Hannah Puleston, Pembroke College, University of Oxford

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Summary of the internship

I would like to thank the Smithsonian UK Charitable Trust for kindly sponsoring this internship for two months. It was an experience of a lifetime and without their generous funding I would not have been able to work and live in Kenya for two months, carrying out my own research project and gaining extremely valuable research experience. This internship has allowed me to explore a country and ecosystem I had never been to before, and I am now considering working in similar ecosystems in the future, after leaving university. I am incredibly grateful to the Smithsonian UK Charitable Trust for creating and funding this internship.

In the summer of 2018, Ingrid Easton (my fellow Smithsonian and Pembroke College intern) and I embarked on our trip to Mpala Research Centre in Laikipia County, Kenya. This was the first time I had been to Kenya and even the continent of Africa itself, therefore everything was new and exciting. Arriving at the research centre was a welcoming experience, after several hours of travel. The centre itself surpassed expectations – it had excellent facilities (such as a gym!) and the staff, researchers and other students were very friendly and helpful. The food was also extremely good (even for vegetarians, such as myself) and allowed us to try various Kenyan dishes (the mandazi were my favourite!). The research centre was an excellent base for us to spend two months in July and August, carrying out our research projects.

Initially there was a bit of confusion as to what the internship involved, as we believed we would be working with a researcher on a project that was already in progress or creating our own project in association with a researcher. However, the researchers had either not arrived at Mpala yet, or were very busy. Therefore, we got the brilliant opportunity to design and carry out our own projects. For the first three weeks we tagged several school groups, such as a group from the Turkana Basin Institute. This allowed us to take part in several game drives, visit local communities (such as the Il Motiok community) and attend some very informative lectures from researchers who were currently at the research centre. These weeks allowed us to gain a better understanding of the ecosystem around us, the variety of species in the area, and any current problems or conflicts in the ecosystem. With advice from the Princeton in Africa Fellows (Zoe Sims, Rebecca Composto and Ciara Nutter), and with our recently gained knowledge of the surrounding area plus some additional research of the literature, we designed our own short projects to carry out in the remaining weeks. My project was comparing the diversity and abundance of species on the main (major) public road that ran through Mpala, and on the minor roads within the conservancy. This involved two different fieldwork techniques, which would hopefully complement each other and make the data more representative. The project included collecting both camera trap data and dung transect data, over a period of three weeks. We had a few issues with sourcing the equipment (in particular, the camera traps) but managed to borrow these from other labs within the research centre. We were allocated a vehicle and a wonderful research assistant, Elkana Korir, who drove us to all the sites we needed to visit, and helped us with
our fieldwork (for example, he was able to identify from which animal a dung sample had come from). The full project (including methodology) is described in the project paper.

Once we had started our projects, we began to have more of a daily routine. This usually involved waking up at 7:15 for breakfast, then heading out into the field with Elkana Korir at 8:00 or 9:00. We usually had a few sites each that we needed to visit that day (for both my project and Ingrid’s project). At each site, the fieldwork usually involved setting up or taking down camera traps (or just checking that they were still functioning properly), and completing a dung transect at each site. The number of sites we could visit in one day depended on how far away they were – some sites were an 1hr 30mins drive away. We would then return just before lunch at 13:00, and spend the afternoon going through camera trap photos, entering our data into excel spreadsheets, going to the gym and doing any other admin we had to do that day. Often, just before dinner, we would go on a ‘sundowners’ with several other researchers and students, who had access to vehicles. This involved driving to a high point nearby (such as, on top of the escarpment or a kopje), and watching the sun set, whilst chatting and eating snacks. After dinner, we would play games (such as bananagrams), watch films, sit around a bonfire or sometimes go on night game drives (one time, we saw an aardwolf!).

We also had the opportunity to take part in several incredible activities, which were usually organised by the Princeton in Africa fellows or other researchers and members of staff. These included: walking part of the way up Mount Kenya; visiting the One More Day orphanage (helping with their chores, cleaning the dormitories, helping to prepare their lunch, and reading with the children); attending the Northern Kenya Conservation Clubs celebration day; visiting Ol Pejeta (meeting the blind rhino (Baraka) and going to the chimpanzee sanctuary); visiting Nanyuki several times and going to the weekend clothes markets; trekking to a waterfall in the Ngare Ndare Forest Reserve; going with the veterinary unit to tranquilise an injured elephant and treat its suspected broken leg; and having the honour of being invited to an emanyatta ceremony in a local Maasai community. This huge range of activities allowed us to really explore the area and gave us the opportunity to meet many wonderful people. We were also constantly able to see a huge variety of animals in the wild, which (as a biologist) I absolutely loved!

As mentioned above, once our project had started, we had more of a daily routine, yet still each day offered new experiences and a few surprises. Often, there were challenges during the day, for example sometimes the camera trap batteries were malfunctioning or the car would get stuck in a ditch. These challenges, however, often had some great rewards once we overcame them. The latter challenge (the car getting stuck in a ditch) meant that we had to wait for help from another Mpala vehicle for a couple of hours. This, however, gave us the opportunity to climb a nearby kopje and see an incredible view of the surrounding savannah. It also meant that by the time we had got the car out of the ditch, we were returning from the field later than usual. On the way back, we suddenly saw a lion crossing the road, then walking alongside our vehicle. This was the only time throughout the whole two months we saw a lion, which made the experience very special. If the car hadn’t gotten stuck earlier on in the morning, we might never have seen lion whilst at Mpala!
The Smithsonian sponsored internship at Mpala was an amazing experience! It allowed me to explore a region of the world I had never visited before, take part in several fascinating cultural experiences, carry out my own research project, gain vital fieldwork skills and obtain a large amount of knowledge of a Savannah ecosystem. It also gave me the opportunity to travel, live and work in a new place for two months. This was the longest I had ever lived in another country, and has improved my confidence in terms of being able to travel, explore and possibly work in different, more remote destinations. Furthermore, the project I completed and the knowledge about the savannah ecosystem I gained has led me to base one of my coursework assignments on the ecology of roads, which counts towards my final degree mark (for the BA Biological Sciences degree at the University of Oxford). Therefore, the internship has also helped me to find what I am most interested in, within the field of Biology. I made some amazing friends from around the world whilst at the research centre, many of whom I am still in frequent contact with to this day. Once again, thank you to the Smithsonian UK Charitable Trust for sponsoring and helping to create this internship. I hope that future Pembroke interns have as many incredible experiences as I did – I know they will hugely benefit from and enjoy all the academic, cultural, and recreational activities!

Some camera trap photos: a reticulated giraffe (top left), a Grevy’s Zebra (top right), a warthog (bottom left) and Ingrid Easton, myself and Elkana Korir (bottom right)!
Comparing the diversity and abundance of species on major and minor roads in a savannah ecosystem.
Mpala Research Centre, Laikipia County Kenya
Hannah Puleston

Introduction

One of the most common changes to natural landscapes around the world is that of the formation and development of roads. (6) Roads are necessary to increase the ease of movement of people and goods across a wide range of areas, from small farms and towns to whole continents. Furthermore, road networks are essential for providing access to facilities and services, such as schools, hospitals, jobs and shops. However, whilst roads are beneficial for the economic and social development of a country, they can often have detrimental effects on the natural ecosystem. Several different factors will impact the extent to which the road has an effect on the surrounding ecosystem, such as whether the road is paved, its width and how frequently it is used. In general, roads effect an area in the following ways: increased mortality of species during road construction and due to vehicle collisions, altered physical and chemical environments, faster spread of invasive species and increased human access of areas. (6) For many species, roads can have numerous negative effects (such as by acting as a barrier to movement (1)), however some studies have demonstrated that a few species use roads, as they allow ease of movement in comparison to the surrounding vegetation. (8) The study of road ecology and expansion of research on the topic is necessary in order to better understand the impacts of building new roads and how they can be optimally managed, so that any negative impacts can be mitigated or avoided altogether.

The Mpala Wildlife Foundation and Mpala Research Trust were founded in 1989 by George Small, in order to fund the conservation of the habitats and wildlife within the Mpala Conservancy, and to support the livelihoods of those who lived and worked within the conservancy. The 48,000 acre Mpala conservancy is located near Mount Kenya, in Laikipia County, Kenya. The area is made up of semi-arid savanna, wooded grassland, acacia scrubland, riverine habitats and rocky escarpments. (9) A network of roads exists throughout Mpala (see figure 1). These roads are all unpaved and most are infrequently used, narrow and private (they are only used by staff, students, researchers, ranch workers and a few tourists). One main road runs through the Mpala conservancy, which is wider, more frequently used and open to the public. This study aimed to compare the abundance and diversity of species on the main road (later referred to as the ‘major’ road) and on the smaller, less frequently used, track-like roads (referred to as the ‘minor’ roads). It was hypothesised that the diversity and abundance of species would be lower on the major road, as species avoid the higher levels of traffic and the wider road could act as a barrier to movement. In turn, the minor road would have higher diversity and abundance of species than the major road, and possibly even the controls (areas with no road). This is because species may find the minor roads easier to travel along, especially in comparison to the vegetation in the thorny acacia scrublands. These minor roads have lower traffic densities than the major road, thus animals are less likely to be scared away, and more likely to use these roads. To test this hypothesis, the study used both camera traps and dung transects to compare the abundance and diversity of species on major and minor roads.
Materials and methods

In order to get a more accurate representation of the species diversity and abundance present on the different types of road, both camera trap data and dung transect data was collected. The camera trap data provided an idea of the animals which were using the roads or were near the roads, during a 5 or 7 day period. The dung transect data was more useful for seeing which species had been in the area, over a longer period of time (as the dung samples would often be several months old). Together, these different data sets should complement each other and can be used to determine whether road type has an effect on species diversity and abundance in a savannah ecosystem.

The camera trap data was collected over a 3-week period, during August 2018. The data was collected systematically, with 4 camera traps being set up per week. There is a main road within Mpala, which is open to the public and runs from the south to the north of the conservancy (see figure 1). This road was frequently used by a wide variety of people (such as tourists, researchers and locals who lived in the area) and vehicles (from piki-piki to large trucks). Most of the other roads in Mpala were much smaller, private, and only used occasionally (for example, by researchers or staff who worked at Mpala research centre or the Mpala ranch). A 10km stretch of the main road (which I refer to as the ‘major’ road) was selected as the study site. This stretch ran from the southernmost point of Mpala to approximately halfway up the conservancy. The area was chosen due to its proximity to Mpala research centre (therefore we didn’t need to drive several hours to reach the camera traps), and because each site had the same soil type (a transition mixture of red soil and black cotton soil), which reduces the number of potential confounding factors (see figure 2).

Along the 10km stretch of road, three areas were chosen systematically. Four camera traps were set up in each area, for 5 or 7 days. The areas were: 2.5km, 5km and 7.5km, along the main road. In the first week, the camera traps were placed 2.5km up the main road. Subsequently in the second and third week, the cameras were moved to the 5km and 7.5km mark.

Each week, one camera trap was set up at the side of the main (‘major’) road, and one control camera trap was set up perpendicularly 100m away from the side of the road. Thus the control camera trap was in a location near to the road, but with no road passing through it. Two other camera traps were set up along with the major road camera trap and its control. One of these camera traps was placed 200m down a minor road (which branched off from the main road and was close to the location of the first camera trap), facing onto the road. The final camera trap was placed 100m perpendicularly from the side of the minor road (to act as a control to the minor road camera trap, in the same way as the major road camera trap and its control complement each other).

When setting up each camera trap, it was necessary to find a suitable tree in the area. The tree had to be wide enough that it would be able to support the camera trap, but not too wide that the lock wouldn’t be able to stretch around it. It also had to be positioned so that there were not too many obstacles in the way of the camera (such as lots of grass), which could easily trigger the camera traps. If there was too much vegetation which could set off the camera trap, it was removed using a panga (a type of machete). Each camera trap was placed at approximately knee height, in order to be able to capture many different sizes of
animal. They were secured (where possible) using a bicycle lock, which passed through the outer casing of the camera trap. Each camera trap was set to take pictures 24 hours a day, with 3 pictures being taken every time the camera trap was triggered. They were also set to a low sensitivity, due to the fact that if the sensitivity was higher, the moving vegetation would lead to thousands of pictures being taken, which contained no animals (this was demonstrated during a trial run of the camera traps, the week before the experiment started). The camera traps were triggered by movement and heat; therefore, they were able to take pictures when it was dark.

The day after setting up the four camera traps for that week, they were checked to ensure that they hadn’t been damaged by any animals, they were taking photos, and that they weren’t being triggered by moving vegetation. The settings and position of the camera trap were changed if there was found to be a problem. After checking the camera traps, they were then left up for 5 or 7 days. The variation in the days they were left in one area was due to several logistical reasons, related to the time restrictions for deploying and collecting the camera traps. Each set of four camera traps, however, remained in place for the same number of days (for example, at the 2.5km area, all four camera traps remained in place for 7 days, whereas at the 5km area, all the camera traps remained in place for 5 days). Once they had been left up for the appropriate number of days, all four camera traps were collected, and the photos were taken off the SD card and checked for presence of any animals. It was noted down into an excel spreadsheet which species appeared on which camera (and thus at which site), and how many individuals of each species appeared on the pictures. The camera traps were then set up at the next area (5km along the road) and the previous method of setting up the camera traps at the first site was used again. This was then repeated once more in the third week, moving the four camera traps to the 7.5km area. Thus, across all the camera traps, a total of 68 camera trap days were recorded.

To complement the camera trap data, data was also collected from 12 dung transects. At each camera trap site (there were 12 sites in total), an 87m dung transect was completed, parallel to the direction of the road, with the camera trap being the midpoint of the transect (see figure 4). The 87m transect was measured using an 87m long tape measure (the tape measure should have been 100m long, but part of it had been broken off by a previous user). With our research assistant (Elkana Korir), we would walk alongside the tape measure, and would note down any dung samples (species and approximate number of samples) that occurred within one metre either side of the tape measure. Our research assistant was able to identify the samples to either genus or species level. The data for the species and number of samples at each site was entered into an excel spreadsheet.
Figure 1 – Map showing the outline of the Mpala conservancy, the road network within, and the main road (red line).

Figure 2 – Map showing the Mpala conservancy with the main road (red line) and the different soil types in the area (dark brown = black cotton soil, light blue = transition soil, green = red soil).

Figure 3 – Map showing the position of each camera trap: the number (e.g. 1st) refers to the week/area; major/minor refers to whether it was a major road or minor road; A/B refers to whether the camera trap was on the road or off the road (B was the control, off the road).
Figure 4 – diagram showing how the camera traps and dung transects were positioned on or near the road.
Results

The camera trap data and the dung transect data were entered into separate spreadsheets in Excel, in a format which allowed for several different factors to be analysed. Each site was identified by their area number (1, 2 or 3 depending on whether the data had been collected from the first site in week one, second site in week two or third site in week three), the road type (major or minor road) and the site type (on the road (A) or control site (B)). The columns had several different titles, to allow the data to be broken down in multiple ways. The camera trap data had columns which first split the data into species diversity and species abundance, then looked into different diversities and abundances based on diet type (for example, herbivore diversity and herbivore abundance). The data then had columns to look at the diversity and abundance of different classes of animals (such as odd-toed ungulates). Finally, each species had a presence/absence column, accompanied by an abundance column for that species (see figure 5a-c). The data for the dung transects was entered in a very similar way, although it looked at genera diversity and abundance, rather than species diversity and abundance.

Using R, the data was then analysed. Each abundance and diversity column was checked for normality (using a histogram), and transformed when appropriate to ensure the data was normal. An ANOVA was carried out for each diversity and abundance subset in both the camera trap and dung transect data (for example, for the species diversity and species abundance columns in the camera trap data set). These tests looked at the data on two levels: whether road type had a significant effect on the data, and whether site type (A or B) had a significant effect on the data. It also showed whether there was a significant interaction between road type and site type. For the presence/absence subsets, a general linear model was fitted. Again this was to see whether road type or site type had a significant effect on the presence or absence of a species, as well as whether either site type or road type interacted. A total of 66 ANOVA tests were carried out, and 28 general linear models were fitted. Several of the ANOVA tests and GLMs showed there was no significant effect of road or site type on abundance or diversity, however some of them did show significance.

Three of the tests carried out on the camera trap data showed significance. It was shown that road type had an overall significant effect on the species diversity. The ANOVA produced a p-value of 0.0196, which is less than 0.05, thus demonstrating the fact that there is a significant difference between the biodiversity on or near major roads, in comparison to on or near minor roads. A graph was produced, to further look into how road type was affecting species diversity (see figure 6). The graph shows that for each area, the species diversity is higher on major roads than minor roads. This is the opposite effect to the one I predicted in my initial hypothesis.

Furthermore, for both herbivore diversity and odd-toed ungulate abundance, it was shown that road type also had a significant effect on the data. The ANOVA tests produced a p-value of 0.0338 for herbivore diversity and a p-value of 0.0322 for odd-toed ungulate abundance. This demonstrates that minor roads and major roads have significantly different herbivore diversity and odd-toed ungulate abundance. Again, graphs were produced to see how the diversity differed on the two different types of road (see figure 7 and figure 8). There is a
slightly higher diversity of herbivores on major roads compared to minor roads, but there is a much higher abundance of odd-toed ungulates on major roads than on minor roads. This, again, contradicts the hypothesis initially suggested, as these graphs show that it is the major road which has higher levels of diversity, rather than the minor roads.

The statistical tests for the dung transect data showed that there were three significant results. There was a significant difference between site type for the overall genus diversity (the ANOVA produced a p-value of 0.0316). The graph (see figure 9) demonstrated that in fact there is significantly higher diversity away from the roads, compared to on the roads (for both major and minor roads). Similarly, site type also has an effect on the herbivore diversity (p-value of 0.0317) and the odd-toed ungulate diversity (p-value of 0.0222). For both, the graphs showed that there is a higher diversity away from the road compared to on the road (see figure 10 and 11).

For all other statistical tests carried out, the results showed that there was no significant effect of road type or site type on the data subsets (all the p-values produced were higher than 0.05). As mentioned before, the data had been formatted into groups of different diet types and different classes (such as even-toed ungulates). For all of these data subsets, the effects on both abundance and diversity were tested. Apart from the ones mentioned above, the abundance and diversity were not affected by the different treatments. Furthermore, each species (or genus, for the dung transect data) was individually tested for whether there was a significant difference in their presence on or near different types of roads, as well as if the abundance of each species (or genus) differed between road and site types. None of the tests carried out on individual species (or genera) proved to be significant. Thus for most categories there was no significant difference between major and minor roads, or between presence and absence of road, especially at the species and genus level.

| area_no | road_type | site_type | spp_div | spp_abun | tot_herb_div | tot_herb_ab | tot_carn_div | tot_carn_ab | tot_omni_div | tot_omni_ab | lat | lng | alt | ins | dive | abs
|---------|-----------|-----------|---------|----------|-------------|-------------|-------------|-------------|-------------|-------------|-----|-----|-----|-----|------|-----
| 1       | major     | A         | 7       | 34       | 32          | 32          | 32          | 32          | 32          | 32          | 32  | 32  | 32  | 32  | 32   | 32  |
| 1       | minor     | A         | 5       | 21       | 19          | 19          | 19          | 19          | 19          | 19          | 19  | 19  | 19  | 19  | 19   | 19  |
| 1       | minor     | B         | 3       | 9        | 9           | 9           | 9           | 9           | 9           | 9           | 9   | 9   | 9   | 9   | 9    | 9   |
| 2       | major     | A         | 3       | 3        | 3           | 3           | 3           | 3           | 3           | 3           | 3   | 3   | 3   | 3   | 3    | 3   |
| 2       | minor     | B         | 4       | 16       | 15          | 15          | 15          | 15          | 15          | 15          | 15  | 15  | 15  | 15  | 15   | 15  |
| 3       | major     | A         | 3       | 4        | 4           | 4           | 4           | 4           | 4           | 4           | 4   | 4   | 4   | 4   | 4    | 4   |
| 3       | minor     | A         | 5       | 25       | 15          | 15          | 15          | 15          | 15          | 15          | 15  | 15  | 15  | 15  | 15   | 15  |
| 3       | minor     | B         | 4       | 17       | 12          | 12          | 12          | 12          | 12          | 12          | 12  | 12  | 12  | 12  | 12   | 12  |

Figure 5a: How the data was formatted in excel. Column headings show species diversity and abundance, as well as diet type (such as carnivore diversity and abundance).
Figure 5b: How the data was formatted in excel. Column headings show different class diversities and abundances (such as primate diversity and abundance).

Figure 5c: How the data was formatted in excel. Column headings show some of the different species presence/absence data, and their abundances.

Figure 6: Graph to show species diversity on major and minor roads (camera trap data).

Figure 7: Graph to show herbivore diversity on major and minor roads (camera trap data).
Figure 8: Graph to show odd-toed ungulate abundance on major and minor roads (camera trap data).

Figure 9: Graph to show genus diversity on a road and not on a road (dung transect data).
Discussion

The focus of this study was to compare the diversity and abundance of several different species on major roads and minor roads, in a savannah ecosystem. Furthermore, the effect of roads in general was studied, by comparing the diversity and abundance of species on roads and in areas with no road. The hypothesis being tested was that there would be a significant difference of species diversity and abundance between major and minor roads. More specifically, major roads would have lower species diversity and abundance than minor roads. This could be due to the fact that the major road is open to the public, and thus more frequently used. Higher density of traffic on the major road would therefore lead to more animals avoiding the road. (1) On the other hand, the minor roads have very low traffic densities, and could be an easier track for many animals to travel along (compared to the surrounding vegetation). (8) Therefore, minor roads may have higher species abundance and diversity, possibly even compared to the areas with no road. It is important to study and understand more about roads and their effect on an ecosystem, as in today’s modern world, the creation of new, more extensive roads is rapidly increasing. By carrying out studies on the ecology of roads and improving our understanding of their impacts, more schemes can be put in place to mitigate or prevent the negative consequences roads might have.

The results above demonstrate that species diversity was significantly higher on the major road, compared to the minor road. This result is the opposite effect to what was predicted in the hypothesis, as it shows a wider variety of species was present on the major road, rather than the minor road. Several reasons could explain this result. Whilst traffic density is higher on the major road than the minor roads, it is still relatively low, as the Mpala conservancy is in a rather remote area. Therefore, this reduces the likelihood that animals avoid the major road. Furthermore, several species (such as Grevy’s zebra Equus grevyi) are habituated to vehicles, thus they are not scared away by passing traffic. (2) As the major road is wider than the minor roads, it could provide a better track for medium to large animals to traverse through the conservancy. One study demonstrated that many large animals use lightly travelled roads, such as the wolf (C. lupus), cheetah (Acinomix jubatus) and lion (Panthera leo). (8) Some species display edge attraction (such as the Mongolian five-toed jerboa), as roads can provide optimal locations for foraging and open areas for basking. (7) Whilst traffic density is low on the major road, it is still slightly higher than on the minor roads, thus vehicle collisions with animals may occur more frequently. This could attract more scavengers to the roadside, who are searching for carrion. (1) That said, throughout the eight weeks we lived at Mpala, not a single road kill was seen (possibly due to the areas status as a conservancy, and strict rules which penalise anyone who hits an animal). The smaller minor roads, on the other hand, may be less used by animals, as animal trails form a dense network throughout the Mpala conservancy, which often cross over with the minor roads. Therefore, the minor roads do not represent a much easier track to traverse or provide special access to certain restricted areas. (2) They could thus not be preferentially used by animals, who are just as likely to use animal tracks rather than the minor roads. These are just a few possible reasons as to why the major road has significantly higher species diversity than the minor road. More research is necessary to explore the reasons for this difference.
Herbivore diversity and odd-toed ungulate abundance were also significantly higher on or near the major road, in comparison to the minor road. As well as the reasons stated above for this potential difference (in relation to overall species diversity), a wider variety of herbivore species may be found near or on the major road, as grazing and browsing opportunities are more easily accessible. The open road space makes movement and therefore foraging easier. (8) There were only two species of odd-toed ungulate in the area: Grevy’s Zebra and Plains Zebra. As odd-toed ungulate abundance is higher on or near major roads, this demonstrates that there are significantly higher numbers of individuals of zebra in this area, compared to minor roads. It was noted by Zero et al. that Grevy’s Zebra are habituated to vehicles, therefore traffic is unlikely to be a significant factor which leads to Zebra avoiding the road. As mentioned above, the open road space makes foraging easier, and the open area means more grass can dominate the spaces near roads. Thus Zebra may be attracted to the edges of roads, as they are grazers. Furthermore, Zebra tend to travel together in small family groups (often consisting of a male, several females, and their young). (5) Moving together as a group would be easier on a wider road, where the lack of obstacles (such as acacia) allows the herd to stay together. Again, these are just some of the possible reasons to explain why herbivore diversity and odd-toed ungulate abundance is higher on or near the major road, compared to the minor roads.

The above explanations refer to the results of the camera trap survey. Similarly, the dung transect data demonstrated significant results for genus diversity, herbivore diversity and odd-toed ungulate diversity. However, unlike the above data, it showed that it was site type rather than road type which significantly affected the diversity. For all three, the diversity was higher away from the road (at the control) rather than on the road. Many studies have found that species abundance and richness is lower within certain distances from roads. (4) Therefore, it could be that animals are more likely to be found in areas further away from roads. Many reasons for these results have been mentioned above, such as traffic avoidance or roads acting as a barrier to movement. However, it could just be that animals prefer to defecate away from the road. Furthermore, dung transects will favourably identify and possibly over-estimate the species which defecate much more frequently, for example, many herbivore species (such as the impala) defecate more often and in larger quantities than carnivore species (such as smaller cat species, which tend to bury their excrement). In addition, the more frequent use of the road by vehicles (compared to the areas of no road) could mean that any dung that is deposited on the road is rapidly broken up and eroded by the fast moving vehicles. Thus whilst dung samples can dry out and remain intact for several months when undisturbed, the frequent passing of vehicles on the road may increase the rate at which the dung samples break apart and decay. Therefore, although the dung data is suggesting that there is a higher diversity of genera, herbivores and odd-toed ungulates away from the road than on the road, there are several problems with the extent to which the dung data accurately represents the presence and frequency of different species. Further studies are necessary to determine whether the dung samples demonstrate genuinely higher diversity away from the road, or if other factors (such as frequent vehicle use rapidly breaking down dung samples on the road) are the cause behind this significant difference.

There are several limitations to this study which could have affected the results. Firstly, there were significant time restraints, due to the fact that by the time the study had been
designed, we only had a total of four weeks left at the Mpala Research Centre in Kenya. The camera traps which we needed for the camera trap survey were on loan to us from various researchers and labs at the research centre, as we didn’t have funds set aside to purchase the equipment ourselves. This meant that the camera traps needed to be returned after three weeks, which limited our study time to just three weeks. This may not have been a sufficient amount of time to obtain an accurate representation of the diversity and abundance of species on or near the different roads, as it only allowed us to take three repeats. Furthermore, the three-week period occurred just in the dry season in Kenya. Similar studies would need to be repeated in the wet season, to see the full picture of how roads affect the diversity and abundance of species in the area.

It was not just the amount of time which limited the sample size of the data, but also the number of camera traps. We were only able to borrow four camera traps in total, which limited the study to just four sites per week. The data, therefore, is unlikely to be representative of the whole Mpala conservancy. The sample size needed to be much larger if it was to be representative. In addition, some of the camera traps were different models and had slightly different settings. In particular, the sensitivities of the camera traps, even though all were on the ‘low’ setting, could have been slightly different. Thus, some camera traps may have been set off less frequently by animal movement compared to other camera traps, which may have skewed the results and under-estimated animal species presence at some sites.

Even though measures were put in place to try and minimise the effect of moving vegetation on setting off the camera traps, some camera traps still took thousands of photos of grass (when no animals were present). This meant that, when manually going through the camera trap photos, due to the sheer volume of photos and the need to go through them rapidly, some animals may have been missed altogether. This again leads to a potential under-estimate of the species present at each site. For several species, only one individual was identified (for example, only one aardvark was seen in the whole study). Such low abundances for some species meant that it was difficult to carry out any statistical tests to determine whether road type or site type significantly affected some species presence or abundance. Consequently, several factors may cause the data to not be representative of the true diversity and abundance of species on or near major and minor roads.

Future studies on the diversity and abundance of species on major and minor roads in the Mpala conservancy should aim to greatly increase the sample size, so that the data is more representative. This could be done by increasing the length of time each camera trap is set up for, using more camera traps (so that more sites can be covered) and using the same model of camera trap. Sampling should also occur throughout the year, to get a better representation of how seasons may affect the diversity and abundance of animal species on or near major and minor roads. Studies should also be done to see the effect of vehicle presence on dung sample breakdown and decay. Such studies could take fresh dung samples from the same species, and place some samples on the road, and some samples away from the road (in a similar area). Each day, the samples could be observed and their state could be recorded (for example, intact or broken-up). This is necessary in order to determine whether the dung transect survey data is truly representative of species abundance and diversity. Further studies could also compare the effect of night and day,
and whether different types of road are significantly used more or less at different times of the day. More studies would increase our understanding of how animals use roads.

In conclusion, this study found that species diversity was significantly higher on or near the major road in comparison to the minor roads. Furthermore, it found that herbivore diversity and odd-toed ungulate abundance was also higher on or near major roads, when compared to minor roads. This finding contrasted with the prediction from the initial hypothesis, that the major road would have lower diversity and abundance of species than the minor road. Some reasons for these results could be: low traffic densities (even on major roads) means that several species do not avoid the major road, as initially predicted; the wider major road allows larger animals to move more easily through the landscape, which could be especially important for species which move together in herds, such as the Plains Zebra; the open road spaces increase foraging opportunities, especially for herbivores; and minor roads are much narrower and very similar to animal tracks, therefore they are not preferentially used by individuals who may find animal tracks just as easy to traverse as the smaller roads. The dung transect data demonstrated that there was a significantly higher genus, herbivore and odd-toed ungulate diversity at the control sites (away from the road) than on the road. This could be because species avoid the road (due to traffic) or they preferentially defecate away from the road. However, these results could have also occurred simply because dung samples break down quicker on the road than off then road, therefore the dung transects on the road would have under-estimated the diversities and abundances of species. Further studies are needed in order to greatly increase the sample size and accuracy of the results, to ensure that they are representative. More studies could also help to determine the underlying causes for the differences in diversity and abundance of species for different road and site types. This information could then be included in the future, when considering how best to manage and construct roads in the Mpala Conservancy and beyond.
Hannah Puleston, Pembroke College, University of Oxford

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