Survivorship, demographics and seasonal trends among electrocuted primate species in Diani, Kenya

A manuscript prepared for *Primate Conservation*

by

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Declaration

I declare that the work in this report was carried out in accordance with the requirements of the University's Regulations and Code of Practice for Taught Programmes and that it has not been submitted for any other academic award. Except where indicated by specific reference in the text, this work is my own work. Work done in collaboration with, or with the assistance of others, is indicated as such. I have identified all material in this report which is not my own work through appropriate referencing and acknowledgement. Where I have quoted from the work of others, I have included the source in the references/bibliography. Any views expressed in the dissertation are those of the author.

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Abstract

Electrocution is a threat to many primate species globally (Schwitzer *et al.* 2014; Kumar and Kumar, 2015) however, minimal research has been conducted on the impact of electrocutions on primate populations. Colobus Conservation, a primate conservation organization in Diani, Kenya, treats a range of primate species for electrocution injuries caused by overhead power cables and transformers. Individuals are rehabilitated and released back into the wild, but many sustain severe injuries that cause mortality. This research project investigates survivorship, demographics and seasonality of electrocution incidents in six primate species. Data were collected by Colobus Conservation between 1998 and 2015, and analysed to investigate: 1) species-specific population off-take rates; 2) weight, age-class and sex electrocution frequencies within and between species; 3) survivorship rates; and 4) the effects of season, rainfall and population size on electrocution frequency. The main factors contributing to species-specific electrocution risk are locomotion type and body size. Arboreal species have a higher electrocution risk than terrestrial species due to increased reliance on power lines to manoeuvre through the suburban environment. Larger arboreal species have a higher electrocution risk than smaller arboreal species due to increased chance of simultaneously touching power cables or creating an electrical short circuit on electricity poles and transformers. Electrocution frequency is highest in males between 8kg and 11.9kg indicating that very small and large species may have little or no electrocution risk. This is emphasised by the absence of *Galagoides* electrocution incidences, despite this species inhabiting Diani forest, and no adult or sub-adult baboon electrocutions. This research improves our understanding of causal factors that contribute to species-specific electrocution risk. Further study is needed in other countries to

determine if locomotion type and body size contribute significantly to electrocution risk in other primate species.

Key words: primates, electrocution, power lines, mortality, locomotion, body size.

Introduction

Many tropical and neotropical primate species inhabit fragmented forests within anthropogenic environments (Moore, *et al.* 2010; Nijman and Nekaris, 2010). This is attributed to human encroachment into primate habitat and the conversion of forest landscapes into urban developments (Nijman and Nekaris, 2010). The co-existence of primates and humans in urban and suburban environments brings primates into close contact with electricity networks and power cables (Rodrigues and Martinez, 2014). The arboreal nature of many primates makes them vulnerable to electrocution from overhead power cables used in domestic and industrial areas (Kumar and Kumar, 2015). Primates utilise these cables to move around their home range, cross roads, access available food resources and disperse (Ram et *al.* 2015). Electrocution occurs when an individual touches a transformer or simultaneously touches two power cables or an electricity pole and cable, with their hands, feet or other body part. This results in an electrical short circuit that sends electricity through the body as it finds the path of least resistance to earth (Lee, 1965). Electrocution causes electrical tissue burns which are often visible at the point where the current enters and exits the body (Fish, 1993; Koumbourlis, 2002). Electrocution also causes muscle necrosis, infections, organ damage, systemic disturbance, clinical shock, temporary unconsciousness, cardiac arrest and mortality (Kumar and Kumar, 2015). Severity of injury depends upon the voltage and amperage of the current, the type of current, i.e. whether it is alternating (AC) or direct (DC), and how long the current remains in contact with the body (Lee, 1965; Koumbourlis, 2002).

There are a number of reports and scientific journal articles citing primate electrocution incidences on three continents: South America, Asia and Africa. In Costa Rica, Boinski and Sirot (1997) cite power line induced electrocution as a major cause of direct mortality in grey-crowned Central American squirrel monkey (*Saimiri oerstedii citrinellus*) and black-crowned Central American squirrel monkey (*Saimiri oerstedii oerstedii*). In Sao Paulo, Brazil, Ampuero and Sa Lilian (2012) suggest electrocution is a significant factor contributing to local decline of the *Critically Endangered* southern brown howler monkey (*Alouatta guariba clamitans*). In Pradesh, northern India, Kumar and Kumar (2015) identified electrocution as a cause of mortality in free-ranging rhesus macaques (*Macaca mulatta*). In Sri Lanka, Dittus *et al*. (2008) and Schwitzer *et al.* (2014) cite collisions between Western purple-faced langur (*Semnopithecus vetulus nestor*) and power lines as a major threat contributing to population decline. In Diani, Kenya, data from Colobus Conservation (2016) suggests power line induced electrocution causes high levels of injury and mortality in five out of six primate species that occur there: Angolan colobus (*Colobus angolensis palliatus*); Sykes monkey (*Cercopithecus mitis albogularis*); vervet monkey (*Chlorocebus pygerythrus hilgerti)*; northern yellow baboon (*Papio cynocephalus ibeanus*); and white-tailed small-eared galago *(Otolemur garnetti lasiotis)*. No electrocution incidences have been recorded in the Kenya coast galago (*Galagoides cocos*). The frequency of primate electrocutions and resulting mortality rates, their impacts on species populations and efficacy of mitigation strategies are poorly understood (Colobus Conservation, 2016). Data collected between 1998 and 2015 by Colobus Conservation, a primate rescue and rehabilitation centre, were analysed to investigate the impacts of electrocution on primates sympatrically inhabiting Diani. Data analysis aims to identify: 1) species-specific population off-take rates; 2) weight, age-class and sex electrocution frequencies within and between species; 3) survivorship rates; 4) and the effects of season, rainfall and population size on electrocution frequency.

Methods

Study site

Colobus Conservation is located in Diani: a suburban town within Kwale County in south coastal Kenya. Diani is situated within the fragmented coastal Diani Forest, which forms part of the Zanzibar-Inhambane Undifferentiated floristic region stretching from Mozambique to Somalia (White, 1983). Diani Forest is approximately 7 km^2 in size and the climate is comprised of two dry seasons and two rainy seasons. Dry seasons occur between January and February, and July through to September. Long rains occur between March and June and short rain falls between October and December.

Study species

Angolan colobus are diurnal, highly arboreal folivorous medium sized primates: mean male body weight is 8.9kg and mean female weight is 7.1 kg (Bocian & Anderson 2013). Troops usually comprise a single dominant male, multiple females and offspring, although multiple males have been recorded (Anderson, 2004). Sykes and vervets are medium sized, diurnal, omnivorous primates that live in hierarchical multi-male, multi-female troops (Emerson *et al.* 2011). Molecular studies suggest these two species belong to different phylogenetic clades: Sykes are considered arboreal and vervets are considered terrestrial (De Jong and Butynski, 2010). Northern yellow baboons are large terrestrial, diurnal omnivorous primates that live in multi-male, multi-female troops (Cawthon Lang, 2006). *Otolemur* galago and *Galagoides* galago are strictly arboreal, nocturnal and omnivorous small solitary primates (Nash *et al.* 1989). Mean body weight for *Otolemur* galago females is 720g and 820g for males (Nash *et al.* 1989; Butynski *et al.* 2008). Mean body weight for *Galagoides* galago females is 137g and 149g for males (Harcourt and Bearder, 1989). However, no *Galagoides* have presented at Colobus Conservation with electrocution injuries, so *Otolemur* galago is the species referred to as galago in this report.

Data collection and analysis

Electrocution data was provided by Colobus Conservation which operates a veterinary clinic specifically for primate welfare cases and has a 24/7 emergency response team (Pamela Cunneyworth, pers. comm. 2016). Welfare cases are reported to Colobus Conservation by local community members. All incoming welfare cases are logged on to a database and records for each case include: date, month and day of the week admitted; species; age; sex; weight; cause of incident; and case conclusion, e.g. dead/euthanised/died/released. Dead animals are also collected and recorded. All electrocution incidents occurring between 1998 and 2015 were collated into a spreadsheet for statistical analysis in IBM SPSS version 23. Data were tested with Kolmogorov-Smirnov and Shapiro-Wilk tests, to ascertain if data met requirements for parametric statistics. Due to data deviation from normality, non-parametric statistics were used. Kruskal-Wallis, Fisher's exact and logistic regression analysis were used to achieve project aims. Significance was determined at a probability level of 0.05. Annual population census data were provided by Colobus Conservation, which conducts line transect surveys throughout Diani for colobus, Sykes and vervet, and repeated counts for individual baboon troops. Population census data were available for 2001, 2002, 2004 to 2006, and 2010 to 2015. Census' were not carried out for either galago species. Rainfall data was provided to Colobus Conservation by a local resident who has collected daily rainfall since 1994.

Results

Between January 1998 and December 2015, 17.0% of all animal welfare cases (*N* = 1734) were electrocution incidents. This equates to an average of 1.36 electrocutions per month. The majority of electrocutions (*N* = 294) resulted in mortality (76.5%), 16.7% were not captured and 6.1% were released after treatment. For those that died (*N* = 225), 47.6% were found dead or died on arrival at the veterinary clinic, 18.7% were euthanised and 10.2% died during treatment. Electrocution occurred most frequently in colobus (72.1%, *N* = 294), followed by Sykes (14.6%), *Otolemur* galago (7.8%), vervet (4.1%) baboon (1.4%) and *Galagoides* galago (0%). Adults were electrocuted more frequently (58.2%, *N* = 294), followed by juveniles (18.7%), sub-adults (17.3%), and infants (2.0%). Unknown age-classes account for 3.8% of electrocutions. Males were electrocuted more frequently (50.7%, *N* = 294) than females (34.4%). Unknown age-classes account for 15.0% of cases and occurred due to decomposition or the individuals were not captured and could not be identified in the field. More electrocutions occurred in July (11.9%) and January (10.9%) than any other month.

Species-specific electrocution off-take rates

The proportion of species-specific annual electrocution off-take rates were calculated using annual population census data and analysed using Kruskal-Wallis. Annual colobus off-take fluctuated between 1.7% and 7.9%. Annual Sykes and vervet off-take were always <1.0%. Annual baboon off-take was also always <1.0% with 0% annual off-take occurring frequently. Significant differences in electrocution off-take occur between species ($X^2 = 24.279$, $df = 3$, $P = <0.001$). Post-hoc tests suggest electrocution off-take is significantly higher in colobus compared to Sykes, vervets and baboons, and is significantly higher in Sykes compared to baboons (Table 1). No significant difference occurs between vervets and baboons or between Sykes and vervets. Galagos were not analysed as population census data were unavailable.

Table 1. Summary of Kruskal-Wallis test results for significant differences between species-specific electrocution off-take proportions.

Species	X^2	*P*	*df*	% variability (effect size)
Colobus – Sykes	14.340	<0.001	1	75.4
Colobus – vervet	12.835	<0.001	1	67.5
Colobus – baboon	15.261	<0.001	1	80.3
Sykes – vervet	0.120	0.73	1	0.60
Sykes – baboon	4.770	0.03	1	25.1
Vervet – baboon	1.548	0.21	1	8.1

Electrocution frequency by weight and age-class

Available weights for combined species electrocutions (*N* = 102) were collated into eight categories (Table 2) and analysed with Kruskal-Walllis. Significant differences occur between electrocution frequency and weight (X^2 = 40.951, *df* = 7, *P* = <0.001). Post hoc testing suggests electrocution frequency is significantly higher in: category 5 compared to categories 1, 2 and 3; and higher in category 5 compared to categories 7 and 8. Electrocution frequency increases with increased weight and peaks between 8kg and 9.9kg, then decreases as weight increases (Figure 1).

Table 2. Electrocution victim weights classified into categories for statistical analysis.

Category	Weight (kg)
1	0.1 – 0.9
2	2 – 3.9
3	4 – 5.9
4	6 – 7.9
5	8 – 9.9
6	10 – 11.9
7	12 – 13.9
8	14+

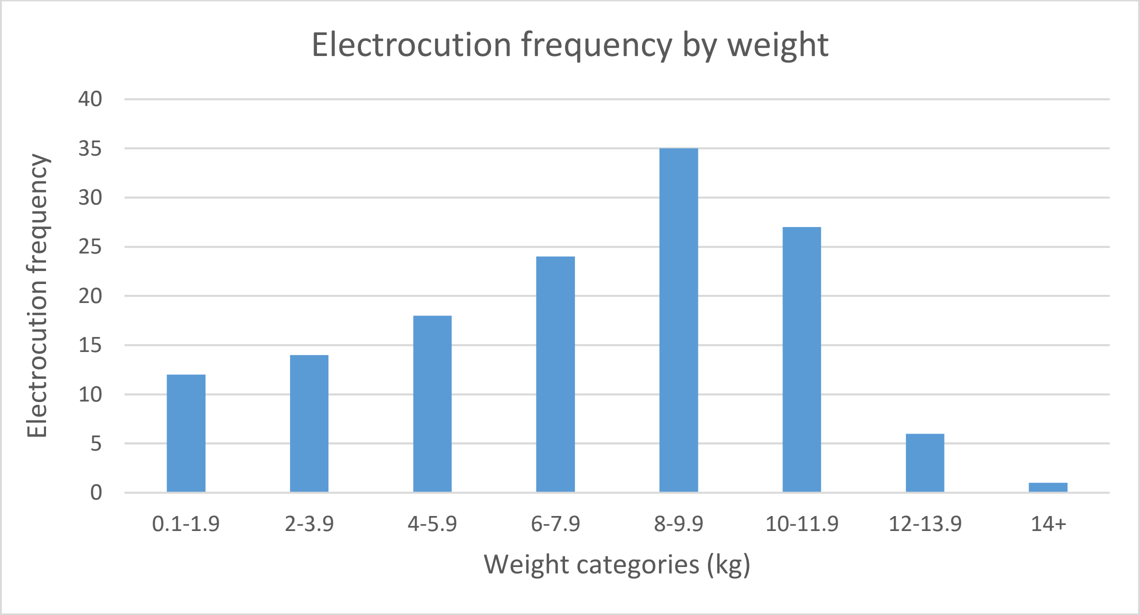

Figure 1. Combined species electrocution frequency increases as weight increases, peaking between 8kg and 9.9kg.

Species-specific age-class electrocution percentages were calculated from the total number of electrocution incidents (Figure 2) and analysed with Kruskal-Wallis. Significant differences occur between colobus electrocution frequency and age-class (X^2 = 34.555, *df* = 2, *P* = <0.001). Adults were electrocuted significantly more than sub-adults (X^2 = 18.178, *df* = 1, *P* = <0.001) and juveniles (X^2 = 23.101, *df* = 1, *P* = <0.001). No significance difference occurs between sub-adult and juvenile electrocution frequency and no results were generated for infants, due to extremely low infant electrocution frequency. To analyse differences between colobus infants and other age-classes, population census data were used to calculate age-class electrocution off-take. Significant differences occur between adult and infant off-take (X^2 = 7.587, *df* = 1, *P* = 0.01) and between juvenile and infant off-take (X^2 = 4.285, *df* = 1, *P* = 0.04) indicating that infants are significantly less likely to be electrocuted than any other age-class.

Significant differences occur between Sykes electrocution frequency and age-class (X^2 = 13.055, *df* = 3, *P* = 0.01). Infant electrocution was significantly lower than adult (X^2 = 12.227, *df* = 1, *P* = <0.001), sub-adult (X^2 = 7.178, *df* = 1, *P* = 0.01) and juvenile (X^2 = 8.708, *df* = 1, *P* = <0.01). Significant differences occur between baboon electrocution frequency and age-class (X^2 = 8.804, *df* = 3, *P* = 0.032). Juvenile electrocution frequency was significantly higher than adult and sub-adult ((X^2 = 5.000, *df* = 3, *P* = 0.025). No significant difference in electrocution frequency occurs between vervet age-classes (X^2 = 2.532, *df* = 3, *P* = 0.47). No infant vervet or adult and sub-adult baboon electrocutions were recorded. Significant differences occur between galago electrocution frequency and age-class (X^2 = 17.552, *df* = 2, *P* = <0.001). Adults were electrocuted significantly more than sub-adults (X^2 = 13.616, *df* = 1, *P* = <0.001) and juveniles (X^2 = 9.535, *df* = 1, *P* = <0.01). No infant galago electrocutions were recorded.

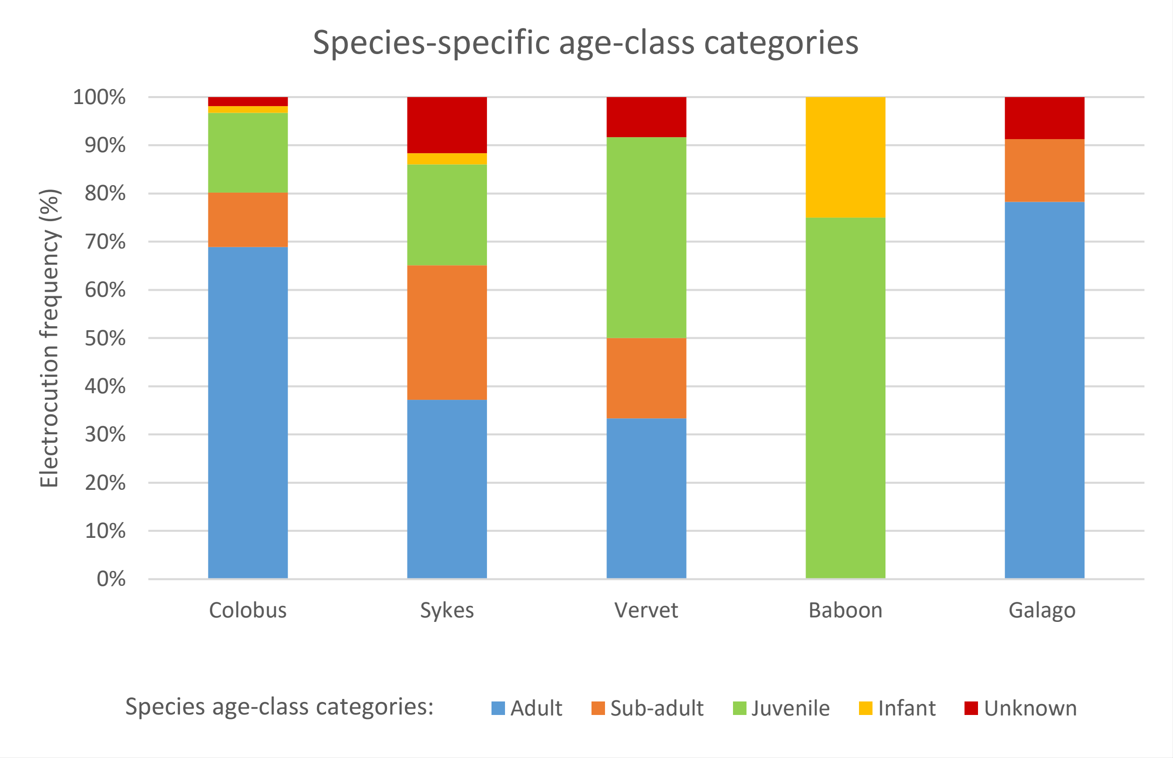

Figure 2. Species-specific age-class electrocution percentages indicate which age-class succumbs to electrocution most frequently.

<u>Electrocution frequency by sex</u>

Species-specific male and female electrocution frequencies were calculated from the total number of electrocution incidents. Electrocution frequency is significantly higher in male galago than females (Kruskal-Wallis: X^2 = 6.234, *df* = 1, *P* = 0.01). No significant differences in male and female electrocution frequency occur in any other species. For all species combined, there is no significant relationship between sex and age-class (Fisher's exact: X^2 = 4.464, *P* = 0.20). For all species combined (Figure 3) there is a significant relationship between sex and weight, as electrocution frequency is significantly higher in males weighing between 8kg and 11.9kg (Fisher's exact: X^2 = 24.343, *P* = <0.001).

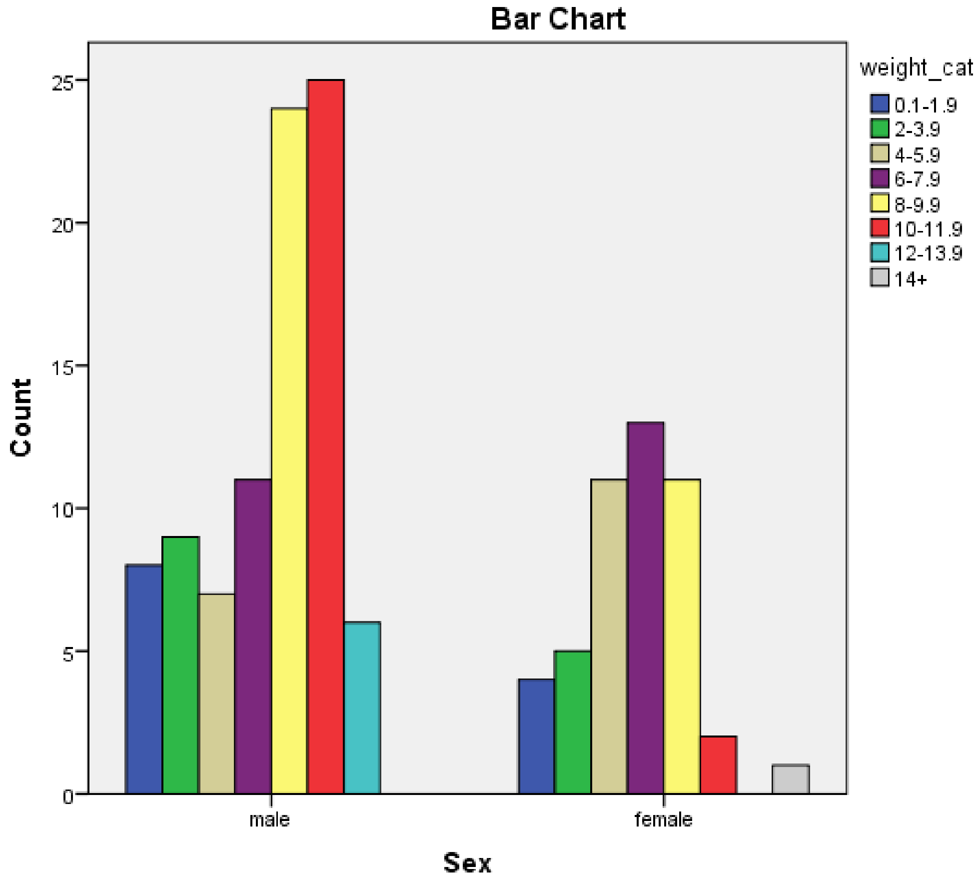

Figure 3. Fisher's exact test for combined species relationship between sex and weight indicates males between 8kg and 11.9kg have a significantly higher electrocution risk.

Electrocution survivorship and mortality

A logistic regression was performed to ascertain the effects of age, weight, sex and species on the likelihood of surviving electrocution. The logistic regression model was statistically significant: $X^2 = 23.501$, $df = 6$, $P = 0.001$. The model explained 22.5% (Nagelkerke R^2) of the variance and correctly classified 92.6% of cases. Species ($P = 0.008$) and sex ($P = 0.018$) added significantly to the model. Weight ($P = 0.221$) and age-class ($P = 0.344$) did not. There is a significant relationship between survival and sex as females survived more ($P = 0.012$) than males ($P = 0.062$). Colobus survival is higher than any other species, but not significantly ($P = 0.074$). Due to the small number of survivors ($N = 16$) Kruskal-Wallis post hoc tests were conducted to further analyse species survivorship (Table 3). Significant differences occur between survivorship and species (X^2 = 10.006, *df* = 4, *P* = 0.04). Colobus survival is significantly higher than galago (X^2 = 8.366, *df* = 1, *P* = 0.004). Galago survival is significantly higher than vervet (X^2 = 5.625, *df* = 1, *P* = 0.02).

Table 3. Summary of Kruskal-Wallis test results for significant differences in electrocution survival between species.

Species	*X²*	*P*	*Df*
Colobus – sykes	2.485	0.12	1
Colobus – galago	8.366	0.004	1
Colobus – vervet	0.582	0.45	1
Colobus – baboon	2.540	0.11	1
Sykes – galago	3.182	0.07	1
Sykes – vervet	0.728	0.39	1
Sykes – baboon	0.033	0.86	1
Galago – *v*ervet	5.625	0.02	1
Galago – baboon	2.657	0.10	1
Vervet – baboon	0.904	0.34	1

<u>Effects of rainfall, season and population size on electrocution frequency</u>

Logistic regression analysis suggests a significant negative relationship between combined species annual electrocution frequency and annual mean seasonal rainfall (*F* = 4.605, *P* = 0.035). Therefore, all species electrocution frequency decreases as rainfall increases. No significant relationship occurs between combined species electrocution frequency and season (*F* = 1.988, *P* = 0.124). However, parameter estimates (Table 4) suggest primate electrocution frequency may be higher (*P* = 0.058) in the long dry season between July and September (season 3) compared to other seasons.

Logistic regression analysis suggests no significant relationships occur between individual species and rainfall, season or population size (Appendix 1). However, colobus electrocution frequency is significantly higher in season 3 (the long dry season between July and September) than season 4 (wet season between October and December). Univariate parameter estimates: $\beta = 1.278$, $P = 0.05$ (Table 5). The value for season 4 is aliased to the intercept value, therefore, 2.444 colobus are electrocuted during season 4. Electrocution frequency was calculated for each season by adding positive values to, or subtracting negative values from, this intercept value. For example, average colobus electrocution frequency in season 1 is: 2.444 + 0.833 = 3.277. Colobus electrocution frequency is also higher in the shorter dry season between January and March (season 1) but not significantly.

Table 4. Parameter estimates for all species electrocution frequency and season, indicating that season may be a driver of electrocutions.

Parameter	B	Std. Error	t	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Intercept	3.611	.529	6.825	.000	2.555	4.667
[season=1]	.611	.748	.817	.417	-.882	2.104
[season=2]	-.222	.748	-.297	.767	-1.715	1.271
[season=3]	1.444	.748	1.931	.058	-.049	2.937
[season=4]	0[a]	.	.	.	.	.

Table 5. Parameter estimates for colobus electrocution frequency and season, indicating increased electrocutions during both dry seasons.

Parameter	B	Std. Error	T	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Intercept	2.444	.453	5.391	.000	1.540	3.349
[season=1]	.833	.641	1.300	.198	-.446	2.113
[season=2]	-.111	.641	-.173	.863	-1.391	1.169
[season=3]	1.278	.641	1.993	.050	-.002	2.557
[season=4]	0[a]	.	.	.	.	.

Discussion

Species-specific electrocution risk

This analysis indicates that two combined factors determine species-specific electrocution risk: locomotion type and body size/weight. Primate electrocution risk is higher in arboreal species compared to terrestrial species, due to increased reliance on power lines for movement between tree canopies and forest fragments. Low electrocution frequency in highly arboreal galagos is likely attributed to their small body size. Electrocution occurs when an individual touches a transformer or simultaneously touches two power cables or an electricity pole and cable, with their hands, feet or other body part. As power cables run parallel to each other, often in multitudes of three (medium voltage lines) or four (low voltage lines), larger arboreal species may be more susceptible to direct contact with power lines/transformers than smaller arboreal species. The absence of electrocution in *Galagoides* suggests very small arboreal primates have no electrocution risk. Population size may contribute to low galago electrocution risk, but anecdotal data suggests the *Otolemur* population is relatively high (Pamela Cunneyworth, pers. comm. 2016).

Sykes and vervets have equal electrocution risk and body size is likely to be a significant factor determining this as both species are classified as medium sized primates of similar body size (Emerson *et al.* 2011). Locomotion type may also be a factor that determines the equal electrocution risk in these two species. De Jong and Butynski (2010) describe Sykes as the more arboreal species but anthropogenic threats, such as predation from dogs, humans and traffic (Colobus Conservation, unpubl. data) may result in Diani vervet troops spending more time in the canopy than vervet populations inhabiting remote woodlands and savannahs in other regions (Kingdon *et al.* 2008). It is suggested that the higher than expected electrocution risk in terrestrial vervets is partly due to their increased arboreal locomotion in this highly anthropogenic environment compared to those in a natural ecosystem.

Electrocution risk by weight and age-class

The analysis suggests electrocution risk increases as weight increases and the highest risk weight range is between 8kg and 9.9kg. Risk decreases when weight increases over 10kg and appears to be negligible over 14 kg. The differences in electrocution risk between species-specific age-classes is also attributed to body size. Adult colobus are larger (mean adult weight is between 7.1kg and 8.9 kg) and thus have a higher chance of touching two power cables simultaneously, which explains the higher electrocution risk in that species. The small size of *Otolemur* galago sub-adults, juveniles and infants may reduce their ability to come into direct contact with multiple cables, thus reducing their electrocution risk in comparison to the larger adults. Sykes and vervet adults, sub-adults and juveniles may all be large enough to simultaneously touch multiple cables, thus have equal electrocution risk. Conversely, adult and sub-adult baboons have no risk of electrocution due a combination of large body size and terrestrial behaviour. Baboons rarely make contact with overhead power cables but can access transformers that are located on electricity poles nearer ground level. Play behaviour may increase electrocution risk in terrestrial juveniles and infants as these age-classes are known to be more inquisitive and playful than adults (Cawthon Lang, 2006). Play behaviour may also be a factor that increases juvenile-infant electrocution risk in other species as juvenile colobus and Sykes electrocution risk is significantly higher than infants'. Only one infant baboon electrocution was recorded and no infant galago or vervet electrocutions were recorded. Juveniles are more independent than infants thus have increased exposure to power lines/transformers. Additionally, body size is likely to be an important determinant of higher juvenile electrocution risk. Small infant body size may reduce their ability to cause electrocution so this factor lowers their electrocution risk. Other contributing factors may include population age-class structure, as juveniles often comprise a larger percentage of the population than infants (O'Dwyer, 2011). Colobus age-class structure in Diani comprises an average of 18% juveniles and 6% infants. Parental infant carrying may reduce access to hazards, thus further reduce infant electrocution risk. Infant 'parking' near or in nests, a technique used by galagos to reduce infant predation (Wright, 1989), explains the lack of galago infant electrocution as infants do not move about in the environment.

Electrocution risk by sex

Analysis suggests males between 8kg and 11.9kg have a significantly higher electrocution risk than males and females of lesser and higher weights. The weight significance can be attributed to larger individuals having a higher chance of simultaneously touching multiple power lines in comparison to smaller individuals. The decrease in electrocution risk in individuals over 12kg can be attributed to individuals of this weight and over being too heavy to utilise arboreal supports of diameter and stability of power lines. Higher electrocution risk in males weighing between 8kg and 11.9kg compared to females of that weight may be attributed to male home range defence behaviours. Primates in Diani have over lapping intraspecific and inter-specific home ranges. Inter-group male aggression during home range defence, and intra-group dominance interactions and take-over attempts from rival males, may result in increased movement through the environment thus increasing male electrocution risk.

The only species to display between sex differences in electrocution risk is galagos as male galago electrocution risk is significantly higher than females'. This may be attributed to the solitary nature of this species which has between sex differences in home range size and ranging patterns (Nash and Harcourt, 1986). Males are reported to have a larger home range (mean 17 ha) than females (mean 12 ha) and to travel further per night (almost 3km) than females (average 1.8 km). Females usually stay in their natal range whereas males disperse (Nash and Harcourt, 1986). Larger home ranges and increased travelling in males will increase power cable exposure explaining the observed electrocution risk.

<u>Electrocution survivorship and mortality</u>

Overall, female survival is significantly higher than male but there is no relationship between weight and survival. Colobus survival is significantly higher than galago survival and galago survival is significantly higher than vervet survival. However, the number of survivors was very low (N = 16) and the sample of survivors with accompanying weight data was even lower (N = 7). Higher colobus-galago survival could be attributed to higher colobus electrocution frequency. Additionally, nocturnal behaviour of galagos could increase the length of time between electrocution and presentation at Colobus Conservation, thus delay treatment and consequently reduce survival rate. Low body weight may also be a factor that reduces electrocution survival but may not be indicated in the analysis due to the sample size. These results are likely to be attributed to survival rate being dependent upon the type and severity of injury sustained, which is influenced by the voltage of the current that caused the electrocution (Lee, 1965; Koumbourlis, 2002). Kumar and Kumar (2015) investigated seasonal differences in electrocution occurrence and mortality in free-ranging *M. mulatta* in northern India and found that low voltage domestic currents caused more electrocutions than high voltage industrial currents but survival rate was low when high voltage currents caused the electrocution (Kumar and Kumar, 2015). Thus type and severity of injury, combined with the small number of survivors, may explain some of the anomalies in survivorship results.

<u>Effects of rainfall, season and population size on electrocution frequency</u>

Electrocution risk appears to be higher at the beginning of both dry seasons and lower in the wet season. This can be attributed to delay between the increased rainfall during the rainy seasons and the increase of vegetation growth, where the greatest vegetation growth occurs nearer to the end of the wet seasons and at the beginning of the dry seasons (Pamela Cunneyworth, pers. comm. 2016). Vegetation growth enables primates to use power lines as aerial pathways by jumping between vegetation and powerlines/transformers that may be inaccessible with vegetation die-back during the end of the dry seasons and at the beginning of the wet seasons. This also suggests that tree trimming around power lines to create a gap which is wider than the resident species can jump, as conducted by Colobus Conservation, can be a seasonally effective electrocution mitigation strategy.

Conclusion

This study provides an insight into the factors that increase electrocution risk in primate species in Diani, Kenya. The main factors contributing to species-specific electrocution risk appear to be locomotion type and body size, and to a lesser degree age-class behaviour patterns, and season. In general, arboreal species have a higher electrocution risk than terrestrial species due to increased reliance on power lines and transformers as structures that allow greater arborealism in the anthropogenic environment. Larger arboreal species have a higher electrocution risk than smaller arboreal species due to increased chance of either simultaneously coming into contact with multiple power cables or creating a short circuit on electricity poles and transformers. Electrocution frequency is highest in males between 8kg and 11.9kg indicating that very small and large species may have little or no electrocution risk. This is emphasised by the absence of *Galagoides* electrocution incidences, despite this species inhabiting Diani forest (Butynski *et al.* 2006; De Jong and Butynski, 2009) and no adult or sub-adult baboon electrocutions. In some species, play behaviours exhibited by certain age classes, particularly juveniles, may increase their exposure to electrocution. Electrocution risk is higher at the beginning of both dry seasons when vegetation growth is at its maximum after the rains. Survival appears to be impacted by the type and severity of injuries but size, sex and activity behaviour (diurnal or nocturnal) may also contribute to survivorship rates. It is hoped that this study will contribute valuable information on temporal and spatial factors affecting primate populations in Diani. Further study is needed in other countries where primate electrocution is prevalent, such as Brazil and India. This will help to determine if body size, locomotion type, age-class behaviour and season contribute significantly to electrocution risk in other primate species. This will facilitate the development of partnerships between conservation organisations and national power companies, to implement better mitigation strategies to reduce primate electrocution risk.

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References

Anderson, J., 2004. *Habitat fragmentation and metapopulation dynamics of the Angola black-and-white colobus (Colobus angolensis palliatus) in coastal Kenya.* PhD dissertation, University College London.

Anderson, J., Cowlishaw, G. and Rowcliffe, J.M. 2007. Effects of forest fragmentation on the abundance of *Colobus angolensis palliatus* in Kenya's coastal forests. *International Journal of Primatology.* 28: 637-655.

Anderson, J., Rowcliffe, J.M. and Cowlishaw, G. 2007b. The Angola black-and-white colobus (*Colobus angolensis palliatus*) in Kenya: historical range contraction and current conservation status. *American Journal of Primatology.* 69 (6): 664-680.

Ampuero, F. and Sa Lilian, R.M. (2012) Electrocution lesions in wild brown howler monkeys (*Alouatta guariba clamitans*) from Sao Paulo city: importance for conservation of wild populations. *ESVP/ECVP Proceedings.* 146, p. 1.

Bocian, C.M. & J. Anderson. 2013. *Colobus angolensis*: Angola colobus (Angola black and white colobus, Angola pied colobus). In *Mammals of Africa: Vol II Primates*, T.M. Butynski, J. Kingdon & J. Kalina eds. Bloomsbury Publishing, London.

Boinski, S. and Sirot, L. (1997) Uncertain conservation status of squirrel monkeys in Costa Rica, *Saimiri oerstedii oerstedii* and *Saimiri oerstedii citrinellus*. *Folia Primatalogica*. 68: 181-193.

Buskas, J. 2011*. Behaviours of wild male and female Colobus angolensis palliatus during morning and afternoon in Diani Beach, Kenya*. MSc thesis, Swedish University of Agricultural Sciences.

Butynski, T.M., de Jong, Y.A., Perkin, A.W., Bearder, S.K. and Honess, P.E. 2006. Taxonomy, Distribution, and Conservation Status of Three Species of Dwarf Galagos (*Galagoides*) in Eastern Africa. *Primate Conservation*. 21: 63-79.

Butynski, T.M., Bearder, S. and De Jong, Y. 2008. *Otolemur garnettii*. The IUCN Red List of Threatened Species 2008. Available from: http://dx.doi.org/10.2305/IUCN.UK.2008.RLTS.T15644A4945217.en. [Accessed 14 August 2016].

Cawthon Lang, K.A. 2006. *Primate Factsheets: Vervet (Chlorocebus) Taxonomy, Morphology, & Ecology*. Available from: http://pin.primate.wisc.edu/factsheets/entry/vervet/taxon [Accessed 2016 August 15].

Colobus Conservation (2016) *Primate Electrocutions.* Available from: http://www.colobusconservation.org [Accessed 22 February 2016].

De Jong, Y.A. and Butynski, T.M. 2009. *Primate Biogeography, Diversity, Taxonomy and Conservation of the Coastal Forests of Kenya.* Report to the Critical Ecosystem Partnership Fund.

De Jong, Y.A. and Butynski, T.M. 2010. Three Sykes's Monkey *Cercopithecus mitis* × Vervet Monkey *Chlorocebus pygerythrus* Hybrids in Kenya. *Primate Conservation.* 25: 43-56.69+-

Dittus, W., Molur, S. and Nekaris, A. (2008) *Trachypithecus vetulus*. The IUCN Red List of Threatened Species 2008. Available from: http://dx.doi.org/10.2305/IUCN.UK.2008.RLTS.T22042A9350371.en. [Accessed 27 June 2016].

Dunham, N.T. and McGraw, W.S. 2014. Positional Behaviour and Habitat Use of Peters' Angola Black and White Colobus Monkey (*Colobus angolensis palliatus*) in Structurally Distinct Areas of the Diani Forest, Kenya. *African Primates*. 9: 1-14.

Emerson, S.E., Brown, J.S. and Linden, J.D. 2011. Identifying Sykes' monkeys', Cercopithecus albogularis erythrarchus, axes of fear through patch use. *Animal Behaviour.* 81: 455-462.

Fish, R. 1993. Electric shock, art II: nature and mechanisms of injury. The Journal of Emergency Medicine. 11 (4): 457 -462.

Harcourt, C.S. and Bearder, S.K. 1989. A comparison of *Galago moholi* in South Africa with *Galago zanzibaricus* in Kenya. *International Journal of Primatology*. 10 (1): 35-45.

Hernandez-Matias, A., Real, J., Pares, F. and Pradel, R. (2015) Electrocution threatens the viability of populations of the endangered Bonelli's eagle (Aquila fasciata) in Southern Europe. Biological Conservation. 191: 110-116.

Kingdon, J., Gippoliti, S., Butynski, T.M. and De Jong, Y. 2008. *Chlorocebus pygerythrus*. The IUCN Red List of Threatened Species 2008. Available from:

http://dx.doi.org/10.2305/IUCN.UK.2008.RLTS.T136271A4267738.en.] Accessed 18 August 2016].

Koumbourlis, A.C. 2002. Electrical Injuries. *Critical Care Medicine.* 30 (11), pp. 424-430.

Kumar, V. and Kumar, V. (2015) Seasonal electrocution fatalities in free-range rhesus macaques (*Macaca mulatta*) of Shivalik hills area in northern India. *Journal of Medical Primatology*. 44: 137-142.

Lee, W.R. 1965. The Mechanisms of Death from Electric Shock. *The Royal Society of Medicine Journals.* 5 (1): 23-28.

Metcalfe, K., French-Constant, R. and Gordon, I. 2009. Sacred sites as hotspots for biodiversity: the three sisters cave complex in coastal Kenya. *Oryx* 44 (1): 118-123.

Moore, R.S., Nekaris, K.A.I. and Eschmann, C. 2010 Habitat use by western purple-faced langurs - *Trachypithecus vetulus nestor* (Colobinae) in a fragmented suburban landscape. *Endangered Species Research*. 12: 227-234.

Nash, L.T. and Harcourt, C.S. 1986. Social organisation of galagos in Kenyan coastal forests: *galago garnettii*. *American Journal of Primatology*. 10: 357-369.

Nash, L., Bearder, S. and Olsen T. 1989. Synopsis of galago species characteristics. *International Journal of Primatology.* 10 (1), pp. 57-80.

Nijman,V. and Nekaris, K.A.I. (2010) Effects of deforestation on attitudes and levels of tolerance towards commensal primates (Cercopithecidae) in Sri Lanka. *International journal of Pest Management*. 56 (2): 153-158.

O'Dwyer, R. 2011. *The black-and-white colobus monkeys (Colobus angolensis palliatus) of Diani forest, Kenya : behavioural responses to habitat fragmentation*. MSc thesis, Swedish University of Agricultural Sciences.

Ram, C., Sharma, G. and Rajpurohit, L.S. (2015) Mortality and Threats to Hanuman Langurs (*Semnopithecus entellus Entellus*) in and around Jodhpur (Rajasthan). The Indian Forester. 10: 141.

Rodrigues, N.N. and Martinez, R.A. (2014) Wildlife in our backyard: interactions between Wied's marmoset *Callithrix kuhlii* (Primates: Callithrichidae) and residents of Ilheus Bahia, Brazil. *Wildlife Biology.* 20: 91-96.

Schwitzer, C., Mittermeier, R. A., Rylands, A. B., Taylor, L. A., Chiozza, F., Williamson, E. A., Wallis, J. and Clark, F. E. (eds). 2014. *Primates in Peril: The World's 25 Most Endangered Primates 2012–2014*. IUCN SSC Primate Specialist Group (PSG), International Primatological Society (IPS), Conservation International (CI), and Bristol Zoological Society, Arlington, VA. pp. 61-64.

White, F. 1983. The vegetation of Africa: A descriptive memoir to accompany the Unesco/AETFAT/UNSO vegetation map of Africa. UNESCO.

Wright, P.C. 1989. Patterns of parental care in primates. *International Journal of Primatology.* 11, (2): 89-102.

Appendices

Appendix 1 – Species-specific univariate regression analysis for relationships between electrocution frequency and rainfall, seasons and population size

	Colobus	Sykes	Vervet	Baboon	Galago
Rainfall	F = 2.320, P = 0.132	F = 3.474, P = 0.067	F = 1.150, P = 0.287	F = 0.038, P = 0.846	F = 0.015, P = 0.902
Season	F = 2.172, P = 0.099	F = 0.650, P = 0.586	F = 1.110, P = 0.355	F = 0.687, P = 0.563	F = 0.336, P = 0.799
Population size	F = 0.395, P = 0.533	F = 3.474, P = 0.067	F = 1.094, P = 0.302	F = 1.314, P = 0.258	N/A