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Distribution, diversity, and den locations of Canidae and Hyaenidae species across habitat type at Enashiva Nature Refuge

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SIT Study Abroad

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Abstract

Due to the importance of top-trophic level predators have on their environment including regulating prey species and influencing ecosystem biodiversity, it is important to monitor top-trophic level predators to understand how they shape their ecosystem. While top-trophic level predators can benefit the ecosystem, they can also cause problems for surrounding human settlements like predation on livestock. Species in the *Canidae* and *Hyaenidae* families occupy the top-trophic level and can influence their ecosystem and cause human-wildlife conflict.

This study looked at the distribution, diversity, and den locations of *Canidae* and *Hyaenidae* species at Enashiva Nature Refuge over the course of 21 days. The goal was to understand whether occurrence and diversity had increased, decreased, or remained stable to give insight on how the Enashiva ecosystem had changed in relation to species in these families. Also, to look at the distribution of occurrence for species across habitat type to understand if there is habitat preference. Several methods of data collection were used including walking transects, opportunistic walking, opportunistic driving, and game cameras. Two-tailed t-tests and ANOVA tests were used to statistically analyze the results.

It was concluded that based on the results that there has not been a change in occurrence frequency of *Canidae* and *Hyaenidae* species at Enashiva when compared to previous studies. In addition, the diversity has also not changed. While there was some fluctuation in number of occurrences between studies they stayed relatively stable. Also, based on occurrence frequencies in habitat it was concluded that there is not a significant difference between occurrence frequencies between species and habitat. However, it does appear that the three-species recorded prefer the woodland for dens. Based on this study the diversity and occurrence of *Canidae* and *Hyaenidae* species has remained stable. Also, occurrences can be found in all habitats. It will be important to continue to monitor these species for diversity and potential human-wildlife conflict.

Table of Contents

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Introduction

Background Information

Compared to other parts of the world East Africa is still home to a wide variety of top trophic level predators including species from the *Canidae* and *Hyaenidae* families. Top trophic level predators, like those found in the *Canidae* and *Hyaenidae* families, play important roles in ecosystems including regulating prey species, which can shape community structure (Palomares & Caro, 1999). In addition, studies have shown that ecosystems with more top-trophic level predators have greater biodiversity than those lacking top-trophic level predators (Sergio, Newton, Marchesi &Pedrini, 2006). This is due to the top-down regulation on lower trophic level species that predators provide (Sinclair, Mduma &Brashares, 2003). This regulation prevents overpopulation of prey species, which would otherwise damage the ecosystem and affect resource availability. Greater biodiversity allows ecosystems to be more resistant to change and thus healthier and more stable than other ecosystems (Hooper et al., 2005). It is important to monitor top-trophic level predators to understand how changes in their presence can affect an ecosystem and future management plans.

The human population is rapidly increasing leading to increased resources needed, encroachment, and human-wildlife conflicts. Top-trophic level predators are often the most vulnerable to human encroachment due to their low populations, space requirements, and conflicts with humans (Lyamuya, Masenga, Fyumagwa & Roskaft, 2014). Another important reason to monitor predator populations besides biodiversity is to understand what potential

human-wildlife conflicts there might be and how to mitigate them. A study conducted in the eastern part of the Serengeti ecosystem including the Loliondo Game Controlled Area and part of the Ngorongoro Conservation Area found that most livestock attacks by predators in this area were from the African wild dog (*Lycaon pictus*) followed by the spotted hyena (*Crocuta crocuta*) as the third and the striped hyena (*Hyaena hyaena*) as the fifth (Lyamuya, Masenga, Fyumagwa & Roskaft, 2014). Predation on livestock presents a tough challenge for conservationists and famers, especially in this area, as livestock represents wealth and loss of livestock can be devastating. By knowing the abundance of predators in an area conservationists can create a management plan that can address potential conflict.

The *Canidae* family is a diverse family made up of 35 species that then fall into 15 genera (Sheldon, 1992). *Canidae* species can be found on every continent except Antarctica and in almost every habitat. The *Canidae* family is a well-known family due to its connections with the domestic dog. The size of species in the *Canidae* family can range from 1 to 80 kg and there are a range of diets including carnivore, omnivore, and insectivore. In Tanzania, there are five *Canidae* species including the side-striped jackal (*Canis adustus*), golden jackal (*Canis aureus*), black-backed jackal (*Canis mesomelas*), African wild Dog, and bat-eared fox (*Otocyon megalotis*) (Foley et al., 2014). All three jackals found in Tanzania fall under the genus *Canis* while the African wild dog falls under the genus of *Lycaon* and the fat-eared fox the *Otocyon* genus (Sheldon, 1992).

The *Hyaenidae* family is made up of only four species. These four species include the spotted hyena, the brown hyena (*Parahyaena brunnea*), the striped hyena and the aardwolf (*Proteles cristatus*) (Werdelin & Solounias, 1991). The *Hyaenidae* family is almost exclusively found in Africa except for the striped hyena that can be found in the Middle East, parts of Russia, Pakistan, and India (Foley et al., 2014). The brown hyena is the only member of the *Hyaenidae* family not found in Tanzania. The spotted, striped, and brown hyena are all carnivores that will hunt and scavenger for their food. They have the capability of crushing bone and will consume the bones providing extra nutrition. The aardwolf is an insectivore that primarily eats termites.

Study Objective

This study focused on the occurrences of *Canidae* and *Hyaenidae* predators present at Enashiva Nature Refuge to better understand the distribution of these species in the area. The objective of the study was to record occurrences of species from the *Canidae* and *Hyaenidae* families to understand their distribution, diversity, and den locations between habitats at Enashiva and to compare results to previous studies. These families were focused on because based on previous studies conducted at Enashiva species from these families usually had the highest rates of occurrences (Bowles 2011, Gulka 2011, Cathcart 2012). Since these species occur at higher frequencies they could give insight into the biodiversity of Enashiva. In addition, these species could be causing the most human-wildlife conflict for the surrounding villagers. Knowing which species are present and what habitats they are most likely to be found will give managers of Enashiva an idea of the predator composition of the land.

Expected Results

Based on previous studies at Enashiva and ranges of animals this study expected to find spotted hyenas, black-backed jackals, and bat-eared foxes (Bowles 2011, Gulka 2011, Cathcart 2012, IUCN 2016). There was also a possibility of finding striped hyenas, aardwolves, African wild dogs, golden jackals, and side-striped jackals as the refuge is near to or part of their range (IUCN, 2016). This study looked at the distribution of species from the *Canidae* and *Hyaenidae* families between habitats including the woodland, wooded grassland, and grassland habitats. Hyenas can be found in a variety of habitats (Foley et al., 2016). For example, the spotted hyena is found in grasslands, woodlands, and montane forests while the striped hyena occurs in dry, open habitat or *Acacia* bushland. Based on this it was expected that occurrences of hyenas will occur in all habitats with little difference. Jackals also are found in a variety of habitats and adapt well to the area they are living. They can be found in grassland, woodland, agriculture land, and more. Based on this it was expected that jackal occurrences will be found in all three habitats with an even distribution. The bat-eared fox is found in open grassland and woodland areas, but will avoid open grassland plains. Their occurrences were expected to be greatest in the grassland and woodland. If the African wild dog is present they can also be found in all three habitats, so occurrences were expected from any habitat. The null hypothesis then was there will be no

difference between habitat for *Canidae* and *Hyaenidae* distribution. This study also looked at the distribution of den sites for these species including habitat preference for dens.

This study also compared changes in diversity and abundance of *Canidae* and *Hyaenidae* species to previous studies at Enashiva to understand how the ecosystem has changed. This study used similar methods to previous studies, but also modified and added more methods of data collection. However, only the data collected in a similar manner for this study was compared to the same style of data collection of the previous studies. If conservation efforts are working and trying to maintain stable *Canidae* and *Hyaenidae* species populations then the diversity and abundance should increase for these species compared to previous studies. The null hypothesis then was that there will not be a difference between diversities and occurrence between studies. The study tried to answer the different factors proposed, but it also looked at differences in methodology and make recommendations for future studies on proper methods.

Study Site Description

This study was conducted at Enashiva Nature Refuge located in the Loliondo Region (Figure 1). Enashiva is near the north-eastern border of Serengeti National Park. It is also 10 km away from the Kenyan border. The refuge is 12,600 acres of moist savannah. Between 1987 to 1989 the land was used as a barley farm for Tanzania Breweries Limited. After the barley farm failed the surrounding community used the land for grazing their livestock and for access to the water sources. In 2006, the ninety-nine-year lease was purchased by Thomson Safaris. Since then it was dedicated as a refuge and tourist destination. Conservation efforts began to increase wildlife presence.

Enashiva includes flat plains with surrounding hills. The elevation ranges between 1,990 and 2,344 meters above sea level (Gulka. 2011). There are five different habitat types in Enashiva. They include woodland, ridge woodland, riverine woodland, wooded grassland, and grassland. For this study the woodland, ridge woodland, and riverine woodland habitats were combined and fell under the classification of woodland habitat. By combining these woodlands, it provided more data sampling from this habitat. The three habitats in this study were then grassland, wooded grassland, and woodland. The grassland habitat was defined as an open area with most short grasses with little to no trees. The woodland was defined as an area with most trees above 20 meters present and with an open or continuous canopy. The wooded grassland

was defined as the area usually between grassland and woodland where there was a mixture of open grasses and trees.

This study was conducted between April 1st, 2017 and April 20th, 2017. This time frame coincided with the long rainy season. However, it only rained four days during the study period.

Figure 1 Map of study site. Study site located in the Loliondo region of northern Tanzania. The black rectangle represents the study site area, Enashiva Nature Refuge, where data was collected between April 1st, 2017 to April 20th, 2017

Methods

The methods for this study were adapted and modified from previous ISP's including Bowles (2011) and Gulka (2011). Data collection occurred between April 1st, 2017 and April 20th, 2017 at Enashiva Nature Refuge. During this time, several data collection methods were used including walking transects, opportunistic walking, opportunistic driving, and game cameras. Three potential occurrences of *Hyaenidae* and *Canidae* species were recorded for each method to analyze the distribution and diversity of these species. These occurrences were spoor, scat, or sighting. In addition, for each occurrence the date, time, type of method used, habitat, GPS coordinates, and metadata were recorded. Each occurrence observed was counted as one occurrence whether there were multiple scats or individuals observed. Identification of species were based on knowledge of ranger and researcher. Den locations of any *Hyaenidae* and *Canidae* species were also recorded to map den locations at Enashiva.

Walking Transects

The walking transects used were based off the transects used by Gulka (2011). Sixteen radiating transects were walked between April 2nd, 2017 and April 20th, 2017 with two rest days and one day where a transect was not walked. Transects were created by using the start coordinate at the camp and the end coordinates used by Gulka (2011). This way the straight-line transects were pre-determined. Gulka created the transects by measuring a line 0º due north through the camp and 180º due south of the camp to the border of Enashiva. Between these two lines sixteen transects were designed. The ideal degree distance between each transect was 11.25º, but in reality ranged from 5º to 20º between transects. See Appendix B, Figure 4 for a map of transects walked.

Transects were walked in the morning except for one transect that was walked in the afternoon due to weather conditions. Time for beginning the transect ranged from 8:00 a.m. to 8:30 a.m. The average distance of the transects was 4.51 km with the longest being 5.94 km and the shortest being 3.2 km. This range in distance was based on the shape of Enashiva. A GPS device was used to follow the pre-determined transect. Each transect was a straight line based on the coordinates from the start camp and the end of the transect. However, due to woodland or thick bush some deviation from the transect occurred, but it was never more than 25m off the transect.

Each transect had a sight range for *Hyaenidae* or *Canidae* occurrences of 100 m for sightings. While occurrences of spoor or scat were recorded based on an observation distance of one meter to each side of the transect. If any dens were found during the transect they were also recorded.

Opportunistic Walking

Opportunistic walking occurred on the return walk to camp and every other afternoon. Opportunistic walking was to mark any sightings, spoor, scat, or dens that were not accounted for on transects. The opportunistic walks were skewed to certain areas of Enashiva including roads and well-known den site areas.

The return walks after transects were primarily along roads and paths. The ranger would lead the way back. If any occurrences were observed during this time they were recorded separately from the transect walked earlier.

Every other afternoon at 3:00 p.m. another walk occurred specifically looking for dens of *Hyaenidae* and *Canidae* species at Enashiva. These walks on average lasted two-hours. The locations of the dens found during this time were based primarily on the ranger's knowledge of the dens. While looking for dens any other occurrences were also recorded.

Opportunistic Driving

Opportunistic driving was used when setting up game cameras and on night game drives. Opportunistic driving consisted of driving around in a car and when any occurrences were observed, primarily sightings, they were recorded. Opportunistic driving was not as planned since not every day were cars used to set out camera traps or go on night game drives.

When the car was used to set game cameras out then it left between 5:30 p.m. and 6:00 p.m. The process usually took about one hour. During this time if any occurrences of *Canidae* or *Hyaenidae* were observed then they were recorded.

Over the course of twenty-one days, five-night game drives were used. The plan had been to have nine (three a week) however due to car difficulties only five were performed. Night game drives began at 8:00 p.m. On average, they lasted one hour. The areas that were driven through were areas that nocturnal animals would most likely be seen and included off road driving. This method was opportunistic non-random sampling. Every other game drive the habitat searched was switched between grassland and woodland. A spot light was used to search for animals in the dark. Most occurrences observed were sightings of animals. The species, number of individuals, habitat, location, time, and any metadata were recorded.

Game Cameras

Camera traps were used for a felid study during the same study period. Shared resources were used and any occurrences of *Canidae* or *Hyaenidae* species observed on the cameras were recorded. The study began with eight game cameras, but due to spotted hyena destruction at the end of the study there were four cameras left. The cameras were placed in areas where felids would most likely occur, but these areas coincided with areas where *Canidae* or *Hyaenidae* were found. Depending on time and car ability the cameras were either placed by driving to areas or by walking to nearby areas. Also, the game cameras were picked up every morning at 7:00 a.m.

due to the possibility of damage or theft by people passing through the area. There was one game camera that stayed in one place twenty-four seven.

Photos for the cameras were reviewed the next day. Any occurrences of *Canidae* or *Hyaenidae* species were recorded. The picture was saved. The picture contained the date and time stamp of each observation. The location of the camera was obtained when the camera was set up. Each observation of a species counted as one occurrence for that time and date. There could be multiple occurrences of the same species in the same area over several days and each observation would count as one occurrence.

Statistical Analysis

Data was analyzed using both two-tailed t-test assuming unequal variance and ANOVA single factor tests. When involving comparing all the groups ANOVA was used. While the two-tailed t-test assuming unequal variance was used when comparing only two groups. In addition, the Simpson's Diversity Index was used to analyze total diversities between studies. Also, it was used to analyze diversity between habitats and total diversity for this study. Finally, percentages and standard error bars were also used.

Results

This study found a total of 182 occurrences of species from the *Canidae* and *Hyaenidae* family. Three species from these families were sighted including the spotted hyena, black-backed jackal, and the bat-eared fox. However, the rangers also said that side-striped jackals and striped hyenas are present at Enashiva (Alias, personal communication, April 15th, 2017). Due to the knowledge of the rangers and the difficulty of distinguishing between species for spoor and scat all hyena species were classified as hyena and all jackal species were classified as jackal.

Selected results for comparison to previous studies

This study compared the results from three previous studies conducted at Enashiva Nature Refuge (Bowles 2011, Gulka 2011, Cathcart 2012). These studies looked at occurrence and diversity of all top-trophic level predators. To compare to the results of this study certain results were selected from their studies for comparison including the occurrences of hyenas, jackals, and bat-eared foxes and the diversity of these occurrences. Due to some differences in

methodology, only the occurrences found during walking transects and the den locations in this study were compared.

The occurrence for each species for each study are represented in Figure 2. The occurrence for hyena was greatest in Gulka Fall 2011 study. The total hyena occurrence in order from Bowles Spring 2011, Gulka 2011, Cathcart Fall 2012, and Bullington Spring 2017 were n=57, 126, 52, 41. The greatest occurrence of jackal also occurred in Gulka Fall 2011. The total jackal occurrences in study order were n=17, 39, 15, 25. Finally, the highest occurrences of bat-eared fox were from Bowles Spring 2011. The total bat-eared fox occurrences in study order were n=19, 13, 3, 4.

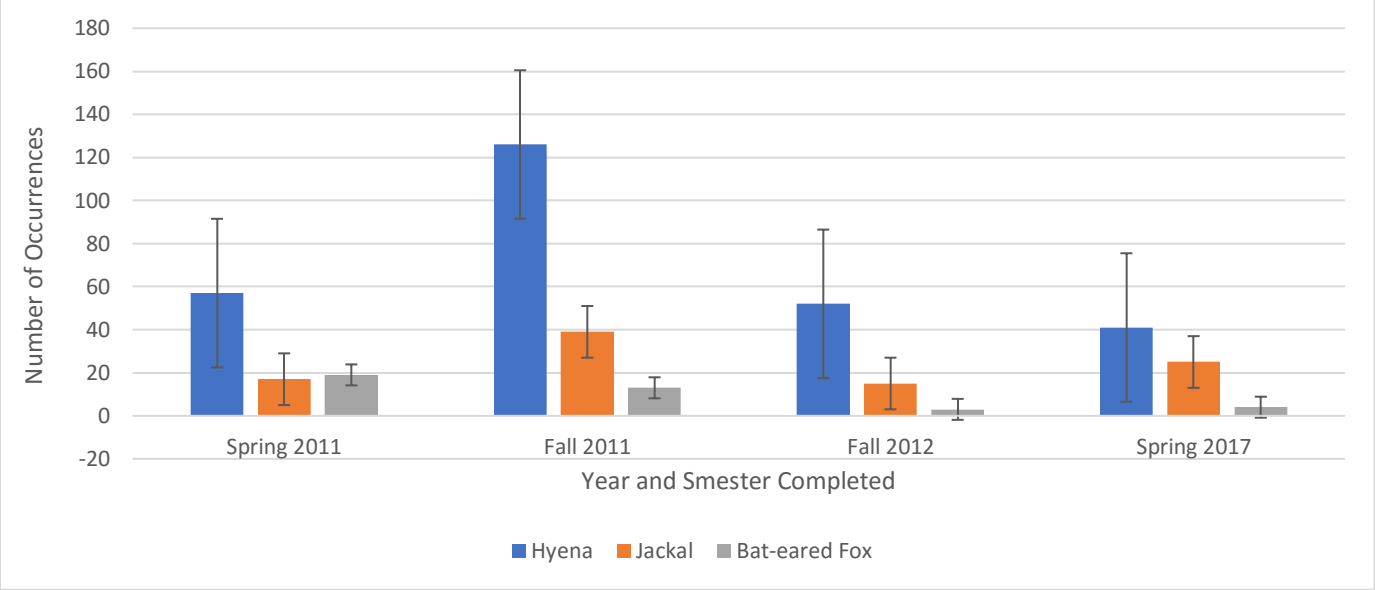

Figure 2 Species occurrence total comparison between studies at Enashiva Nature Refuge standard error bars were calculated from the average of total occurrence of species over the four studies

The standard error bars were calculated using the average number of occurrence of each species from all studies. The standard error bars that do not overlap were the hyena occurrence from Fall 2011 with the three other hyena occurrences. Also, the standard error bar for the bat-eared fox from Spring 2011 did not overlap with the bat-eared fox standard error bars from the Fall 2012 and Spring 2017 studies.

A two-tailed t-test was used to analyze the average number of occurrences of all species from each previous study with the average number of occurrences of all species from this study. For example, the average number of occurrences of all three species for the Spring 2011 study was tested against the average number of occurrences of all three species for this study. None of

the p-values found when comparing the averages were significant (p>0.05, see Appendix C, Table 3 for p-values from this test). In addition, an ANOVA single-factor test was performed to compare all the average occurrences from each study to see if there was significance between the whole group. All p-values from the t-tests and the ANOVA test were insignificant, so the null hypotheses were supported.

The Simpson's Diversity Index was calculated for each study using the occurrence totals of each species.

Table 1 Simpson's Diversity Index of Canidae and Hyaenidae species between studies at Enashiva Nature Refuge, Tanzania Spring 2017

Study Period	Spring 2011	Fall 2011	Fall 2012	Spring 2017
Simpson's Diversity Index of *Canidae* and *Hyaenidae*	0.555	0.472	0.451	0.534

The closer the number is to one the higher the biodiversity of the area calculated. The highest biodiversity was from Spring 2011. However, all diversities were below 0.600 and within a range of 0.104 between one another.

Selected results for this study for habitat and diversity

When accounting for all occurrences when using all methodology, this study found n=182 occurrences of *Canidae* and *Hyaenidae* species at Enashiva Nature Refuge. Of these 182 52.7% of the observed occurrences were of hyenas (96/182). Of the occurrences 37.4% were of jackals (68/182). Finally, of the occurrences 9.89% were of bat-eared foxes (18/182). Hyenas had the highest rate of occurrence at Enashiva.

A two-tailed t-test was used to compare the average occurrence difference between species. For example, the average occurrence of hyenas was compared to the average occurrence of jackals. All p-values for these tests were insignificant (p>0.05). Also, an ANOVA test was run comparing all the average occurrences of each species to the other two. This test also was insignificant (p>0.05). There was no difference between average occurrences of species at Enashiva.

Occurrences were broken down by habitat including the woodland, wooded grassland, and grassland habitats. The total occurrence of species in the woodland habitat was n=106 with hyena n=59 occurrences, jackal n=39 occurrences, and bat-eared fox n=8 occurrences. The total occurrence of species for the wooded grassland was n=35 with hyena n=18 occurrences, jackal n=13 occurrences, and bat-eared fox n=4 occurrences. Finally, the total occurrence of species for the grassland was n=41 with hyena n=19 occurrences, jackal n=16 occurrences, and bat-eared fox n=6 occurrences.

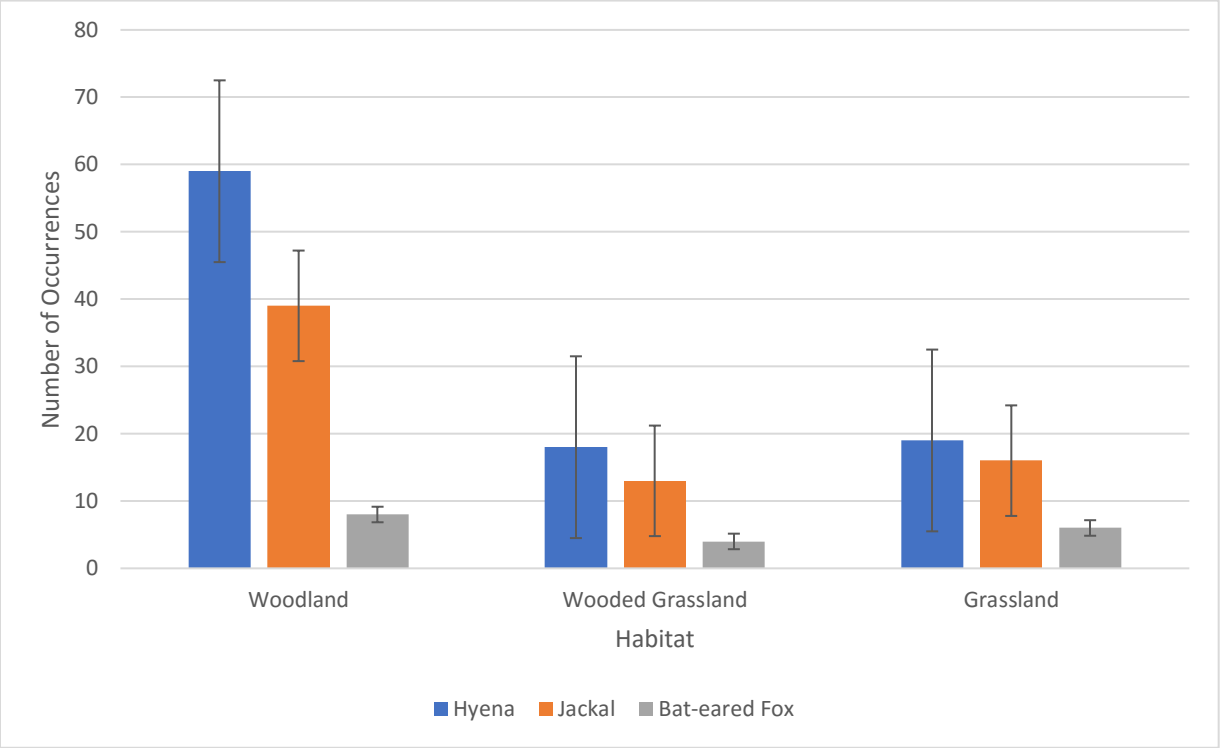

Figure 3 Species occurrence totals between habitat at Enashiva Nature Refuge, Tanzania Spring 2017 Standard error bars were calculated using the average number of occurrence for each species in each habitat

In Figure 3 all standard error bars overlap for each species in the wooded grassland and the grassland. However, neither the wooded grassland or grassland standard error bars overlap with the corresponding species in the woodland. The hyena standard error bar for the woodland habitat does not overlap with the wooded grassland. The same is true for the jackal woodland standard error bar and the bat-eared fox woodland standard error bar.

A two-tailed t-test was used to analyze the average number of total species occurrences for each habitat to find if there was significant difference between habitat. For example, the total species occurrence average for the woodland was tested against the total species occurrence

average for the wooded grassland. All p-values were insignificant when comparing each of the three habitats ($p > 0.05$). In addition, an ANOVA test was run to compare all the total species occurrence average in each habitat at the same time. Again, this p-value for this test was insignificant ($p>0.05$). All the p-values for these tests were insignificant and the null hypotheses supported.

The Simpson's Diversity Index was calculated for each habitat and the total Ensahiva area (Table 2).

Table 2 Simpson's Diversity Index of Canidae and Hyaenidae species between habitat and total area at Enashiva Nature Refuge, Tanzania for Spring 2017

Habitat	Woodland	Wooded Grassland	Grassland	Total Enashiva
Simpson's Diversity Index of *Canidae* and *Hyaenidae*	0.554	0.602	0.627	0.576

The area with the highest biodiversity was the grassland with an index of 0.627. However, again the diversities were similar and the biggest and smallest had a difference of 0.073. Total biodiversity of Enashiva with all occurrences included was 0.576. The total biodiversity of Enashiva calculated for comparisons to previous studies was 0.534 when only accounting for the den occurrences and occurrences found on walking transects. The difference between these two diversities was 0.042.

There was a total of 15 dens found at Enashiva during this study period (see Appendix B, Figure 5 for map of den locations). Of those 15 dens 73.3% of the dens were found in the woodland habitat (11/15). There was 13.3% of the dens found in the wooded grassland (2/15). Finally, there was 13.3% of dens also found in the grassland (2/15). Of the 15 dens found 60% were hyena dens (9/15). While 26.7% were jackal dens (4/15). Finally, 13.3% of the dens found were bat-eared fox dens (2/15).

A two-tailed t-test was used to compare the occurrence of dens between habitat. For example, the average number of dens found in the woodland was compared to those found in the wooded grassland. All the t-tests ran concluded that the results were insignificant ($p>0.05$). An ANOVA single factor test was also run to compare all the habitats at one time. This test calculated a significant p-value ($p=0.0456$). There was a significant difference between habitat for den locations based on this ANOVA test.

Discussion

This study looked to answer what is the distribution, diversity, and den locations of *Canidae* and *Hyaenidae* species at Enashiva Nature Refuge? And how has these changed from previous studies and how does it differ between habitats? It is important to answer these questions due to the benefit of top-trophic level predators have on biodiversity and the potential conflicts of top-trophic level predators with surrounding villages. This study broke down the question in two parts, first by comparing to previous studies and second by comparing within the results of this study. In addition, based on species observed this study gives suggestions why some species are present at Enashiva and why others are absent.

Discussion of comparison to previous studies

The previous studies used for comparison occurred in spring 2011, fall 2011, and fall 2012 (Bowles 2011, Gulka 2011, Cathcart 2011). This left a five-year gap period where occurrences of top-trophic level predators had not been studied at Enashiva. While this study focused on *Canidae* and *Hyaenidae* it is important to compare the results of this study to previous studies.

To keep results consistent when comparing this study to previous studies only the occurrences from the walking transect and the den location occurrences were used for comparisons. This is because the other studies did not have the additional methods that this study used.

While the total occurrence for each species were different and occurrences ranged from 126 occurrences of hyena recorded by Gulka 2011 to three occurrences of bat-eared fox recorded by Cathcart 2012. All other occurrences for the studies fell in this range. The 126 occurrences for hyena is significant based on the error bars (Figure 2). All the jackal error bars overlapped showing that occurrence of jackals has not significantly changed. Finally, the spring 2011 error bar did not overlap with the error bars from fall 2012 and this study for bat-eared fox. It does look like there was a big reduction in occurrence of bat-eared fox over these studies with the high being n=19 occurrences and the low being n=3 occurrences.

In addition, when looking at the average number of occurrences of each species from previous studies and comparing to this study it was found that there was no significant difference between the average number of occurrences. This means that the null hypothesis that there would

not be a difference in average occurrence of species between studies was supported. In addition, when comparing all the averages to the other averages at the same time it was again found to be insignificant. This means that the average total occurrence of species has not significantly changed over study periods. This would indicate that there are stable populations of these species at Enashiva that are not increasing.

Also, when looking at the calculated Simpson's Diversity Indexes there was not a big difference between calculations. Each study fell within the range of 0.556 and 0.450 index (Table 1). This shows that each study has a relatively similar total diversity for Enashiva. This would indicate that abundance and evenness and of species has not changed at Enashiva.

Based on these comparisons it is understood that there has not been a change in total abundance of species from the *Canidae* and *Hyaenidae* families. In addition, the diversity of these species at Enashiva has also not changed. However, when looking more closely at changes in individual species it appears that there was a change in hyena occurrences between spring 2011 and the other three study periods. In addition, there appears to be a change in bat-eared fox occurrences from fall 2011 when compared to fall 2012 and this study. The bat-eared fox occurrence decreased each subsequent year until it increased by one during this period.

There are several reasons that these results appear the way they do. This includes that during fall 2011 there was a spike in hyena populations resulting in increased occurrences. This could be from an increased resident population and possibly an increase in non-resident hyenas visiting Enashiva. However, it could also be due to poor sampling especially because the other three total occurrences for hyenas are similar. The bat-eared fox is more concerning because the first two studies had higher occurrence totals than the last two. This dip in occurrence of bat-eared fox could be that during this time some outside pressure was put on the bat-eared fox population resulting in a decline of occurrence. However, again it could be an error in sampling as the bat-eared fox occurrences are hard to observe.

The total occurrence and diversity of species between studies did not significantly change, indicating that the total occurrence and diversity are stable. Despite being a conservation area for longer there has not been a change in the occurrence average of *Canidae* and *Hyaenidae* species or in the diversities. Possible reasons include these species have reached a stable population where they are no longer increasing or decreasing significantly. They could have hit the carrying capacity of Enashiva and leveled back out. Enashiva is not the largest conservation

area, so it is reasonable that it cannot support a very high population of any of these species. While the occurrences have not significantly increased, they have not significantly decreased either, so conservation efforts seem to be stable. Although, it would be important to further monitor and keep an eye on the bat-eared fox population as this study shows that they could have suffered a decline and efforts should be made to support their population.

Discussion on this study looking at habitat and diversity

This section included all forms of methods used including walking transects, opportunistic walking, opportunistic driving, and game cameras. When including all those methods there were 182 occurrences of *Canidae* and *Hyaenidae* species at Enashiva. The hyenas had the highest occurrence of any species. This was expected as in previous studies hyena had the highest frequency of occurrence. In addition, hyenas are larger than jackals who would be their main competition. There are some other large predators in the area like leopards, but hyenas appear to occur at a higher frequency leaving them with little competition due to their ability to outnumber other predators. At one point during one of the night game drives of this study ten or more hyenas were sighted surrounding an eland carcass, so it appears Enashiva is supporting a strong population of hyenas. While this is beneficial to the hyena population it could harm other large predators in the area especially if there is interspecific killing among the predators, especially of young (Palomares & Caro, 1999). If future conservation goals are to promote the populations of other large predators at Enashiva then considering ways to control the hyena population could be beneficial. Culling of a species is one possible solution, but this action needs to be done carefully and the species highly studied prior to culling (Packer, 2009).

As of right now it appears that the hyena is the species that is providing the most top-down pressure on prey populations and thus shaping the ecosystem. Hyenas will scavenger, but they will also hunt and will kill prey up to 250 kg like the wildebeest (Sinclair, Mduma &Brashares, 2003). In addition, if hyenas are the most present species at Enashiva then they are the predator most likely to cause conflict in the surrounding villages. Understanding which species is likely to cause problems can allow for managers to better educate the surrounding area on conflict prevention or to know what compensation villagers might need after conflict.

While hyena had the highest occurrence the bat-eared fox had the lowest. Reason for this low occurrence could be that these animals are smaller than the other species found at Enashiva.

This would make it more difficult to find signs of these animals like spoor and scat since they are much harder to see than other species like hyenas and jackals. Most of the occurrences for the bat-eared fox were sightings. When sighted there were usually an average of three bat-eared fox. This is a normal viewing as family groups are primarily made up of one male and up to three related females (Foley et al., 2014. It would be important to continue to look at the occurrences of bat-eared fox to determine if there are lower occurrences from poor visibility of signs or if there is a concern for the population at Enashiva.

Despite the difference in occurrence numbers, after running the two-tailed t-test it was found that there was no significance between the average number of occurrence when compared to the other average number of occurrence for the other species. This could be due to a small sample set making it difficult to find differences between occurrences. However, based on the insignificance it seems that although there was the highest frequency of hyenas based on the average number of occurrence there was no difference between hyena occurrence and bat-eared fox occurrence. This means that Enashiva has similar occurrences of hyenas, jackals, and bat-eared foxes.

Based on Figure 3 it appears that there is significance between the occurrences of species in the woodland with the other two habitats. The standard error bars do not overlap with the corresponding species in both the wooded grassland and grassland. The most common habitat to find both *Hyaenidae* and *Canidae* species was the woodland habitat. While the wooded grassland and grassland had similar rates of occurrences and the standard error bars did not overlap. However, when the two-tailed t-test was applied to compare the average number of occurrences per habitat there was no significance between occurrence and habitat. In addition, the ANOVA test comparing all species and all habitats was insignificant. This means that each habitat does not have a significant difference in average number of occurrence of all the species in the habitat.

It was predicted that the hyena and jackal will not have a preferred habitat. However, the highest frequency of hyena and jackal occurred in the woodland and the standard error bars did not overlap the wooded grassland and grassland indicating woodland preference. Although there was not a significant difference in average occurrence of species between habitat. Occurrence of hyena and jackal might be found more frequently in the woodland at Enashiva because of the greater ability to see spoor and scat. In addition, it is possible that the woodland offers greater coverage and security for these animals especially considering past problems with human threats.

It was predicted that the bat-eared fox would occur more in the woodland and grassland, which was true, but there was no significant data to support this.

When the Simpson's Diversity Index was calculated for each habitat the grassland had the highest diversity index. This is because although the woodland had the highest occurrence of species the Simpson's Diversity Index looks at both abundance and evenness. This means that while the woodland would seem most diverse it appears to lean towards hyena occurrences skewing the index towards hyena. Habitats with greater diversity should have more evenness of species and not be dominated by one species. The grassland did not have as high of occurrences, but these occurrences were more of an even distribution between species. The total diversity of Enashiva for *Canidae* and *Hyaenidae* species was 0.576 which is higher than the one calculated for this study when only using walking transect and den location occurrences, 0.534. It seems that there was not much of a difference between calculations. The calculation using all methods seems to be a stronger choice for diversity because it has a larger sample set and covered more areas of Enashiva. It would be recommended to continue to use additional methods in the future.

Den locating was more difficult than anticipated. Heavy reliance on ranger knowledge of where dens were located caused many den locating walks to occur in the same areas as previously surveyed. In addition, bat-eared fox and jackal dens can look similar and they both can use dens previously made by other animals (Kamler, Stenkewitz, Klare, Jacobsen, & Macdonald, 2012). For example, they might take over a den created by springhares (*Pedetes capensis*), aardvarks (*Orycteropus afer*), or they might live in hollowed-out termite mounds under shrubs. These factors made observing these dens difficult. However, the results of this study, including the location of the den sites by habitat, was still analyzed.

While den abundance was lower, this year compared to previous years, it was still analyzed to get an idea of the distribution of den locations between habitat. The most dens recorded were of hyena due to their easily identifiable dens. Only two dens were found for the bat-eared fox, but they were confirmed bat-eared fox dens by observing bat-eared foxes returning to or leaving the den. When the number of dens per habitat were compared, there were no significant values. However, when the ANOVA test was run a p-value less than 0.05 was calculated ($p=0.0456$). Based on that p-value the null hypothesis that there is not a preference for one denning habitat can be rejected. Based on the results it appears that all three species prefer the woodland habitat for dens. Reasons this might be is due to coverage and security in the

woodland habitat. In the grassland and even wooded grassland dens are more exposed compared to woodlands.

Comparison of species present and species absent

As mentioned in the discussion of results three species were identified by primary observation sightings including the spotted hyena, black-backed jackal, and the bat-eared fox. However, rangers did mention that there are some striped hyena and side-striped jackals present at Enashiva (Alias Thomas, Personal Communication, April 15, 2017). In addition, there are packs of African wild dog in the surrounding areas of Enashiva that occasionally visit Enashiva. The expectation for this result was that this study would find the mentioned three species that were observed. This was primarily due to previous studies' findings (Bowles 2011, Cathcart 2011, Gulka 2012). While it was believed, there could be a possibility of finding the other species at Enashiva because prior studies had not listed them as present, it was not expected. However, when looking at the range of the species it makes sense that rangers at Enashiva have found these other species (IUCN, 2016).

Potential reasons that there were less sightings of these other species could be that they have lower populations at Enashiva. In addition, the African wild dog is not known to have a resident pack at Enashiva, so it was unlikely that occurrences for this species would be found during this short study period. A potential reason that no side-striped jackals were sighted could be because they are more nocturnal than the other jackals in Tanzania (Foley et al., 2014). This means that the best chance for sightings of this species would be during night game drives, only five of which were performed over the study period. Also, the side-striped jackal is well adapted to living near human settlements meaning their occurrences could be closer to the edge of Enashiva, which was surveyed less than the core. Finally, it is possible that there was misidentification of this species during sighting occurrences and been confused for the black-backed jackal.

For the striped hyena, it is near threatened according to the IUCN. It is believed that the areas that have striped hyena populations have low densities (Foley et al., 2014). They are found in the Lake Natron area and prefer the dry open land or the acacia shrubland. It is possible that there are striped hyenas at Enashiva since it is near their population ranges. A reason there might not have been any sightings is because like mentioned they occur in low densities in the areas

they inhabit. Also, they seem to prefer a different habitat than the ones investigated during this study, but are present at Enashiva. These additional species that have been seen at Enashiva in the past, but were not seen does not mean they were not there. While there were no sightings some of the spoor and scat could have belonged to them and counted as occurrences. However, due to similarity between spoor and scat of species, like the striped hyena and spotted hyena or the side-striped jackal and the black-backed jackal, it was not possible to distinguish between species.

Limitations, biases, recommendations

There were several limitations and biases in this study. Due to a short time period the data collected was a small data set. With a longer time frame this study could get a more representative sample of the *Canidae* and *Hyaenidae* species at Enashiva. In addition, due to limited resources traditional monitoring methods of carnivores were not used like radio collars. Instead walking transects and other methods were used that were not as randomly sampled and accurate. Also, due to the shape of Enashiva some areas were studied more than others.

Another bias is there was a heavy reliance on the ranger for identification of spoor and scat. Also, a reliance on the ranger for den locations and den identifying. While the ranger is believed to be correct in identification there could still be human error in these identifications. Also, due to difficulty of distinguishing spoor difference between similar species like the spotted hyena and striped hyena the occurrences of these species fell under the same encompassing category as hyena. There could also be a disproportionate occurrence viewing of some species than others because of the ability to see occurrences of these species. For example, it is much easier to see and identify hyena spoor than it is to see and identify bat-eared fox spoor due to differences in size. Also, habitats could have disproportionate occurrences because in some habitats it is easier to find occurrences than others. For example, it is easier to find spoor in the woodland habitat than the grassland due to the animal paths and soil.

Based on these results *Canidae* and *Hyaenidae* species distribution, diversity, and den locations have not significantly changed from previous years. In addition, there is not a significant difference between occurrences of these species between habitat. Although, it does appear that the woodland habitat is the preferred habitat for dens. Due to these results, it appears that the conservation plan of Enashiva has not affected the *Canidae* and *Hyaenidae* populations,

but rather they have remained stable at Enashiva. Depending on the goals of future conservation and biodiversity at Enashiva possible recommendations for improved *Canidae* or *Hyaenidae* occurrences would be to conserve the habitats required for these animals. In addition, reduce the number of human threats to these animals like herders passing through the area, which there were a lot during this study period. However, if the conservation goal would be to increase the number of occurrences of other species, Enashiva should look in to methods of controlling hyena populations and possibly jackal populations. Hyenas in large numbers can outcompete other predators and predators are known to perform interspecific killing of young. One example are jackals who could be putting pressures on the bat-eared fox populations by competing for denning sites and possibly killing bat-eared fox young (Kamler, Stenkewitz, Klare, Jacobsen, & Macdonald, 2012).

It is also predicted that the most problematic species for Enashiva when it comes to human-wildlife conflicts would appear to be hyenas. Hyenas seem to have the highest abundance. Hyenas have also been documented predating on livestock (Lyamuya, Masenga, Fyumagwa & Roskaft, 2014). Jackals can also cause potential conflicts because they too can predate on livestock. By knowing that these two species occur in high frequencies at Enashiva allows for mangers to better prepare for these potential conflicts with the surrounding villages.

Future recommendations for studies include to continue to monitor these species and other predators to understand how the Enashiva ecosystem is changing. If future management plans are interested in increasing the biodiversity of other large predators it would be important to study whether the *Canidae* or *Hyaenidae* species are preventing other top-trophic level predators from residing in Enashiva. Due to the limitations of den locating a more detailed, systematic, and up-to-date map would give a better idea of the preference of denning habitats for these species. It is also recommended that future studies use all available data collected methods especially if the study period is short to obtain a larger data set. Finally, due to the proximity of Enashiva to surrounding villages and its value as a grazing area for herders it could be beneficial to survey the surrounding villages to understand the conflicts with wildlife. In addition, looking at the usage of Enashiva as a grazing area for primarily Maasai from both Tanzania and Kenya.

Conclusion

Due to rising pressures on ecosystem including increasing populations, encroachment, and resource demand it is important to monitor ecosystems for change. It is also important to monitor the biodiversity of an area especially when the area is home to top-trophic level predators like species from the *Canidae* and *Hyaenidae* families which can influence the ecosystem. These animals and areas are at risk for degradation, so by studying the areas and understanding the species present, improvement to conservation management plans can be made, especially in areas where there is risk of human-wildlife conflict. This study's goal was to provide information including changes in occurrence frequency of species from the *Canidae* and *Hyaenidae* families. Also, habitats where these species are likely to be found and thus habitats that should be monitored and conserved.

This study found that occurrences of *Canidae* and *Hyaenidae* hyena species at Enashiva have remained relatively stable while the diversity for these families has also not fluctuated. This concludes that populations of these species at Enashiva have neither drastically improved, or decreased leaving the populations relatively stable. In addition, these species can be found in all habitats at Enashiva with the woodland habitat being the habitat with the greatest dens. To ensure that these species remain at Enashiva it is important to conserve these woodland and other habitat areas by preventing degradation and exploitation. While hyenas, jackals, and bat-eared foxes are important parts of an ecosystem, if future goals are to increase other predator populations to increase biodiversity at Enashiva. Then more studies will need to be conducted to look at the effects of these species on other predators' opportunities to reside at Enashiva. In addition, by understanding which species are present at Enashiva management can better predict future human-wildlife conflicts in the surrounding area. Habitat fragmentation for ecosystems are becoming serious problems for wildlife worldwide. To protect species, more areas need to be conserved for wildlife, especially for top-trophic level predators who are greatly affected by loss of habitat. Continuation of monitoring these ecosystems are key to save top-trophic level predators and to save the biodiversity of these important ecosystems.

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Appendix

Appendix A: Map of walking transects used at Enashiva Nature Refuge

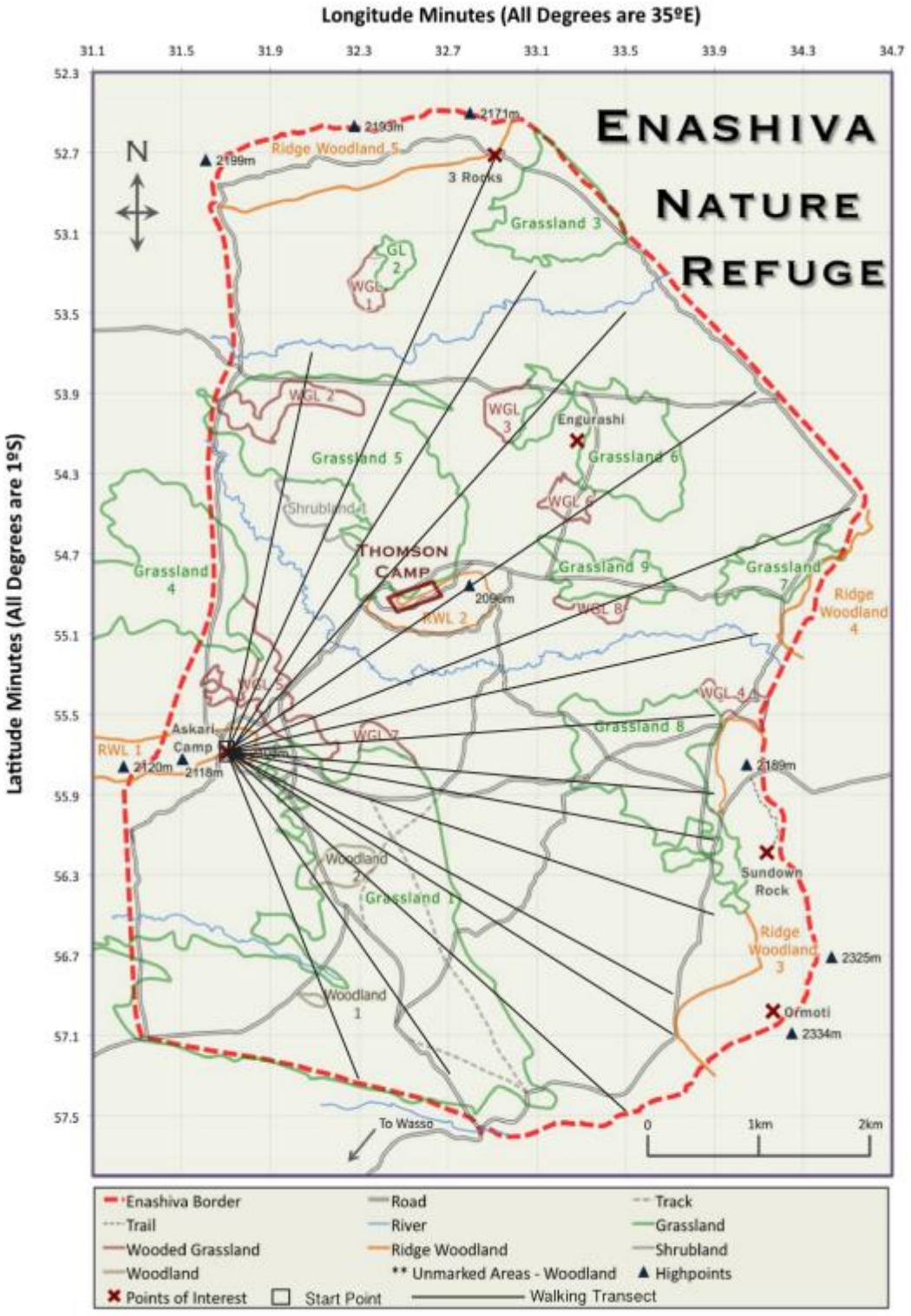

Figure 4 Map of Enashiva Nature Refuge with the 16 walking transects used during the study period from April 1st to April 20th, 2017

Appendix B: Map of den locations of hyena, jackal, and bat-eared fox at Enashiva Nature Refuge

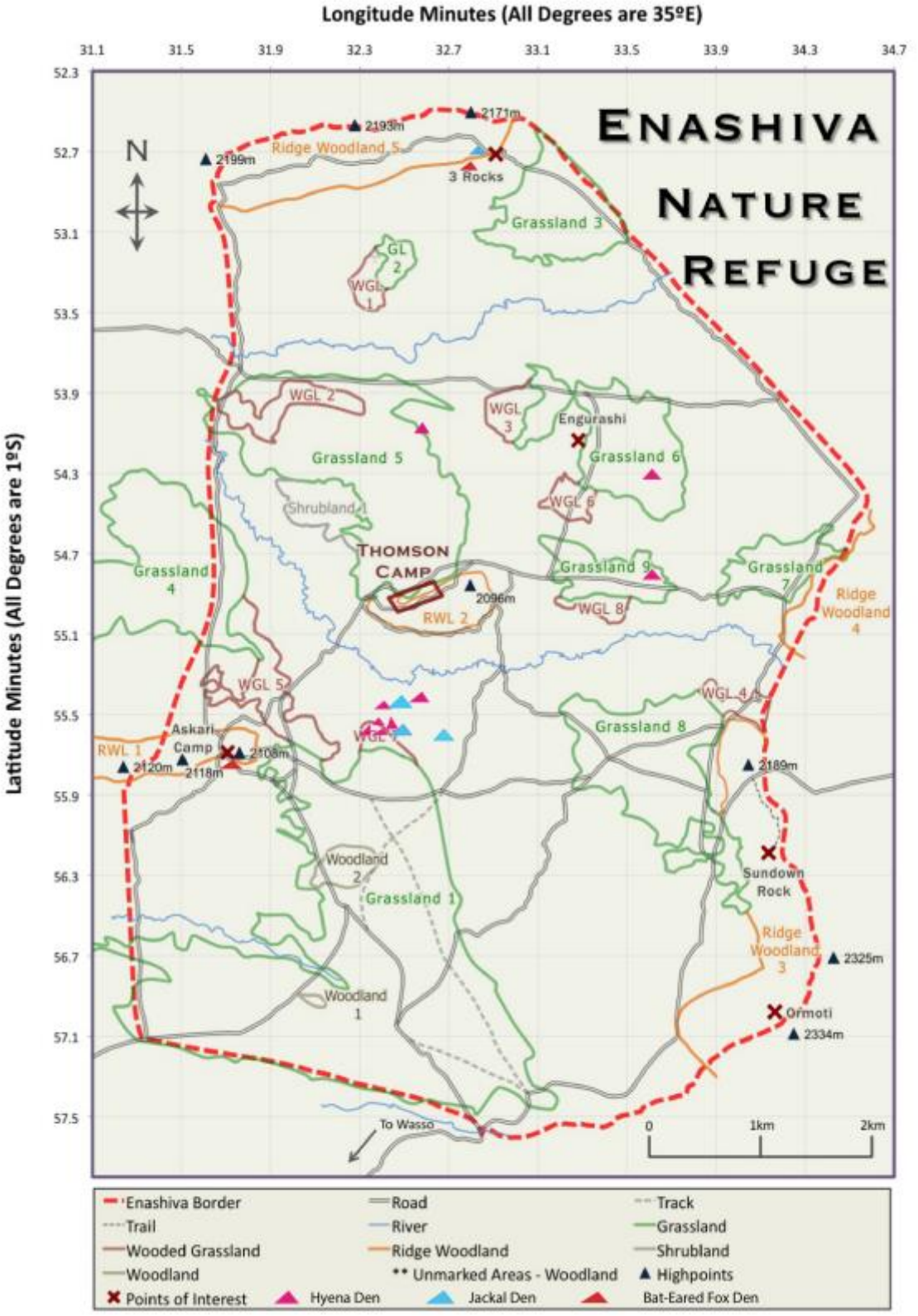

Figure 5 Map of den locations found for hyena, jackal, and bat-eared fox at Enashiva Nature Refuge, Tanzania

Appendix C: Table of P-Values Calculated

Table 3 Comparison and type of statistic tests run to determine significance in study

Comparison and Type of Test	**Comparisons**	**P-Value**
Average occurrence of species comparison between studies. Two-tail T-test with unequal variance	Spring 2011 vs Spring 2017	0.673
	Fall 2011 vs Spring 2017	0.421
	Fall 2012 vs Spring 2017	1
Average occurrence of species between all studies. Single Factor ANOVA	Spring 2011, Fall 2011, Fall 2012, Spring 2017	0.577
Comparison of average occurrence of species to the other species. Two-tail T-tests with unequal variance	Hyena vs Jackal	0.596
	Hyena vs Bat-eared Fox	0.195
	Jackal vs Bat-eared Fox	0.091
Comparison of average occurrence of all three species. Single Factor ANOVA	Hyena, Jackal, Bat-eared Fox	0.182
Average occurrence of species comparison between Spring 2017 habitats. Two-tail T-test with unequal variance	Woodland vs Wooded Grassland	0.264
	Woodland vs Grassland	0.294
	Wooded Grassland vs Grassland	0.742
Average occurrence of species between all habitats. Single Factor ANOVA	Woodland, Wooded Grassland, Grassland	0.210
Average occurrence of den comparison between Spring 2017 habitats. Two-tail T-test with unequal variance	Woodland vs Wooded Grassland	0.053
	Woodland vs Grassland	0.053
	Wooded Grassland vs Grassland	1
Average occurrence of dens comparison between all habitats. Single Factor ANOVA	Woodland, Wooded Grassland, vs Grassland	0.0456