaller individuals. Other primate studies also indicate that adult (and subadult) males are more likely to be electrocuted than immature individuals or females (Montilla *et al.* 2020; Pereira *et al.* 2020). We suggest that the risks become greater when individuals of the arboreal species reach 8 kg, given the distribution of our data.

We found only one other study that provided data on the number of electrocutions of two sympatric arboreal species of monkey of different adult body mass—capped langur

(*Trachypithecus pileatus*) with a body mass of 9.5–14 kg and Phayre's langur (*Trachypithecus phayrei*) with a body mass of 6.5–7.5 kg (Al-Razi *et al.* 2019). The number of electrocution cases in the capped langur was more than twice that of Phayre's langur, consistent with our hypothesis, although relative population size was not presented. While that study implicated the langur's long tail as the short-circuit contact point between two parallel cables, this may not be the case. Investigations of electric shock and electrocution injuries of black-tufted marmosets (*Callithrix penicillata*), brown howlers (*Alouatta guariba clamitans*), and rhesus macaques (*Macaca mulatta*) indicate that tails were rarely affected (Ampuero and Sá Lilian 2012; Kumar and Kumar 2015; Pereira *et al.* 2020).

A brief examination reveals multiple scenarios for how electric shocks and electrocutions occur, such as vegetation to phase, phase to phase, between pole terminals and phase, and between transformer terminals, each with varying likelihoods. We suggest that spacing distances between cables and the cable arrangement—horizontal or vertical—are likely to affect the relationship between body size and risk. Additionally, we suspect that risk increases for colobus and perhaps other larger-bodied monkeys due to their locomotion mode of quadrupedal walking: climbing through rather than jumping past specific infrastructure elements (i.e., uninsulated terminals) may predispose them to higher risk. Given the paucity of previously published data on the specifics of incidents, we suggest that authors include, when possible, the body mass of individuals involved in the incidents and a complete description of the structural elements of the electrical infrastructure where the incident occurred. Furthermore, how species navigate the various structural elements of the electrical infrastructure is an area for further investigation.

Electric shocks and electrocutions were more frequent in months with lower rainfall than in months with higher rainfall. One might expect that this result occurs because daily path lengths are longer during the drier months, when food is less readily available, meaning that monkeys spend more time using the electrical infrastructure moving between foraging areas. However, in Diani, colobus home ranges are small (*ca.* 6–11 ha: Dunham 2017), and daily path lengths are not correlated with rainfall (N. Dunham, *unpubl. data*; Santarsieri 2019). In comparison, no seasonal pattern of electrocutions was found in black-tufted marmosets (Pereira *et al.* 2020), and a higher percentage of cases occurred in the rainy months than in drier months in rhesus macaques (Kumar and Kumar 2015), the opposite to the pattern we found. Further investigation is needed to determine if these differences are due to study methodology, environmental factors, or species differences.

In conclusion, we reviewed electric shock and electrocution reports in four sympatric species of monkeys. Our study shows that species differ in their risk of injury and death related to electrical infrastructure. Based on our findings, we suggest that more susceptible species are arboreal, with greater risk to individuals ≥8 kg compared to more terrestrial species, and arboreal species with smaller individuals. Electricity cable spacing and arrangement may differ across sites, affecting which species or size individuals are at higher risk. Electric shocks are likely much more common than reported, raising welfare concerns relating to poor site selection for electrical infrastructure and installation of uninsulated electrical hardware. Other organizations can estimate risks based on the factors reviewed in this article, even when the impact of electrical infrastructure on populations is not known. Further understanding of how body mass affects the risk of electric shock and electrocution can inform infrastructure design and consequently have far-reaching implications for primate conservation planning.

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Authors' contributions PMKC conceived the study. PMKC and AMS designed and performed the analyzes, PMKC wrote the manuscript and AMS provided editorial advice.

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