Evaluating the factors affecting road traffic accidents involving non-human primates in Diani Beach, Kenya.

Joshua James Duke

B.Sc. (Hons), Zoology, Anglia Ruskin University.

2017

WORD COUNT

5512

ABSTRACT

The increasing development of road infrastructure globally, is of mounting concern for many conservationists, as it is known to have negative impacts upon many wildlife populations. A primary effect of road infrastructure is the associated road traffic accidents (RTAs), which are recognised to have a large, direct effect on animal mortality. Tropical, forest species, in particular non-human primates, are of increased risk from RTAs due to their highly-specialised adaptations for the dense forests which leaves them vulnerable when their habitat is disturbed. This study looks to determine the causal factors contributing to the risk of primate RTAs on Diani Beach Road, south-east Kenya. The data collected by Colobus Conservation between 1998 – 2016 listed 658 RTA cases, and included five primate species; Zanzibar Sykes' monkeys (*Cercopithecus mitis albogularis*), the black-and-white colobus (*Colobus angolensis palliatus*), northern yellow baboon (*Papio cynocephalus ibeanus*), Hilgert's vervet monkeys (*Chlorocebus pygerythrus hilgerti*), and the small-eared galago (*Otolemur garnettii lasiotis*). Species-specific annual population off-take rates; age-class, weight and sex frequencies for species-combined and species-specific; and the effects of season and rainfall were analysed. The main factors contributing to the primate RTA risk were seasonal variation and age-class differences. The primates were found to be most involved in RTAs during the dry seasons, in comparison to the rainy seasons, this is likely to be due to the increased foraging range observed during the dry seasons when food and water availability is scare. All species' adults and baboon juveniles were the most frequently involved in RTAs, with infants being the least involved. This is likely due to adults showing the furthest dispersal of the age-classes and juvenile baboons show a high level of play behaviour which encourages movement on to the road. Infant RTA involvement was low, this was possibly due to parental carrying behaviours which are likely to reduce infant RTA risk. This study has provided a valuable insight into the causal factors contributing to primate RTA risk. Further study is needed to determine the spatial distribution of local RTAs, this would allow appropriate measures to be put in place which would help to ameliorate the effect of Diani Beach Road on the local primate populations.

TABLE OF CONTENTS

INTRODUCTION

The ecological impact of anthropogenic, linear development, such as roads on wildlife, is acting as a major threat to biodiversity globally (Polak, *et al.,* 2014). Roads can influence wildlife in numerous ways (Ament, *et al.,* 2008; Ward, Dendy & Cowan, 2015), impacting indirectly – through habitat loss, degradation and most strongly habitat fragmentation (Van Der Ree, *et al.,* 2011; Ogden, 2012); whereby roads act as barriers creating small, isolated habitat patches reducing wildlife permeability (Trombulak & Frissell, 2000; Beyer, *et al.,* 2016). This restriction to movement dynamics can lead to the development of subpopulations, in turn increasing the likelihood of localised extinction (Forman & Alexander, 1998; Bissonette, 2002; Reed, 2004). More directly, roads can lead to road avoidance behaviour (Fahrig & Rytwinski 2009) and mortality through direct collisions with vehicles (Ree, *et al.,* 2007). It has been suggested that wildlife moralities are the most direct ecological effect of roads (Bissonette, 2002; Wang, *et al.*, 2013) and a leading source of vertebrate mortality (Forman & Alexander, 1998; Glista, Devault & DeWoody, 2009). Road mortality has been described as 'non-selective', affecting healthy, weak or sick individuals, meaning that the population viability is affected more than mortality sources that preferentially affect less-fit individuals (Bujoczek, Ciach & Yosef, 2011; Polak, *et al.,* 2014).

These negative impacts are becoming more pronounced due to the unprecedented rate of road infrastructure development, particularly in tropical regions where few road networks previously existed (Laurance, Goosem & Laurance, 2009; Laurance, *et al.,* 2014). Species that inhabit tropical forests are particularly vulnerable to the impacts of roads, as many are specialised for the dense forests and show canopy gap and forest edge avoidance (Laurance, Stouffer & Laurance, 2004; Goosem, 2007; Laurance, Goosem & Laurance, 2009). The increasing encroachment and conversion of forested landscape to urban development is threatening many tropical species, in particular, non-human primates (hereafter primates) (Mazumder, 2014; Estrada, *et al.,* 2017). A number of studies have highlighted the impacts of roads on varying primate taxa, including the yellow baboon, *Papio* *cynocephalus* (Drews, 1995); Zanzibar red colobus, *Procolobus kirkii* (Struhsaker & Siex, 1996) and the chimpanzee, *Pan troglodytes* (McLennan & Asiimwe, 2016). However, limited study has been carried out to specifically determine the factors associated with increasing threats posed by roads.

Diani Forest, Kenya, is recognised as a site of high primate biodiversity with six primate species present. In 1971, 'Diani beach road' was constructed bisecting directly through Diani Forest. Since its construction, an expansion of the tourism industry has followed, leading to Diani becoming an international tourist destination. This development has subsequently led to increased traffic flow, in turn increasing the potential risk for primates to face vehicle induced injuries and mortalities. This was highlighted between 1999 and 2012, where 518 primates were recorded as injured or killed by vehicles on Diani Beach Road (Donaldson & Cunneyworth, 2015), further emphasizing the prominence for primate conservation across Diani, Kenya. However, the precise relationships between road traffic accident (RTA) occurrence and the associated temporal and spatial factors is still poorly understood.

My project aims to evaluate and determine the most significant causal factors of RTAs in the primate species along a 10-kilometre section of Diani Beach Road, Kenya. The project will be undertaken in collaboration with Colobus Conservation, a primate conservation and rescue centre which operates to promote the conservation, preservation and protection of south eastern Kenya's primate populations. A pre-existing database provided by Colobus Conservation will be analysed.

The database contains 658 cases, recorded from 1998 to 2016. Each case includes; date and day of week; species; age (infant/juvenile/sub adult/adult); sex (male/female); weight and case conclusion. The analysis will determine if there is a difference between the number of primate injuries and deaths between each of these categories, with the aim of determining the primary factors that are inducing road traffic related primate injuries and mortalities across this section of Diani beach road, Kenya.

METHODS & MATERIALS

Study Site

Diani Forest is a remnant patch of the "Zanzibar-Inhambane floristic region", which stretches from the Kenya-Somalia border to the Mozambique and Tanzania border, it is recognised as a global biodiversity hotspot (Myers, *et al.,* 2000; Metcalfe, Ffrench-Constant & Gordon, 2010). The forest is located within the Kwale District of southern coastal Kenya (4°15′30′′, 4°35′30′′S and 39°35′00′′, 39°34′30′′E) (Okanga, *et al.,* 2006; Dunham, 2015), and measures approximately 455ha in area (Anderson, Rowcliffe & Cowlishaw, 2007). The climate is characterised by two dry seasons, the longer – December to March, and shorter – July to September; and two rainy seasons, with longer rains between April – June and shorter between October – November (*pers. comm.* Pamela Cunneyworth). Temperatures range from 28°C during the rainy seasons and can reach up to 35°C during the dry seasons (Okanga, *et al.,* 2006). Six primate taxa occur in and around the Diani Forest: Zanzibar Sykes' monkeys (*Cercopithecus mitis albogularis*), the black-and-white colobus (*Colobus angolensis palliatus*), Northern yellow baboon (*Papio cynocephalus ibeanus*), Hilgert's vervet monkeys (*Chlorocebus pygerythrus hilgerti*), small-eared galago (*Otolemur garnettii lasiotis*) and Kenya coast galago (*Galagoides cocos*) (De Jong & Butynski, 2010). No RTAs involving Kenya coast galago were recorded, thus hereafter galago refers singly to the small-eared galago. The RTA data was provided by Colobus Conservation and was recorded on the section of Diani Beach Road between Southern Palms Beach Resort and KFI Supermarket, an approximate distance of 10 kilometres (Fig. 1).

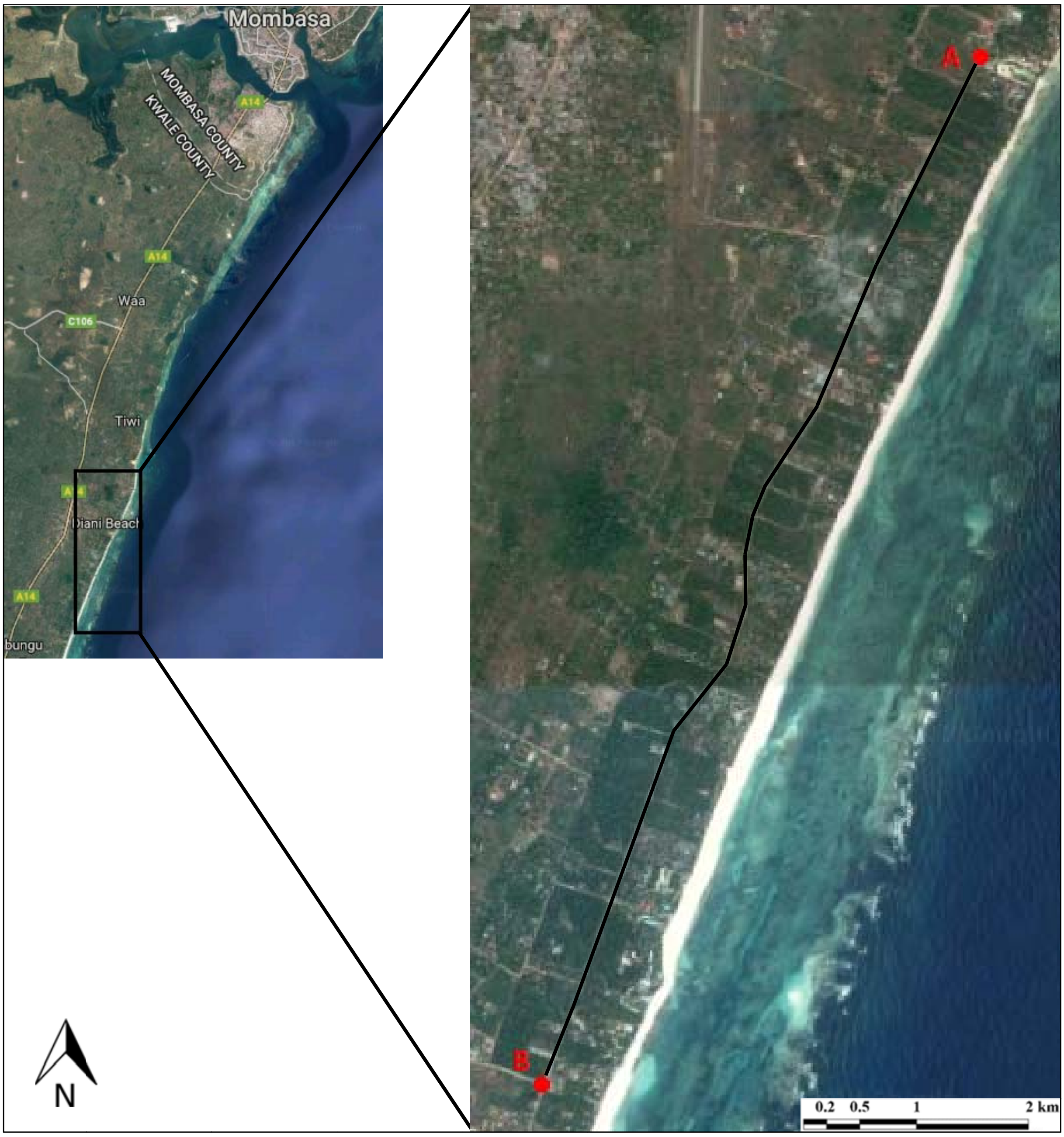

Figure 1. Diani Beach area, showing the study section of Diani Beach Road from Southern Palms Resort (A) to KFI Supermarket (B) (Digitalglobe, 2017).

Study Species

The Zanzibar Sykes' monkey (*C. m. albogularis*; hereafter Sykes), is found from southeastern Kenya into Tanzania and are a subspecies of the most common and widely distrusted forest guenon of eastern and southern Africa (Else, *et al.,* 1985; Kingdon, *et al.,* 2008b). They are medium sized primates, with adult males weighing approximately 7.6 kg and adult females 4.4 kg (Harvey, Martin & Clutton-Brock*,* 1987). They are semi-arboreal, diurnal and form single-male, multi-female troops, with a group size of 4 to 65 (Rowe, 1996; Coleman & Hill, 2014).

The Angola black-and-white colobus (*C. a. palliatus*; hereafter colobus), is one of six described sub-species of *C. angolensis* (Kingdon, *et al.,* 2008c), and has a range from the forests of Tanzania to southern Kenya (McDonald & Hamilton, 2010). They are also commonly known as Peters' Angola Colobus (Anderson, *et al.,* 2007) and belong to the family *Cercopithecidae* and the sub-family *Colobinae* (Fimbel, *et al.,* 2001). They are medium sized primates; males weigh approximately 8.9 kg and females 7.1 kg (Bocian & Anderson, 2013). They typically live in small social troops of a single adult male and several adult females – with group sizes ranging around 10 – 15 individuals (O'Dwyer, 2012). The Angola colobus is diurnal, highly arboreal and shows an energy-conservative lifestyle (Wijtten, *et al.,* 2012; Dunham & McGraw, 2014; Dunham, 2015).

The northern yellow baboon (*P. c. ibeanus*; hereafter baboon), is one of two subspecies of *P. cynocephalus*, and is found in southern Somalia and southeast and coastal Kenya (Kingdon, Butynski & De Jong*,* 2016). They are diurnal, terrestrial and live in multi-male, multi-female troops (Napier & Napier, 1985). They are the largest of the primates that inhabit the Diani area, with males weighing approximately 25 kg and females approximately 12 kg, and have an average group size of 28 (Rowe, 1996).

The Hilgert's vervet monkey (*C. p. hilgerti*; hereafter vervet) are widespread across eastern and southern Africa, ranging from Ethiopia and Southern Somalia, through eastern Africa, and south to South Africa (Kingdon, *et al.,* 2008a). Vervet monkeys live in multi-male, and multi-female groups, with a typical troop size less than 20 individuals (Willems & Russell, 2009a). They are diurnal, semi-terrestrial and are relatively small, with males weighing approximately 4 – 8 kg and females 3 – 5 kg (Willems, & Russell, 2009b).

The small-eared galago (*O. g. lasiotis*; hereafter galago) is found along the coastal regions of East Africa, ranging from the Ruvuma River in Tanzania to the Juba River area in Somalia (Nash, Bearder & Olson, 1989) and is one of four subspecies of *O. garnettii* (Butynski, Bearder & De Jong, 2008). They are the smallest of the primates recorded by Colobus Conservation, with males weighing approximately 820g and females approximately 720g (Rowe, 1996). Galago's are solitary, arboreal, nocturnal (Nowak, 1999; Bearder, *et al.,* 2003) and are described as promiscuous (Rowe, 1996).

Data collection

An emergency rescue team at Colobus Conservation is on hand, 24 hours a day, 7 days a week to respond and investigate any primate welfare cases reported by local community members to Colobus Conservation. Each case is subsequently logged and where possible, records of the date; species; weight; age; cause of incident; and case conclusion: dead/died/euthanised/released/not captured are recorded. The age of each individual is determined by species-specific weight measurements (Appendix, Table 1). Census data for all diurnal primates will be used.

Statistical Analysis

All RTAs recorded between 1998 and 2016 were collated into a spreadsheet for subsequent statistical analysis. All analysis was conducted through SPSS statistic software (IBM Corp, Version 24). Shapiro-Wilk tests of normality were conducted against the data to determine if parametric statistical requirements were met, and as it was found to be non-normally distributed, thus non-parametric statistical analyses were carried out.

Annual census data for the primate populations was made available by Colobus Conservation and was available for all diurnal species; colobus, Sykes, vervet and baboon from 2001, 2002, 2004 to 2006, and 2010 to 2016. No annual census data was available for galagos. Rainfall data was also available from Colobus Conservation.

RESULTS

Between January 1998 and December 2016, a total of 1916 welfare cases were recorded by Colobus Conservation. Of those, 658 cases were RTAs which represented 34% of the total number of cases reported to Colobus Conservation.

Species

The species involved most frequently in RTAs were Sykes, 54.5% (n = 358), respectively - colobus, 23.0% (n = 151); vervet, 14.0% (n = 92); baboon, 6.5% (n = 43) and galago 2.0% (n = 13). To determine the species-specific annual population percentage involvement in RTAs (off-take rates), annual census data for each population was used.

No significant differences in RTA off-take rates were observed between the species (Kruskal-Wallis: X^2 = 6.078, df = 3, P = 0.108). Annual colobus off-take fluctuated between 0.00% and 5.02%, with a median of 2.64% (IQR = 1.59 – 3.61); Sykes' between 2.23% and 6.60%, median of 3.32% (IQR = 2.13 – 4.59); vervet between 1.19% and 5.00%, with a median of 2.66% (IQR = 2.01 – 3.59) and baboon between 0.00% and 5.10%, with a median of 1.79% (IQR = 1.00 – 2.90). No census data was available for galago.

Age-class

Adults were involved in RTAs most frequently, 46.0% (n = 302), respectively – juvenile, 26.6% (n = 175); subadult, 19.3% (n = 127); infant 5.2% (n = 34) and 2.9% unknown age was observed (n = 19).

Analysis provided strong evidence that the species-combined RTA frequency showed significant differences across the age-classes (Kruskal-Wallis: X^2 = 54.724, df = 3, P = <0.000). Subsequent Bonferroni post hoc tests showed that adults were involved in RTAs significantly more than all other age classes (P = <0.000) and that infants were involved significantly less than all other age classes (P = <0.000).

Analysis on the RTA frequency across species-specific age-class provided strong evidence that there are significant differences between species-specific RTA involvement and age-class variation. Subsequent application of Bonferroni post hoc tests highlighted where the significance lies.

Significant differences were observed between colobus RTA frequency and the varying age-classes (Kruskal-Wallis: X^2 = 30.612, df = 3, P = <0.000; Fig. 2). Adults were involved in RTAs significantly more than all other age-classes; sub-adults (X^2 = 5.868, df = 1, P = 0.015), juveniles (X^2 = 14.031, df = 1, P = <0.000) and infants (X^2 = 22.302, df = 1, P = <0.000). Infants involved in RTAs were significantly lower than subadults (X^2 = 13.495, df = 1, P = <0.000).

Significant differences were seen to occur between Sykes RTA frequency and the different age-classes (Kruskal-Wallis: X^2 = 49.758, df = 3, P = <0.000; Fig. 2). Adults were involved in RTAs significantly more than all other age-classes; infants (X^2 = 27.967, df = 1, P = <0.000), sub-adults (X^2 = 20.550, df = 1, P = <0.005) and juveniles (X^2 = 11.148, df = 1, P = 0.001). Infants involved in RTAs were significantly lower than subadults (X^2 = 13.143, df = 1, P = <0.000) and juveniles (X^2 = 24.578, df = 1, P = <0.000).

Significant differences were observed between vervet RTA frequency and the differing age-classes (Kruskal-Wallis: X^2 = 21.794, df = 3, P = <0.000; Fig. 2). Adults were involved in RTAs significantly more than infants (X^2 = 15.474, *df* = 1, *P* = <0.000) and sub-adults (X^2 = 5.935, *df* = 1, *P* = 0.015). Infants involved in RTAs were significantly lower than juveniles (X^2 = 13.363, *df* = 1, *P* = <0.000).

Significant differences were seen between baboon RTA frequency and the different age-classes (Kruskal-Wallis: X^2 = 23.976, *df* = 3, *P* = <0.000; Fig. 2). Juveniles were involved in RTAs significantly more than all age-classes; infants (X^2 = 15.989, *df* = 1, *P* = <0.000), sub-adults (X^2 = 14.181, df = 1, P = <0.000) and adults (X^2 = 5.248, df = 1, P = 0.022). Infants involved in RTAs were significantly lower than juveniles (X^2 = 13.363, *df* = 1, *P* = <0.000).

Significant differences were also seen to occur between galago RTA frequency and age-class variation (Kruskal-Wallis: X^2 = 13.195, *df* = 3, *P* = 0.004; Fig. 2). Adults RTA frequency was significantly higher than infants and juveniles (X^2 = 6.892, *df* = 1, *P* = 0.009). No infant or juvenile galago RTAs were recorded.

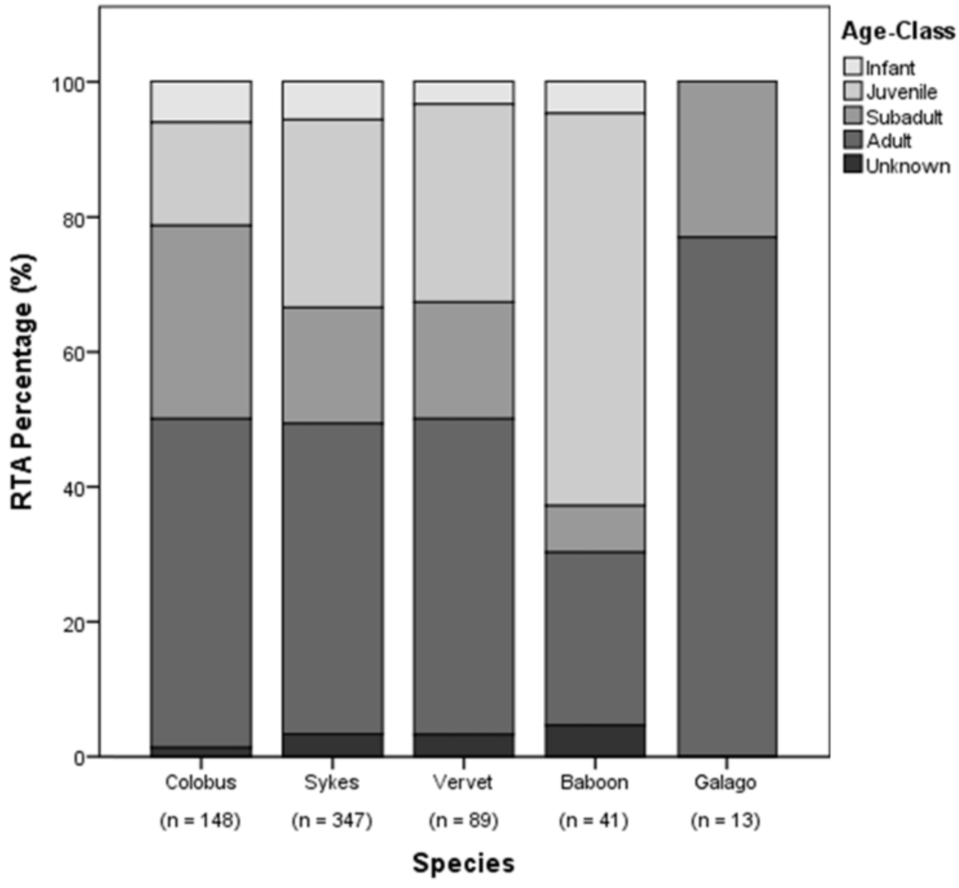

Figure 2. Species-specific age-class RTA frequency percentages.

Sex

Females were involved in RTAs slightly more frequently; 45.7% (n = 300), than males; 44.3% (n = 291) (Table 1). Unknown sex accounted for 9.9% (n = 65) and hermaphrodite for 0.2% (n = 1).

No significant differences were observed between male and female annual RTA involvement for species-combined (Kruskal-Wallis: X^2 = 0.156, df = 1, P = 0.693), colobus (Kruskal-Wallis: X^2 = 0.042, df = 1, P = 0.837), Sykes (Kruskal-Wallis: X^2 = 1.562, df = 1, P = 0.211), vervet (Kruskal-Wallis: X^2 = 2.989, df = 1, P = 0.084), baboon (Kruskal-Wallis: X^2 = 0.503, df = 1, P = 0.478) and galago (Kruskal-Wallis: X^2 = 0.771, df = 1, P = 0.380).

Table 1. Summary of the total number of male and female individuals involved in RTAs.

	Male	**Female**
Colobus	68	73
Sykes	145	178
Vervet	51	31
Baboon	23	16
Galago	4	2

Sex and Age-class

For all species combined, a significant association between sex and age-class was seen (Two-way Chi-square Classification: X^2 = 12.383, N = 585, df = 3, p = 0.006; Fig. 3). A post hoc standardised residual analysis was carried out to identify the cases that were significantly different from that of the expected, if the null hypothesis were true (> 1.96), thus contributing to the significant result. Standardised residuals were transformed, and exact P-values were determined and subsequently compared to the Bonferroni adjusted *P*-value of 0.0062. Both male and female adults have significantly greater RTA risk, whilst infants show the lowest potential RTA risk (Table 2).

Table 2. Statistical significance of the association between species-combined sex and age-class variation. Summary of the chi-square values and adjusted P-values.

	Male		**Female**	
	Chi-Square Values	*Adjusted P-values*	*Chi-Square Values*	*Adjusted P-values*
Infant	1.46	0.2263	1.46	0.2263
Juvenile	2.40	0.1211	2.40	0.1211
Subadult	6.30	0.0121	6.30	0.0121
Adult	8.07	0.0045*	8.07	0.0045*

**P values less than the Bonferroni adjusted P value of 0.0062.*

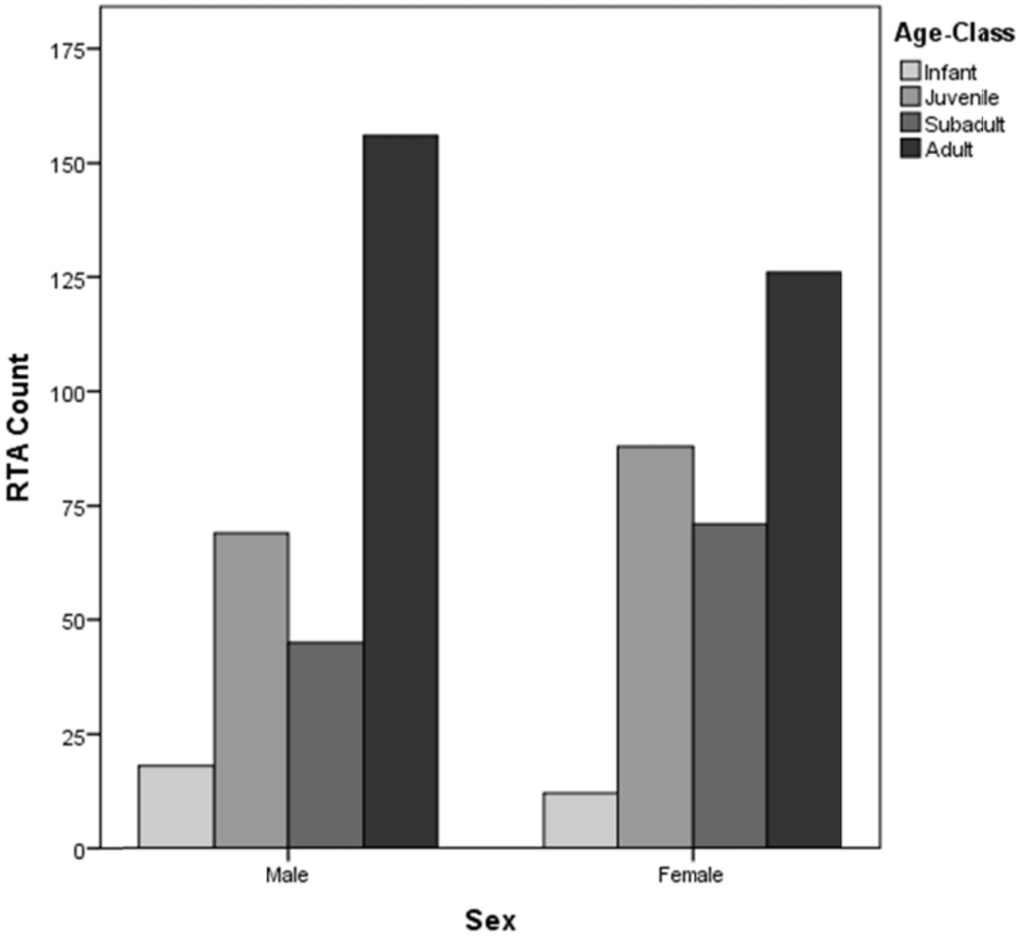

Figure 3. Species-combined RTA count for combined sex and age-class.

Weight

The weights available for species-combined (*N* = 372) were grouped into fourteen categories (Appendix, Table 2) and subsequent analysis was carried out. No significant difference was observed between the species-combined RTA frequency and weight categories (Kruskal-Wallis: X^2 = 21.596, *df* = 13, *P* = 0.062). However, an indication that RTA risk is greatest between 4.0 – 4.9 kg, and subsequently reduces above 6.9 kg can be made from Figure 4.

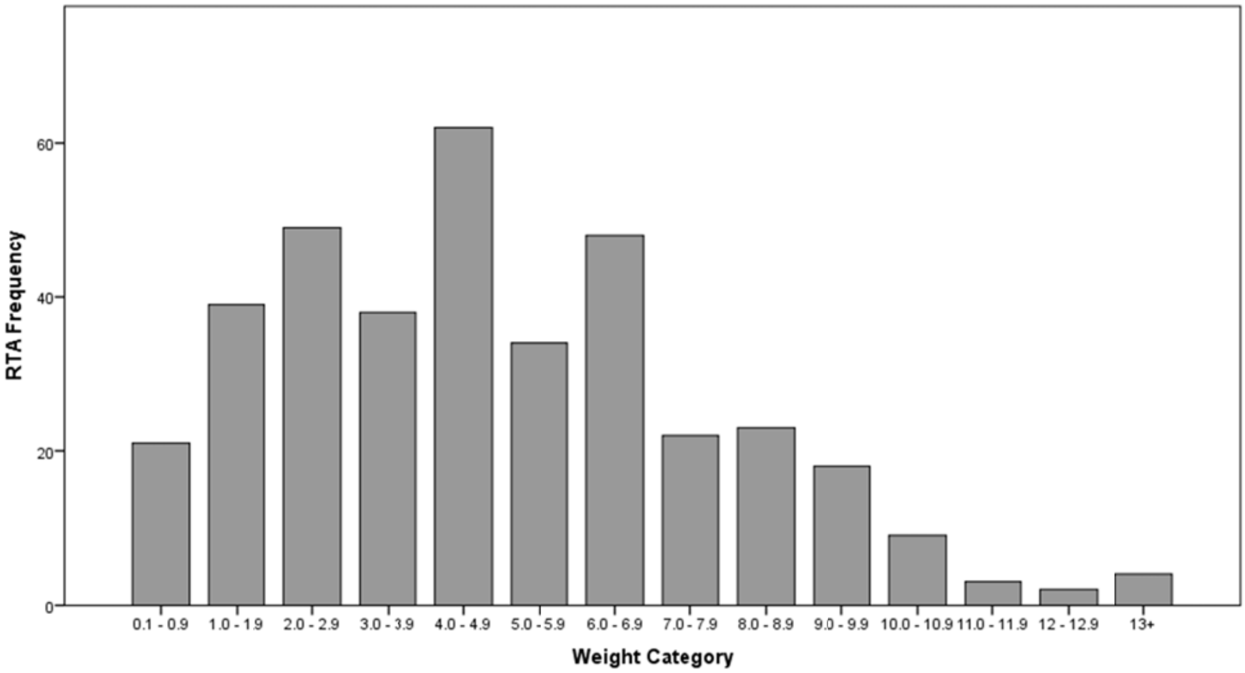

Figure 4. Species-combined RTA frequency across fourteen weight categories.

Seasonal Variation

RTAs occurred most prominently during the long dry season, season 1 (39.7%, *n* = 261) and the short dry season, season 3 (23.9%, *n* = 157), compared to the long rainy season, season 2 (19.0%, *n* = 125) and the short rainy season, season 4 (17.4%, *n* = 114).

RTA frequencies were weighed against the associated number of months in each season to allowed for subsequent seasonal comparison.

A univariate general linear model analysis on the average RTA frequency provided strong evidence that there was a significant difference in species-combined RTA frequency and the four seasons ($F_{3,72}$ = 7.474, n_1 = 19, n_2 = 19, n_3 = 19, n_4 = 19, P = <0.000; Fig. 5). Parameter estimates suggest that RTA frequency is significantly less during the longer rainy season, season 2 (P = 0.032), compared to the other seasons. The longer rainy season showed the lowest median annual RTA frequency; 2, *IQR* = 1.64 – 2.78, and the long dry season showed the highest; 3.25, *IQR* = 2.79 – 4.08 (Fig. 5).

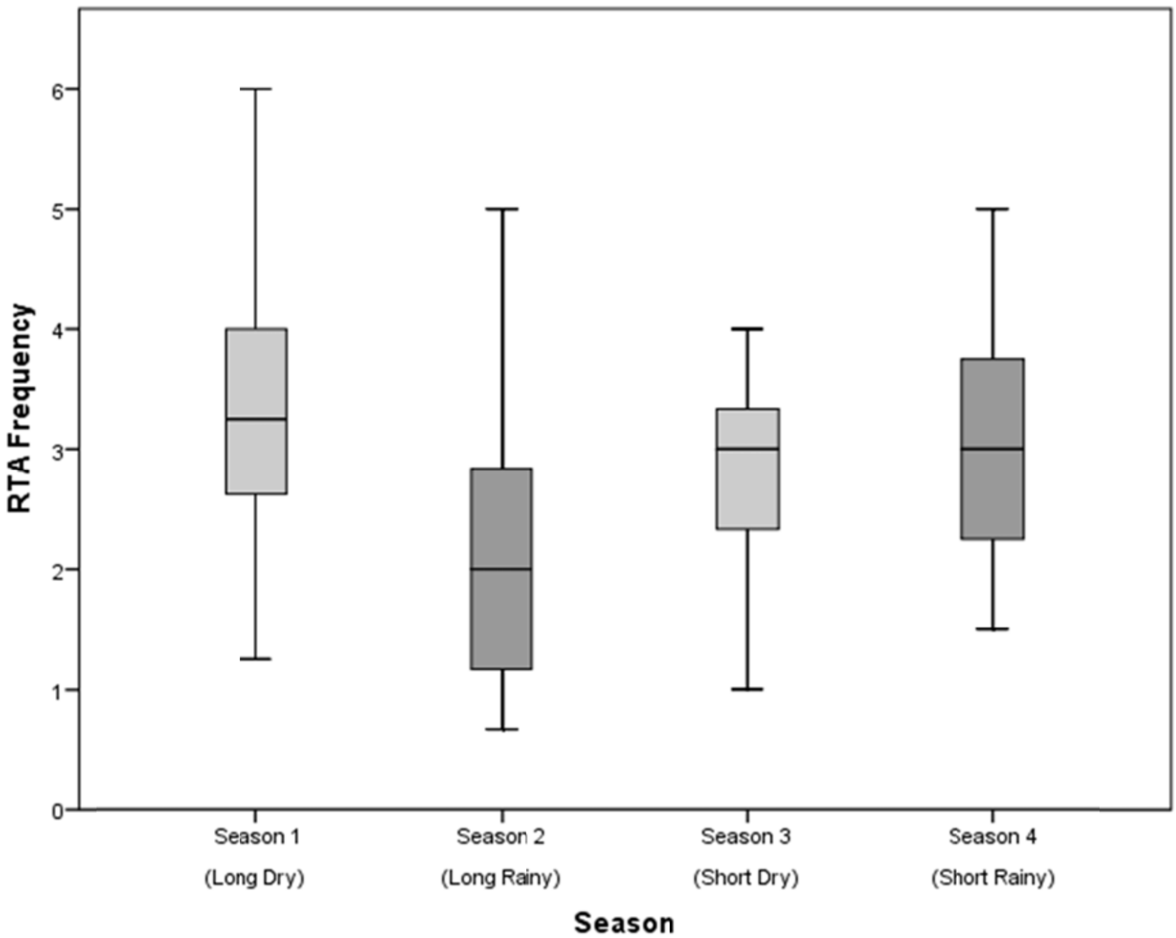

Figure 5. Annual RTA frequency of species-combined across the four seasons; Season 1 (median = 3.25, *IQR* = 2.79 – 4.08); Season 2 (median = 2.00, *IQR* = 1.64 – 2.78); Season 3 (median = 3.00, *IQR* = 2.35 – 3.13); Season 4 (median = 3.00, *IQR* = 2.50 – 3.50).

Univariate general linear model analysis for species-specific RTA frequency and seasonal variation showed varying significance.

Significant differences occur between colobus involved RTA frequency and seasonal variation (F = 7.478, df = 3, P = <0.000; Fig. 6). Parameter estimates suggest that colobus RTA frequency is significantly higher during the longer dry season, season 1, (P = 0.019), and significantly lower during the longer rainy season, season 2 (P = 0.022), compared to the other seasons. Significant differences occur between Sykes RTA frequency and seasonal variation (F = 3.907, df = 3, P = 0.012; Fig. 6). Parameter estimates suggest that Sykes RTA frequency is significantly lower during the short dry season, season 3, (P = 0.018). Significant differences occur between vervet RTA frequency and seasonal variation (F = 4.484, df = 3, P = 0.006; Fig. 6). Parameter estimates suggest that vervet RTA frequency is significantly higher during the short dry season, season 3, (P = 0.018). No significant difference is observed between baboon or galago RTA frequency and seasonal variation.

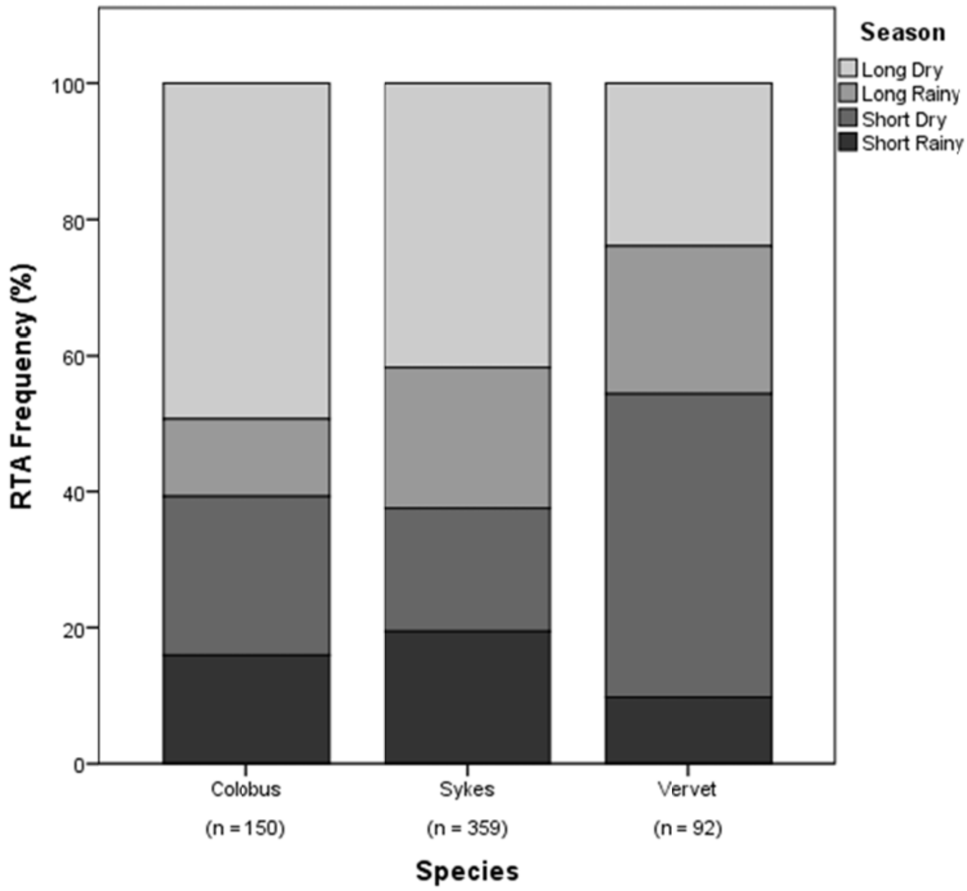

Figure 6. Significant species-specific age-class RTA frequency percentages across the four seasons.

Day of Week

Kruskal-Wallis analysis showed that there was no significant difference between the days of week and species-combined RTA frequency (X^2 = 5.445, *df* = 6, *P* = 0.488).

Rainfall

A linear regression model showed that there was no significant relationship between annual mean rainfall and annual species-combined mean RTA frequency ($y = 0.006\ x + 34.022$, $F = 0.006$, P = 0.937, R^2 = 0.000).

Mortality Rate and Survivorship

Case conclusions of the species-combined RTA cases showed low survival rates, as only 6.7% of individuals were treated and released from the Colobus Conservation veterinary clinic. Mortality occurred in 85.9% of cases, while 7.3% were not captured or found to be present on arrival at the reported incident site. For those that incurred mortality (*n* = 562), 79.9% were discovered dead or died on arrival at the veterinary clinic, 9.8% died during treatment, and 10.3% were euthanised. Species-specific case conclusions can be found in Table 3.

Table 3. Case conclusion percentage rates for colobus, Sykes, vervet, baboon and galago.

	Colobus (*n* = 150)	Sykes (*n* = 356)	Vervet (*n* = 92)	Baboon (*n* = 43)	Galago (*n* = 13)
Survivorship Rates	6.7%	7.0%	10.9%	2.3%	0.0%
Mortality Rates	81.3% (83.6% dead*; 8.2% died**; 8.2% euthanised)	89.0% (80.8% dead* 9.1% died** 10.1% euthanised)	89.0% (80.8% dead* 9.1% died** 10.1% euthanised)	79.3% (72.6% dead* 11.0% died** 16.4% euthanised)	92.3% (58.3% dead* 33.3% died** 8.3% euthanised)
Not Captured or found	14.0%	3.7%	9.8%	9.3%	7.7%

**Dead - were discovered dead or died on arrival at the veterinary clinic*

***Died – died during treatment*

DISCUSSION

This study examined the factors that were found to increase the RTA risk for primates on a 10-kilometre section of Diani Beach road, Kenya.

Species

Sykes showed the highest RTA-offtake rate, subsequently followed by vervets, colobus then baboons. The species-specific RTA-offtake rates observed seem to be a reflection on how often the species are crossing the road. Though in the case of baboons the reflection does not appear to hold true as in the work of Jacobs (2015), the road crossing rates of these species were recorded, and it was shown that baboons showed the highest road crossing rates, followed by Sykes, vervet then colobus. Baboons showed the lowest RTA-offtake rate, yet it would be expected that baboons showed higher offtake due to their terrestrial nature, high road crossing rate and frequent presence on roads as they typically utilise the tarmac for travelling long distances and foraging on roadside vegetation (Drews, 1995). However, it can be suggested that the offtake for baboons is relatively low due to their frequent road use, which has led to baboons developing a clever nature to avoid moving vehicles (*pers. comm.* Pamela Cunneyworth). Often individuals are only involved in RTAs as drivers are known to deliberately target baboons, as some perceive them as vermin and pests due to their raiding behaviour (Drews, 1995; Healy & Nijman, 2014). It can be suggested that the RTA-offtake for Sykes and vervets is greatest due to their generalist and omnivorous diet which would encourage more frequent road crossing between the forest and the human-dominated landscape (Jacobs, 2015). In comparison, colobus whose arboreal and energy-conservative nature (Wijtten, *et al.,* 2012) would restrict their range and dispersion, consequently reducing road crossing rates, thus likelihood of being involved in RTAs. Sykes are more arboreal than vervets (De Jong & Butynski, 2010), suggesting that vervets would spend more time on the ground, thus are at a higher risk of RTAs. However, due to Diani's anthropogenic threats, including dog and human predation (*pers. comm.* Pamela Cunneyworth), the vervets of Diani are believed to spend more time in the canopy than vervet populations in other areas.

Age-Class

It was observed that for species-combined, adults of both sexes showed the greatest RTA involvement, whilst infants were the least involved (Fig. 3). Across the majority of species, it was also seen that adults showed the highest involvement in RTAs, with the exception of baboons; where juveniles showed the highest involvement, and infants showed the least involvement across all species (Fig. 2). The presence of low infant mortality compared to other age-classes is likely due to parental infant carrying, which may lead to the carrying parents' body providing protection from the impact of the vehicle, leading to infant survival. The infant mortality rate may have been further reduced as there were no reported galago infant RTA cases, this is likely due to the parenting behaviour of galagos, who are known to "park" infants within or near nests whilst foraging (Wright, 1990; Rowe, 1996; Ross, 2001). The increased juvenile baboon RTA involvement is likely to be explained by the inquisitive and playful behaviour seen in juveniles in comparison to adults (Jones, 2004), together with the fact that they will be following conspecifics that use the tarmac as a natural route, in comparison to the other species who tend to avoid the tarmac. This was similarly seen by Drews (1995), who also recorded the juvenile age-class to show the largest proportion involvement in RTAs for baboons. The play behaviour observed in juveniles may have also increased the risk for Sykes and vervet juveniles as they were significantly higher than infants. Adults are seen to show the primary involvement in RTAs due to them representing the largest proportion of the population, whilst also being the age-class that shows the most active of dispersion behaviours, such as foraging, which leads to an increased likelihood of exposure to roads.

Sex

A significant difference in RTA frequency was not observed between the sexes for any species. However, in the galago species, double the number of males were involved in RTAs than females (Table 2), providing an indication that males are at a higher risk of RTAs than females. This may be due to the solitary nature of galagos, and the associated variation in ranging patterns and home range size. Males have been recorded to disperse further from their natal region and show a greater home range size; 17.9 ha, than females; 11.6 ha (Rowe, 1996). Males are also known to travel further per night (approximately 3 km), in comparison to females (approximately 1.8 km) (Nash & Harcourt, 1986). The larger ranges and increased travel distance observed in male galagos, suggests a likely reason for higher male RTA risk than females.

Weight

A distinct difference in RTA frequency can be observed across the age categories, with the most pronounced category being 3.0 – 3.9 kg and a reduction in RTA frequency is seen above 6.9kg (Fig. 4). However, this is likely to be a reflection of the population age-class structure, with 3.0 – 3.9 kg encompassing Sykes adults; which account for a predominate proportion of the population, alongside vervet adults and baboon juveniles. Whilst, over 6.9 kg encompasses juvenile, subadult and adult baboons, and subadult and adult colobus (Appendix, Table 2), which account for significantly less individuals. Weight is also unlikely to be a factor in regard to influencing RTA involvement as roads are known to negatively affect a wide range of species, with varying weights, from small invertebrates to large vertebrates such as moose and brown bears (Carvalho & Mira, 2011).

Season

Collectively the primate species showed the greatest involvement in RTAs during the long dry season, with the least RTA risk during the long rainy season (Fig. 5). For individual species; colobus, Sykes and vervets showed greatest RTA risk during the dry seasons and lowest involvement in RTAs during rainy seasons (Fig. 6). Baboons and galagos RTA frequency showed little seasonal variation.

The difference observed between the dry and rainy seasons coincides with the associated variation in resource availability and quality, subsequently leading to primate behavioural and dietary change. During the dry season, primates are seen to shift to foods that show low profitability, yet are abundant; these are known as “fallback foods” (Marshall & Wrangham, 2007), these foods consequently increase the time spent foraging due to their poor nutritional quality relative to that of the rainy season (Lowe & Sturrock, 1998; Alberts, *et al.,* 2005; O’Dwyer, 2012). The scarcity of water during the dry season is also seen to increase the time spent foraging, both of which are likely to have led to an increased exposure to Diani road and thus subsequently increasing susceptibility to RTA risk.

Survivorship and Mortality

Galagos show the lowest rate of survivorship across all of the species, with no recorded survival (Table 3). This is likely explained by their nocturnal behaviour, which increases the length of time between the RTA and associated treatments at the Colobus Conservation clinic – consequently reducing the likelihood of survival due to delayed treatment. Galagos are also the least likely of the species to show survival due to their small size, and heightened impact severity in comparison to the other, larger primates of Diani. Baboons are also seen to show low survival rates in comparison to the other diurnal primate species, this may be attributed to their "pest" status which could reduce the likelihood of community members reporting the case to Colobus Conservation due to baboons being a less favourable species.

CONCLUSIONS & RECOMMENDATIONS

This study has highlighted the mortality risks from RTAs, which is faced by primate populations on a section of Diani Beach Road, Kenya. It has provided a valuable insight into the temporal and spatial factors that are most influencing the susceptibility of Diani primates to RTAs. A limitation of this study was the inability to determine the true effects of roads on the nocturnal galago species due to the lack of population census data.

As this area of Kenya continues to grow economically and its level of tourism rises, inevitably, the dangers faced by road crossing primates will continue to persist, as the number of people using the road and the demand for faster and more efficient transport links rises. This increasing human development will unavoidably exert pressures on the natural ecosystem of Diani. However, measures to help ameliorate these pressures can be implemented to help reduce the affect upon the primates. Current approaches by Colobus Conservation to protect and conserve the primates along Diani Beach road, include; Colobridges, speed limitations, speed bumps, education and signage. However, the appropriate locations and true effectiveness of these measures has yet to be scientifically determined. Thus, further studies, including spatial distribution analysis and galago population census data, are needed to help identify the most effective ways and areas for placement of future approaches.

ACKNOWLEDGEMENTS

Firstly, I would like to give special thanks to Pamela Cunneyworth of Colobus Conservation for sharing her knowledge and expertise, in the area of primate conservation. I am extremely grateful to Andrea Donaldson and the Colobus Trust for allowing me access to their road traffic accident data set which has allowed this research project to be undertaken. Thank you to Dr Andrew Smith of Anglia Ruskin University for his advice during the writing of the manuscript. I would like to give a huge thanks to all the staff and volunteers of Colobus Conservation for the amazing work they do with these very special animals.

REFERENCES

Alberts, S.C., Hollister-Smith, J.A., Mututua, R.S., Sayialel, S.N., Muruthi, P.M., Warutere, J.K., and Altman, J., 2005. Seasonality and long-term change in a savanna environment. In: *Seasonality in primates: Studies of living and extinct human and non-human primates*. Brockman, D.K., and Schaik, C.P., 2005. Cambridge: Cambridge University Press.

Ament, R., Clevenger, A.P., Yu, O., and Hardy, A., 2008. An assessment of road impacts on wildlife populations in U.S., National Parks. *Environmental Management,* **42**(3), pp. 480-496.

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

Bearder, S.K., Ambrose, L., Harcourt, C., Honess, P., Perkin, A., Pimley, E., Pullen, S., and Svoboda, N., 2003. Species-typical patterns of infant contact, sleeping site use and social cohesion among nocturnal primates in Africa. *Folia Primatologica*, **74**(5), pp. 337-354.

Beyer, H.L., Gurarie, E., Börger, l., Panzacchi, M., Basille, M., Herfindal, I., Moorter, B.V., Lele, S.R., and Matthiopoulos, J., 2016. 'You shall not pass!': quantifying barrier permeability and proximity avoidance by animals. *Journal of Animal Ecology*, **85**(1), pp. 43-53.

Bissonette, J., 2002. Scaling roads and wildlife: the Cinderella principle. *Zeitschrift für Jagdwissenschaft*, **48**, pp. 208–214.

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

Bujoczek, M., Ciach, M., and Yosef, R., 2011. Road-kills affect avian population quality. *Biological Conservation*, **144**(3), pp. 1036-1039.

Butynski, T.M., Bearder, S., and De Jong, Y., 2008. *Otolemur garnettii. The IUCN Red List of Threatened Species 2008*. Available at: <http://www.iucnredlist.org/details/15644/0> [Accessed 27 February 2017].

Carvalho, F., and Mira, A., 2011. Comparing annual vertebrate road kills over two time periods, 9 years apart: a case study in Mediterranean farmland. *European Journal of Wildlife Research,* **57**(1), pp. 157-174.

Coleman, B.T., and Hill, R.A., 2014. Biogeographic variation in the diet and behaviour of *Cercopithecus mitis*. *Folia Primatologica*, **85**(5), pp. 319-334.

Collinson, W.J., Parker, D.M., Bernard, R.T., Reilly, B.K., and Mostert, H.T., 2014. Wildlife road traffic accidents: a standardized protocol for counting flattened fauna. *Ecology and Evolution,* **4**(15), pp. 3060-3071.

De Jong, Y.A., and Butynski, T.M., 2010. Three Sykes's monkey *Cercopithecus mitis* x vervet monkey *Chlorocebus pygerythrus* hybrids in Kenya. *Primate Conservation*, **25**, pp. 43-56.

Donaldson, A., and Cunneyworth, P., 2015. Canopy Bridges for Primate Conservation. In: *Handbook of Road Ecology.* Ree, R.V., Smith, D.J., and Grilo, C., 2015. Chichester: John Wiley & Sons, Ltd.

Drews, C., 1995. Road kills of animals by public traffic in Mikumi National Park, Tanzania, with notes on baboon mortality. *African Journal of Ecology*, **33**(2), pp. 89–100.

Dunham, N., 2015. Ontogeny of positional behavior and support use among *Colobus angolensis palliatus* of the Diani Forest, Kenya. *Primates*, **56**(2), pp. 183-192.

Dunham, N.T., and McGraw, W.S., 2014. Positional behavior 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**, pp. 1-14.

Else, J.G., Eley, R.E., Suleman, M.A., and Lequin, R.M., 1985. Reproductive biology of Sykes and blue monkeys. *American Journal of Primatology*, **9**(3), pp. 189-196.

Estrada, A., Garber, P.A., Rylands, A.B., Roos, C., Fernandez-Duque, E., Di Fiore, A., Nekaris, A.I., Nijman, V., Heymann, E.W., Lambert, J.E., Rovero, F., Barelli, C., Setchell, J.M., Gillespie, T.R., Mittermeier, R.A., Arregoitia, L.V., Guinea, M., Gouveia, S., Dobrovolski, R., Shanee, S., Shanee, N., Boyle, S.A., Fuentes, A., MacKinnon, K.C., Amato, K.R., Meyer, A.L., Wich, S., Sussman, R.W., Pan, R., Kone, I., and Li, B., 2017. Impending extinction crisis of the world's primates: Why primates matter. *Science Advances,* **3**(1), e. 1600946.

Fahrig, L., and Rytwinski, T., 2009. Effects of roads on animal abundance: an empirical review and synthesis. *Ecology and Society*, **14**(1), pp. 1-20.

Fimbel, C., Vedder, A., Dierenfeld, E., and Mulindahabi, F., 2001. An ecological basis for large group size in *Colobus angolensis* in the Nyungwe Forest, Rwanda. *African Journal of Ecology*, **39**(1), pp. 83-92.

Forman, R.T., and Alexander, L.E., 1998. Roads and their major ecological effects. *Annual Review of Ecology and Systematics*, **29**, pp. 207–231.

Glista, D.J., Devault, T.L., and DeWoody, J.A., 2009. A review of mitigation measures for reducing wildlife mortality on roadways. *Landscape and Urban Planning*, **81**, pp. 1-7

Digitalglobe, 2017. *Diani Beach Road*, Scale undetermined. Google Maps. Available at: <https://www.google.co.uk/maps/@-4.3234123,39.5640928,10160m/data=!3m1!1e3> [Accessed 24 April 2017].

Goosem, M., 2007. Fragmentation impacts caused by roads through rainforests. *Current Science*, **93**(11), pp. 1587-1595.

Harvey, P.H., Martin, R.D., and Clutton-Brock, T.H., 1987. Life histories in comparative perspective. In: *Primate Societies.* Smuts, B.B., Dorothy, L., Seyfarth, R.M., and Struhsaker, T.T., 1987. Chicago: University of Chicago Press.

Healy, A., Nijman, V., 2014. Pets and pests: vervet monkey intake at a specialist South African rehabilitation centre. *Animal Welfare*, **23**(3), pp. 353-360.

IBM Corp. Released 2016. IBM SPSS Statistics for Windows, Version 24.0. Armonk, NY: IBM Corp.

Jacobs, A., 2015. *Factors affecting the prevalence of road and canopy bridge crossing by primates in Diani Beach, Kenya*. M. Sc. The University of Kent.

Jones, M.A., 2004. *Social foraging in captive baboons: implications for enrichment*. M. Sc. University of the Witwatersrand.

Kingdon, J., Butynski, T.M. and De Jong, Y. 2016. *Papio cynocephalus*. *The IUCN Red List of Threatened Species 2016.* Available at: <http://www.iucnredlist.org/details/92250442/0> [Accessed 25 February 2017].

Kingdon, J., Gippoliti, S., Butynski, T.M. and De Jong, Y. 2008a. *Chlorocebus pygerythrus*. *The IUCN Red List of Threatened Species 2008.* Available at: <http://www.iucnredlist.org/details/136271/0> [Accessed 25 February 2017].

Kingdon, J., Gippoliti, S., Butynski, T.M., Lawes, M.J., Eeley, H., Lehn, C., and De Jong, Y., 2008b. *Cercopithecus mitis*. *The IUCN Red List of Threatened Species 2008.* Available at: <http://www.iucnredlist.org/details/4221/0> [Accessed 24 February 2017].

Kingdon, J., Struhsaker, T., Oates, J.F., Hart, J., Butynski, T.M., De Jong, Y., and Groves, C.P., 2008c. *Colobus angolensis*. *The IUCN Red List of Threatened Species 2008*. Available at: <http://www.iucnredlist.org/details/5142/0> [Accessed 24 February 2017].

Laurance, S.G., Stouffer, P.C., and Laurance, W.F., 2004. Effects of road clearings on movement patterns of understory rainforest birds in Central Amazonia. *Conservation Biology*, **18**(4), pp. 1099-1109.

Laurance, W.F., Clements, G.R., Sloan, S., O'Connell, C.S., Mueller, N.D., Goosem, M., Venter, O., Edwards, D.P., Phalan, B., Balmford, A., Van Der Ree, R., and Arrea, I.B., 2014. A global strategy for road building. *Nature*, **514**(7521), pp. 229–232.

Laurance, W.F., Goosem, M., and Laurance, S.G., 2009. Impacts of roads and linear clearings on tropical forests. *Trends in Ecology & Evolution*, **24**(12), pp. 659-669.

Lowe, A.J., and Sturrock, G.A., 1998. Behaviour and diet of *Colobus angolensis palliatus* Peters, 1868, in relation to seasonality in Tanzanian dry coastal forest. *Folia Primatology*, **69**, pp. 121-128.

Marshall, A.J., and Wrangham, R.W., 2007. Evolutionary consequences of fallback foods. *International Journal of Primatology,* **28**, pp. 1219-1235.

Mazumder, M.K., 2014. Diversity, habitat preferences, and conservation of the primates of Southern Assam, India: The story of a primate paradise. *Journal of Asia-Pacific Biodiversity*, **7**(4), pp. 347-354.

McDonald, M.M., and Hamilton, H., 2010. Phylogeography of the Angolan black and white colobus monkey, *Colobus angolesnsis palliatus*, in Kenya and Tanzania. *American Journal of Primatology*, **72**(8), pp. 715-724.

McLennan, M.R., and Asiimwe, C., 2016. Cars kill chimpanzees: case report of a wild chimpanzee killed on a road at Bulindi, Uganda. *Primates*, **57**(3), pp. 377–388.

Metcalfe, K., Ffrench-constant, R., and Gordon, I., 2010. Sacred sites as hotspots for biodiversity: the Three Sisters Cave complex in coastal Kenya. *Oryx*, **44**(1), pp. 118-123.

Myers, N., Mittermeier, R.A., Mittermeier, C.G., Gustavo, A.B., Fonseca, G.A., and Kent, J., 2000. Biodiversity hotspots for conservation priorities. *Nature*, **403**(6772), pp. 853-858.

Napier, J.R., and Napier, P.H., 1985. *The natural history of the primates*. Wallingford: Gem Publishing Company (Oxon) Ltd.

Nash, L.T., and Harcourt, C.S., 1986. Social organization of Galagos in Kenyan coastal forests: II. *Galago garnettii. American Journal of Primatology*, **10**(4), pp. 357-369.

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

Nowak, R.M., 1999. *Walker's mammals of the world.* Baltimore: Johns Hopkins University Press.

O'Dwyer, R., 2012. *The black-and-white-colobus monkey (Colobus angolensis palliatus) of Diani Forest, Kenya: behavioural responses to habitat fragmentation*. M. Sc., Swedish University of Agricultural Sciences.

Ogden, L.E., 2012. Road Ecology: Reconnecting a Fragmented Landscape. *BioScience*, **62**(1), p. 100.

Okanga, S., Muchemi, G., Malngi, N., Mogoa, E., and Munene, E., 2006. Gastrointestinal parasites of free-ranging colobus monkeys (*Colobus angolensis palliatus*) in Kwale District, Kenya coast. *African Journal of Ecology*, **44**, pp. 410-412.

Polak, T., Rhodes, J.R., Jonathan, R., Jones, D., and Possingham, H.P., 2014. Optimal planning for mitigating the impacts of roads on wildlife. *Journal of Applied Ecology*, **51**(3), pp. 726–734.

Ree, R., Jaeger, J.A., Grift, E.A., and Clevenger, A.P., 2011. Effects of roads and traffic on wildlife populations and landscape function: Road ecology is moving towards larger scales. *Ecology and Society*, **16**(1), p. 48.

Ree, R.V., Gulle, N., Holland, K., Grift, E.V.D., Mata, C., and Suarez, F., 2007. Overcoming the barrier effect of roads - How effective are mitigation strategies? *Center for Transportation and the Environment*, North Carolina State University, pp. 423-431.

Reed, D.H., 2004. Extinction risk in fragmented habitats. *Animal Conservation,* **7**, pp. 181-191.

Ross, C., 2001. Park or ride? Evolution of infant carrying in primates. *International Journal of Primatology*¸**22**(5), pp. 749-771.

Rowe, N., 1996. *The pictorial guide to the living primates*. New York: Pogonias Press.

Seiler, A., Helldin, J.O., and Seiler, C., 2004. Road mortality in Swedish mammals: results of a drivers' questionnaire. *Wildlife Biology*, **10**(3), pp. 183-191.

Struhsaker, T.T., and Siex, K.S., 1996. The Zanzibar red colobus monkey, Procolobus kirkii: conservation status of an endangered island endemic. *African Primates*, **2**(2), pp. 54-61.

Sutherland, R.W., Dunning, P.R., and Baker, W.M., 2010. Amphibian encounter rates on roads with different amounts of traffic and urbanization. *Conservation Biology*, **24**(6), pp. 1626-1635.

Trombulak, S.C., and Frissell, C.A., 2000. Society for Conservation Biology Review of ecological effects of roads on terrestrial and aquatic. *Conservation Biology*, **14**(1), pp. 18–30.

Wang, Y., Piao, Z.J., Guan, L., Wang, X.Y., Kong, Y.P., and Chen, J., 2013. Road mortalities of vertebrate species on Ring Changbai Mountain Scenic Highway, Jilin Province, China. *North-Western Journal of Zoology,* **9**(2), pp. 399–409.

Ward, A.I., Dendy, J., and Cowan, D.P., 2015. Mitigating impacts of roads on wildlife: an agenda for the conservation of priority European protected species in Great Britain. *European Journal of Wildlife Research,* **61**(2), pp. 199-121.

Wijtten, Z., Hankinson, E., Pellissier, T., Nuttall, M., and Lemarkat, R., 2012. Activity budgets of Peters' Angola black-and-white colobus (*Colobus angolensis palliatus*) in an East African coastal forest. *African Primates*, **7**(2), pp. 203-210.

Willems, E.P., and Hill, R.A., 2009a. Predator-specific landscapes of fear and resource distribution: effects on spatial range use. *Ecology*, **90**(2), pp. 546-555.

Willems, E.P., and Hill, R.A., 2009b. A critical assessment of two species distribution models: a case study of the vervet monkey (*Cercopithecus aethiops*). *Journal of Biogeography*, **36**(12), pp. 2300-2312.

Wright, P.C., 1990. Patterns of paternal care in primates. *International Journal of Primatology*, **11**(2), pp. 89-102.

APPENDIX

Table 1. Age-Class Standardization (kg).

Species	Infant	Juvenile	Subadult male	Subadult female	Adult male	Adult female
Lesser galago	-	-	-	-	> 0.135	> 0.125
Greater galago	< 0.2	0.21 - 0.39	0.4 - 0.69	0.4 - 0.69	> 0.7	> 0.7
Colobus	0 - 1.9	2.0 - 4.9	5.0 - 7.9	5.0 - 7.9	> 8.0	> 8.0
Sykes	0 - 0.9	1.0 - 2.9	3.0 - 3.9	3.0 - 3.9	> 4.0	> 4.0
Vervet	0 - 0.9	1.0 - 1.9	2.0 - 2.9	2.0 - 2.9	> 3.0	> 3.0
Baboon	1 - 3.0	3.0 - 8.9	9.0 - 19.9	9.0 - 15.9	> 20.0	> 16.0

Table 2. Weight categories used for statistical analysis.

Category	Weight (kg)
1	0.1 – 0.9
2	1.0 – 1.9
3	2.0 – 2.9
4	3.0 – 3.9
5	4.0 – 4.9
6	5.0 – 5.9
7	6.0 – 6.9
8	7.0 – 7.9
9	8.0 – 8.9
10	9.0 – 9.9
11	10.0 – 10.9
12	11.0 – 11.9
13	12.0 – 12.9
14	13.0 +