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The Optimal Foraging of Equus burchelli at Enashiva Nature Refuge

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SIT Study Abroad

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Abstract

Within the country of Tanzania lies a vast ecosystem known as the Serengeti. This unique landscape, primarily of grasslands and woodlands, shapes the seasonal feeding habits of the abundant wildlife that call the area home. While these feeding habits on a large spatial scale are well understood, such behavior within a specie's specific environment remains of interest. With the theory of optimal foraging in mind, which considers how animals should look for and select food (Green, 1990), I studied the foraging habits of resident Burchell's zebra (*Equus burchelli*) by observing if they move and forage among distinct resource patches within their environment of the greater Serengeti region. To do so, I conducted 84 hours of data collection in which I followed herds of zebra, of whom were selected through nonrandom opportunistic sampling. During such follows the herd's GPS position was noted every five minutes and behavioral scans of the majority of the group were done simultaneously. The data was then mapped into five separate zones within the study area and was analyzed using a chi-squared goodness of fit test with a Poisson distribution. The test yielded significant results (p = < .01), supporting the noticeably uneven distribution of the herds' foraging positions within each zone. These results, thus, support the idea of distinct resource patches within the *Equus burchelli*'s environment.

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Introduction

As the second largest continent on Earth, Africa boasts an extreme abundance of wildlife, some of which unique to the rest of the world. Within this African-specific group includes a type of equid known as the zebra, of which include three different species: Grévy's zebra (*Equus grevyi*), the mountain zebra (*Equus zebra*), and Burchell's zebra (*Equus burchelli*). The three's range spreads across the continent, spanning the reaches of and crossing multiple countries and a variety of habitats.

The country of Tanzania, along the continent's eastern coast, lies in the upper half of *Equus burchelli*'s range, which runs from the southeast part of Sudan down to Angola and South Africa. There, dissimilar to its other members, the species calls home mostly to savannah habitats. Ranging from "treeless short grassland to tall grassland and open woodlands," these areas are where the zebra spends most of its day, over sixty percent of it in some studies, grazing. Such behavior proves necessary given their eating habits, which requires it to be both excessive, in order to make up for a "less efficient digestive system" (Estes, 1991), and grass dependent, fulfilling around ninety percent of their overall diet (Grubb, 1981). And while this ideal habitat for the zebra finds itself over various sections of Tanzania, one of its more popular locations is in the northern part of the country, within the Serengeti ecosystem.

The Serengeti ecosystem is not only a prominent destination for just the grazing zebra but for most other grazers as well. The ecosystem they live in consists of an almost fifty percent split in area between the plains in the south, which are unable to grow trees due to shallow alkaline soils (de Wit, 1978; Belsky, 1990), and the woodlands in the north. Across this area, however, is a vast grassland whose growth is dictated by an annual rainfall gradient, increasing as it moves from the short grasslands in the south (receiving between 400-600mm of annual rainfall), the intermediate grasslands in the middle (receiving between 600-800mm of annual rainfall), and the long grasslands in the north (receiving more than 800m of annual rainfall) (McNaughton, 1985). Grazers, such as the *Equus burchelli*, are found at all grassland levels during such rainfall, with continuous wet season grazing from migrant herds in the short grassland, resident herds in the intermediate grassland, and both herds in the long grassland during the dry season, where growth can still continue (McNaughton, 1984).

These rains, which are tracked by grazers "with considerable accuracy", tend to come about stochastically. Thus, when they arrive at a certain area, the area becomes "an extremely productive forage resource." Seeing as it is in their best interest to receive the most worthwhile forage, grazers, as a result, move to these resourceful locations when the rainfall occurs to reap its benefits. This creates a noteworthy correlation between grassland productivity and grazer density, which increases when there is rain and decreases when there is no rain (McNaughton, 1985).

In addition, during these events of grazing activity on rain-fallen areas, the grazers present "exert a powerful controlling influence" on the composition of the occupied grassland by enriching the underlying soil they forage upon (McNaughton, 1983). Within the various layers of the foraged soils are certain nutrients, such as calcium or sodium. Some species prefer certain nutrients to others based on their dietary needs. While foraging, they may associate with "and perform better in" foraging patches high in their desired nutrient, which "tends to progressively enrich the occupied spot." They may also forage in a patch not of their preferred nutrient, and, as a result, enrich the spot with the nutrient they prefer, differentiating the nutrients of the patch accordingly (Snaydon, 1970). These effects on the soil composition not only have both short term results, such as urination and plant nitrogen content, and long term results, such as the effect of constant nutrient differentiation overtime, but also play a role in patterns of spatial distribution among foraging patches (Jarmillo and Detling, 1988; Georgiadis and McNaughton, 1990).

For migrants, this idea is dependent on the seasons. The rainfall gradient discussed earlier that increases as it moves from the southern part of the ecosystem to the north is coupled with a grassland nutrient gradient that, in contrast, decreases as it moves from the southern part of the ecosystem to the north. The heavier wet season rains in the north create the long grassland, which lack nutrient quality, but in the dry season provide for an abundant source of foraging. The lack of rain in the south creates its short grassland, proving disadvantageous during the dry season, but, with its richer nutrient quality, is beneficial during the wet season when rains are present. Thus, migrant herds tend to occupy the short grasslands in the wet season and the long grasslands in the dry season (Fryxell, 1995).

For residents in the Serengeti ecosystem, this idea is more regional due to their "residency", and depends on rainfall more than the particular season (Campbell and Hofer, 1995). Resident herds remain in the intermediate grassland, benefitting from the sufficient wet season rains and following the "sporadic showers" in the dry season (McNaughton, 1985).

These spatial distribution patterns of foraging patches for migrants and residents, however, are on a relatively large scale, a scale that takes up a major portion of the Serengeti ecosystem. What about their spatial distribution pattern of foraging patches on a smaller scale, such as in a specie's specific environment? If a species prefers certain nutrients to others, wouldn't that, amongst other criteria, affect where they choose to forage within their environment, thus creating a pattern of distinct resource patches? The theory of optimal foraging, in a similar way, asks "How should animals look for and select food?" (Green, 1990) I plan to test such a combination of questions on resident *Equus burchelli* located within the greater Serengeti ecosystem, and predict that the presence of distinct resource patches will be evident by the species' continued pattern of foraging at these certain spots within the study area.

Site Description

Located east of Serengeti National Park and west of the town of Wasso, at 1°56’9.03” S and 35°34’0.64 E, the Enashiva (meaning “happiness” in Kimaasai) Nature Refuge is comprised of 12,600 acres of land rising to around 6,600-7,000 feet above sea level. Its wooded savannah, riparian, and grassland habitats are home to over 40 species of mammals (including *Equus burchelli*) and over 130 species of birds. And keeping all of this protected and sustained are the efforts of the staff run by Thomson Safari Company.

Starting as a tourism company out of Arusha in 1981 and now operating throughout Tanzania ever since, Thomson Safari Company acquired Enashiva, formerly known as Sukenya Farm, in 2006 from Tanzania Brewing Ltd. Prior to its selling, the brewery owned the land starting in 1984 with the intention of using it for large-scale barley farming. Such production ceased in 1992, however, when animal migratory activities became too much of a disturbance for the agriculture.

Figure 1: Location of Enashiva Nature Refuge

Additionally during this time the land was also being used for pasture by Maasai pastoralists from around the area, and, over time, it would become an integral part to their livestock grazing. Thus, when the land was turned over into a private nature reserve in 2006 and pastoralist activities of the last twenty years were now excluded, surrounding villages became relatively upset. As a result of this public outcry and years of countless lobbying efforts, the Ngorogoro District Council made a decision in 2009 to reopen the land for community use, where today many local Maasai pastoralists are allowed to graze and water herds during the dry season (Yamat, 2013).

This site was chosen for the study due to its abundance of *Equus burchelli* and the ease of being able to observe and follow them with just the accompaniment of an askari. With the large number of *Equus burchelli* present at the location and the vast amount of land available to them, Enashiva makes for an ideal place to conduct a study based on observing such a species within their environment.

Methods

Procedure

The following procedure and data analysis were adopted from Sloan (2013), with slight changes made for the relevance of this study. In order to study the optimal foraging theory on zebra within Enashiva Nature Refuge, I conducted 84 hours of data collection, approximating to six hours a day for fourteen days. On each day three hours was done in the morning (7:30am-10:30am) and another three hours was done in the afternoon (2:30pm-5:30pm). During these three hour time periods, I did herd follows (≥6 individuals) of zebra on foot while being accompanied by an askari. During these herd follows, which were selected through nonrandom opportunistic sampling, I marked the herd's GPS coordinates every five minutes and, additionally, did simultaneous scan sampling of the majority of the herd's behavior with the use of the ethogram in Table 1. The method of scan sampling worked well given the fact that group behavior was being looked at, not individual behavior. The GPS also worked well, though due to the limitation of physically not being in the exact location of the herd the coordinates noted were those that mirrored the movements of the herd and their relative position with reasonable accuracy.

Behavior	Definition
Foraging	Orientation of head towards the ground with the head moving in a sweeping motion to browse and intermittently place food in mouth followed by chewing and swallowing
Moving	Sustained locomotion ranging from walking to galloping
Resting	Lack of motion or other actions in a sitting or standing position; includes ruminating
Vigilant	Raising of head accompanied by viewing surroundings, sniffing the air, and/or perking up ears
Other	Any behavior not listed in the ethogram including, but not limited to nursing, aggressive behaviors, and affiliative behaviors

Table 1. *Ethogram of Behaviors Collected on Equus burchelli*

Data Analysis

To analyze the collected data, GPS coordinates for where the majority of the herd's behavior was foraging were taken from the scan sampling data and plotted on a Google map of Enashiva Nature Refuge. This area was then divided into five separate zones, of similar area measures, where foraging positions tended to cluster. Each zone consists of a plotted grid where each plot measures 625 m^2 in area, which was based on the observed spatial arrangement of the herd and their land occupation as a whole at any given point during the follows. A chi-squared goodness of fit test with an α of .05 then compared the results with a Poisson distribution to analyze the GPS coordinates within each zone. This analysis would then show the presence or lack of resource patches in the environment of the separate zones by determining if such foraging points were arranged in a significantly different arrangement than the expected random distribution.

Results

The chi-squared goodness of fit test compared with the Poisson distribution yielded significant results (where $p = < .01$), as can be seen in Table 2. These results show that points within the plotted grid of each foraging zone are unevenly distributed, indicating that they are, instead, clustered, which supports the presence of distinct resource patches foraged by the observed herds of zebra. Figure 2a displays the map of the overall study area with the numerous points of foraging by the observed zebra herd. Figure 2b displays the same map with the defined boundaries of each foraging zone. Figure 2c adds to the map of 2a with the inclusion of movement points observed by the herds of zebra, indicating their movement between resource patches, and Figure 2d provides the addition of the foraging zone boundaries to the map of 2c.

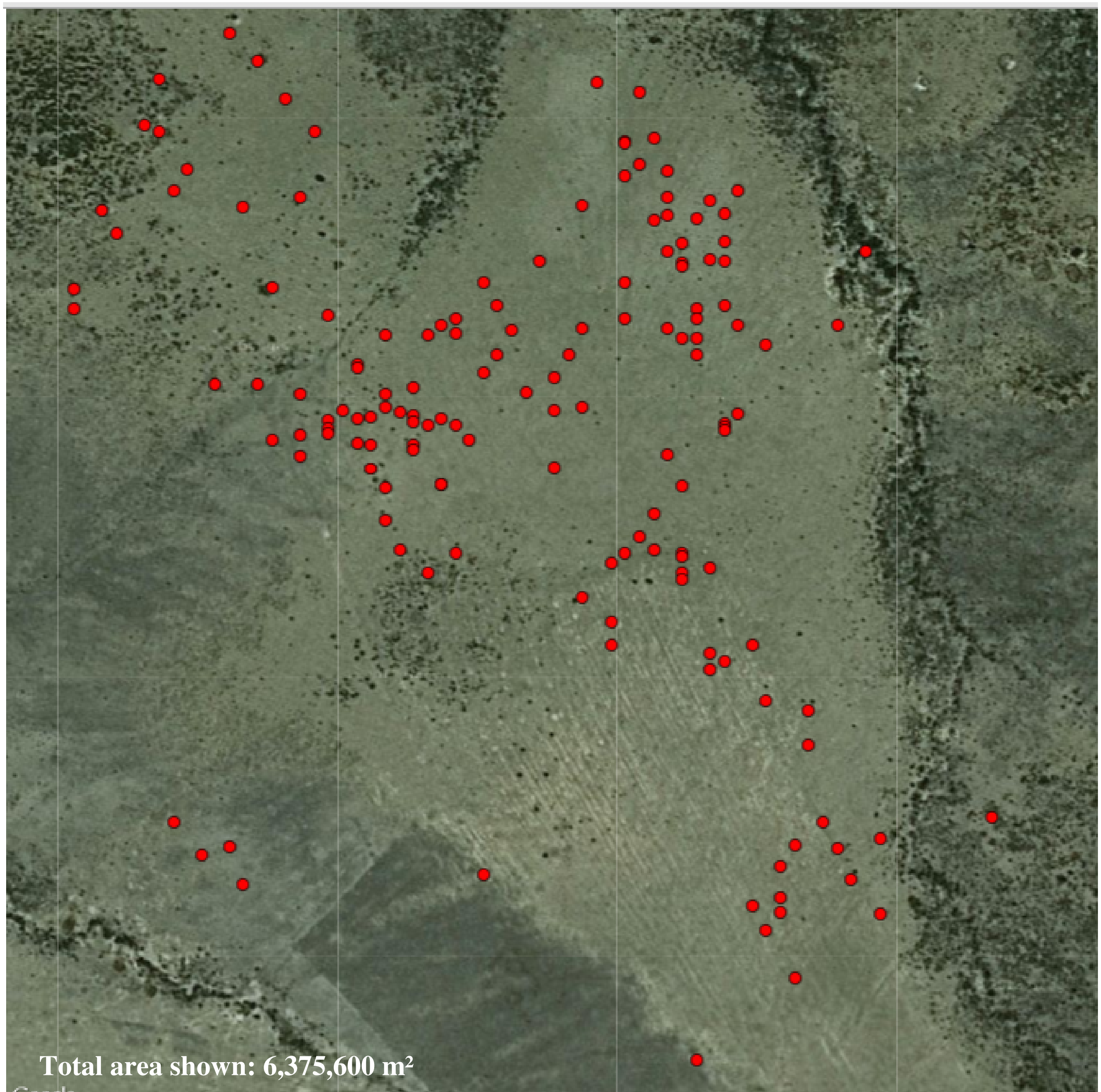

Figure 2a: Map of the overall study area, where the red dots indicate the points of foraging of the observed zebra herds.

Foraging Zone:	**1**	**2**	**3**	**4**	**5**
Total Area (m²):	210347.238	188978.020	207149.335	232273.232	283419.194
# of Grids:	336.556	302.365	331.439	371.637	453.471
# of Points:	19	37	51	24	16
Poisson Results (*p* value):	6.1647E-116	2.40993E-83	3.02079E-82	3.3044E-124	1.8193E-168

Table 2. *Characteristics of Each Foraging Zone with its Respective Results*

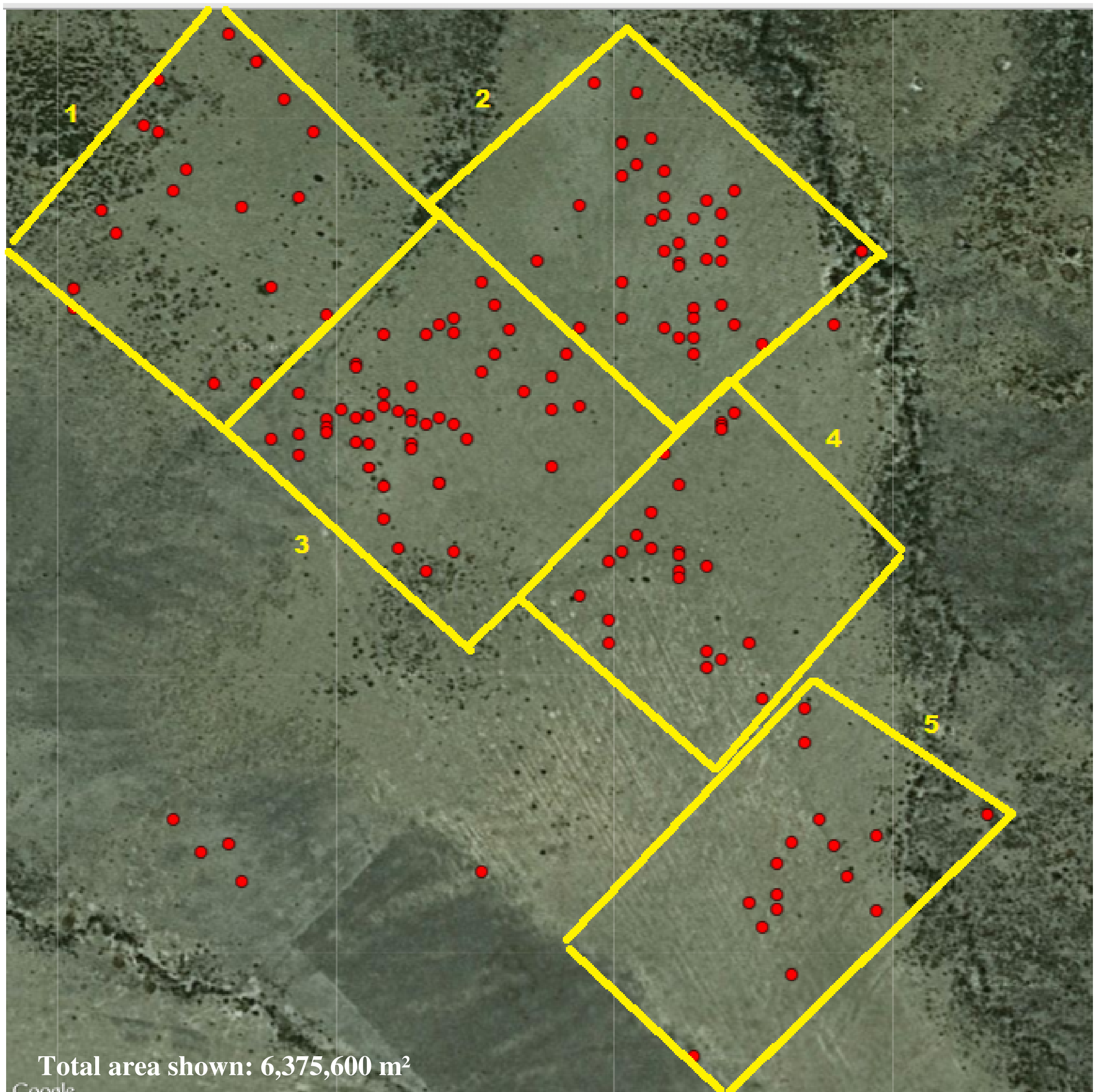

Figure 2b: Same map as in 2a, now with the addition of the defined boundaries separating each foraging zone. Zone boundary designation was based on noticeable clustering patterns of the foraging points within the overall study area.

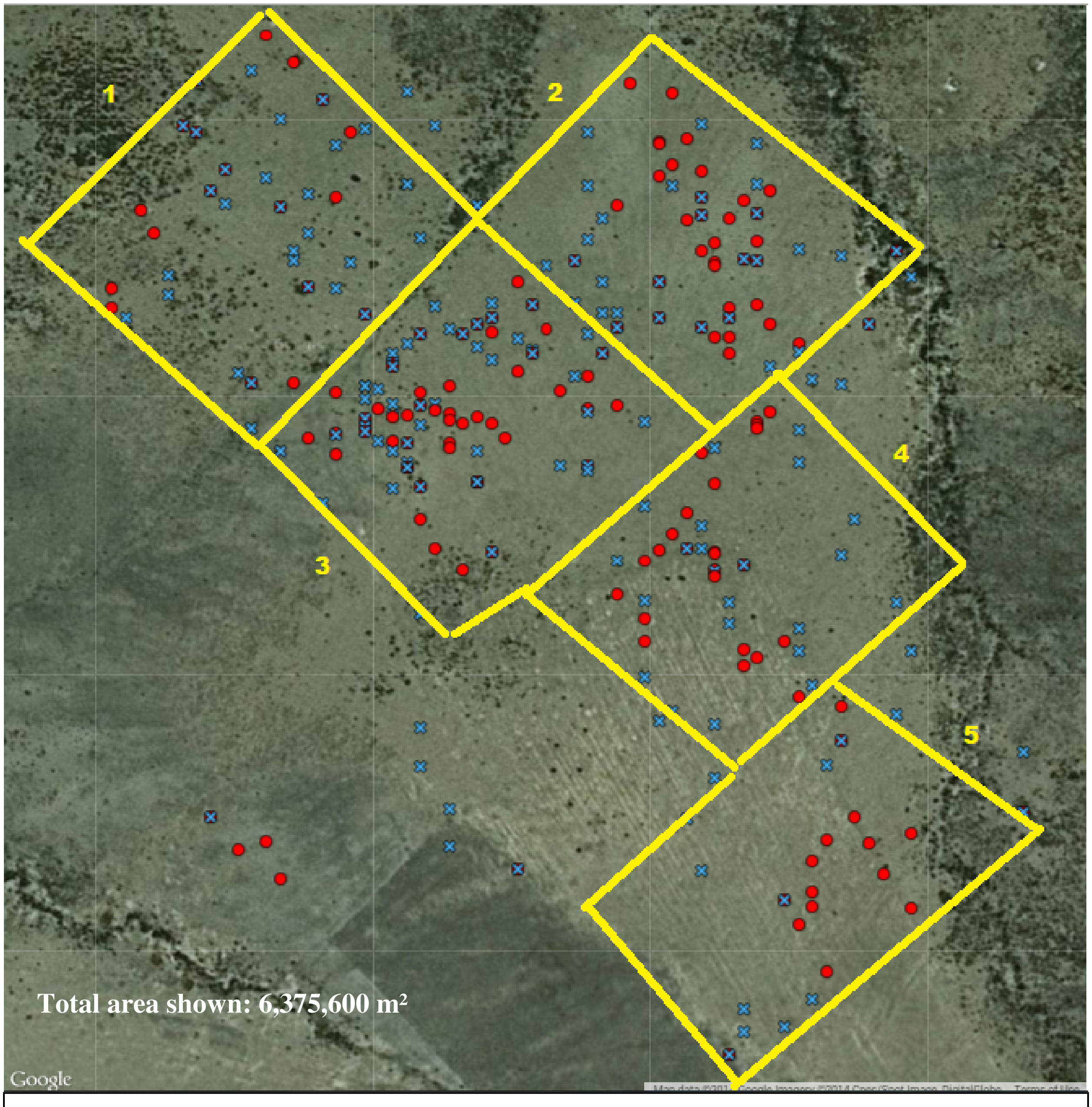

Figure 2d: Same map as in 2c, now with the addition of the boundaries for the separation of foraging zones.

Discussion

The results of the conducted study were significant ($p = < .01$), which supports the hypothesis that resident *Equus burchelli* do forage according to distinct resource patches within their environment. Evidence of this can first be seen in Figure 2a, where such patches are located throughout the study area in a noticeably clustered form. The points of resource patches move from the northwest/north-central portion of the study area to the southeastern portion, with only a few outlying points outside of that trend. Because the trend encompasses such a specific part of the whole study area, an area with an extremely large range of 6,375,600 m^2, boundaries of similar sized foraging zones were formed to emphasize each area within the trend where clustering was evident, which can be seen in Figure 2b.

Support for this trend of southeastern-bound resource patches is strengthened with the addition of observed movement points of the zebra herd, seen in Figure 2c. These points of movement display how the zebra move from one specific resource patch to the next, and over time a trend of visiting the same patches and movement in a consistent direction forms. Additionally, with zone boundaries in place in Figure 2d, it can be seen that movement points tend to remain primarily within the zones than outside of them, providing even further support for the presence of distinct resource patches within each zone.

A key trait surrounding this phenomenon is the fact that these foraging and movement points take place almost entirely in open grassland. The studied zebra herds were very rarely ever seen entering heavily wooded areas; the closest encounter to such a habitat was foraging in few spots near its edges. As stated in the introduction, zebra, specifically *Equus burchelli*, have a diet consisting ninety percent of grass (Grubb, 1981). Thus it would only be pertinent for them to spend so much time occupying grassland since it plays right into their dietary needs.

Within this vast expanse of grassland, though, why do the zebra forage in the distinct patches that they do? The introduction gave a glimpse of how grazers in general follow certain underlying soil patterns, but what about for *Equus burchelli* and Enashiva specifically? Unfortunately grass species in the study area was not collected, so the soil patterns from the study cannot be determined. Literature, on the other hand, does provide some insight on zebra and landscape structure of the region where Enashiva is located.

While conducting the study, there were times where zebra and other grazers, of whom were typically wildebeest, were associated within the same group. Studies on the zebra of the Serengeti ecosystem suggest that their diet of various plant parts on the top layer of grasses, such as “grass leaves, sheaths, and stems”, make way for the feeding habits of these other grazers. In conjunction, wildebeest and other grazers will act in the same way, providing “different strata in the herb layer” for the zebra to forage upon (Grubb, 1981). Such a relationship makes sense given their harmony amongst one another within the same environment. The feeding habits of zebra then, in addition to possible underlying soil patterns, must stem from this type of mutualism as a result.

Of course one would think the land that these processes are done on would be affected in some way. Enashiva lies on the eastern plains of the Serengeti ecosystem, where the “structure of the grassland is strongly influenced by grazing” (McNaughton, 1983). Some studies consider that this influence may possibly be leading to overgrazing due to both “changes in grass species” and a rise in browser activity (McNaughton, 1983; Sinclair, 1979). While not much from this study can be said about the change in grass species, major browser activity was definitely noticeable at the site. In accordance with this observation, other studies have pointed out how pastoral land use in this particular part of the greater Serengeti ecosystem “has resulted in significant wildlife populations" (Campbell and Borner, 1995). It was certainly noticed that the surrounding communities of Enashiva did boast a large amount of cattle grazing from the Maasai, moving through the various pastures throughout the day. While there was no directly affective interaction observed between grazing cattle and the zebra at the time of the study, such practices over a long term period of time may have some influence on resource richness, or lack thereof, in certain patches, and by that way impact where zebra choose to forage.

Another mentionable observation during the study was the group sizes of each followed zebra herd. Most groups, with some thoroughly integrated into wildebeest herds, were around seven or eight individuals, with no group ever having less than six or more than twelve except for two occasions. Literature on resident zebra suggests that densities should be higher given the smaller range (Grubb, 1981). This contradiction could be due to a variety of reasons. One reason could be caused by the times where wildebeest were part of the group, creating more competition for foraging and, thus, driving away any potentially new group members. Another reason may be the time of day that the observations took place: Estes (1991) observed that "after reaching a pasture, zebra groups spread out and move somewhat independently the rest of the day", eventually congregating "back to the short grass areas in the late afternoon." Although his term of "late afternoon" is undefined, such a time could have been when the study usually ended, which was around 5:30 P.M. each day. Finally, personal communications with Reese Matthews (2014) brought about the idea that groups that were observed were zebra families rather than herds, making sense as to why the group was smaller than what it is assumed to be.

Overall, the study provided revealing insight to the optimal foraging of resident *Equus burchelli* and the spatial patterns of their feeding, with the hypothesis of the presence of distinct resource patches being successfully supported. With only fourteen days, though, the study could only cover so much. In addition to spending more time on the study itself, looking into the various grass species at Enashiva and possibly connecting some of them to the foraging by the resident zebra there would certainly contribute to the making of a more comprehensive study. Other factors that could provide further understanding would be interactions and possible influences on land processes by other grazers and cattle, and their possible effect on optimal foraging. A better knowledge of such concepts will only help to aid in the conservation and care for these unique lands and wildlife.

Limitations and Recommendations

Limitations:

- Accuracy of GPS coordinates of herd in comparison to observer's position
- Accuracy of scan sampling when observing a large group
- Visibility trouble when following herds through woodland areas
- Observer position's possible influence on herd behavior/position
- Boundary placement of each foraging zone
- Differences in area of each foraging zone

Recommendations:

- Basic understanding of statistics
- Understanding an appropriate distance to keep between the observer and the herd so not to influence their behavior/position
- A way to transfer the collected data directly from the GPS to a computer instead of taking the time to do it all manually
- For future study: a study on the possible differences in grass types among favored foraging spots of zebra

Conclusion

The Serengeti ecosystem boasts a unique landscape, hosting an abundance of wildlife whose feeding habits are dictated by both this landscape and the varying wet and dry seasons. While feeding habits are understood on a large spatial scale, not as much is known about such habits within a specie's specific environment. Thus, I set out to find more about any possible patterns through the species *Equus burchelli*. Using the idea of optimal foraging, the possibility of distinct resource patches within the zebra's environment was found through a statistical test of the conducted study. This test yielded significant results ($p = < .01$), thereby supporting the presence of distinct resource patches foraged by these zebra. With a better understanding of a specie's environment, one can better understand how to conserve and sustain such a species. This sort of knowledge, as a result, can then lead to countless benefits to the overall management of wildlife as a whole.

Works Cited

Belsky, A.J. (1990). Tree/grass ratios in East African savannas: A comparison of existing models. *Journal of Biogeography*, 17: 483-489.

Campbell K., and Borner M. (1995). Population trends and distribution of Serengeti herbivores: Implications for management. *Serengeti II: Dynamics, management, and conservation of an ecosystem*, 3: 142.

Campbell, K., and Hofer H. (1995). People and wildlife: Spatial dynamics and zones of interaction. *Serengeti II: Dynamics, management, and conservation of an ecosystem*, 5: 557.

de Wit, H.A. (1978). Soils and grassland types of Serengeti plains (Tanzania), Ph.D. dissertation, Agricultural University, Wageningen.

Estes, R.D. (1991). Zebras, asses, and horses. In *The Behavior Guide to African Mammals*, 235-246. Berkeley/Los Angeles, California: University of California-Berkeley Press.

Fryxell, J.M. (1995). Aggregation and migration by grazing ungulates in relation to resources and predators. *Serengeti II: Dynamics, management, and conservation of an ecosystem*, 3: 263.

Georgiadis, N.G., and McNaughton, S.J. (1990). Elemental and fibre contents of savanna grasses: Variation with grazing, soil type, season, and species. *Journal of Applied Ecology*, 27: 623-634.

Green, R.F. (1990). A comment on optimal foraging theory, University of Minnesota, Duluth, Minnesota.

Grubb, P. (1981). Equus burchelli. In *Mammalian Species*, 5. The American Society of Mammalogists.

Jarmillo, V.J., and Detling, J.K. (1988). Grazing history, defoliation, and competition: Effects on shortgrass production and nitrogen accumulation. *Ecology*, 69: 1599-1608.

Matthews, R. (December 2014). Study abroad faculty, World Learning Inc, Tanzania Wildlife Conservation and Political Ecology Program. Personal communication. Arusha, Tanzania.

McNaughton, S.J. (1983). Serengeti grassland ecology: The role of composite environmental factors and contingency in community organization. *Ecological Monographs*, 53: 291-320.

McNaughton, S.J. (1984). Grazing lawns: Animals in herds, plant form, and coevolution. *American Naturalist*, 124: 863-886.

McNaughton, S.J. (1985). Ecology of a grazing ecosystem: The Serengeti. *Ecological Monographs*, 55: 259-294.

Sinclair, A. R. E. (1979). Dynamics of the Serengeti ecosystem: Process and pattern. In *Serengeti: Dynamics of an ecosystem*, ed. A. R. E. Sinclair and M. Norton-Griffiths, 1-30. Chicago: University of Chicago Press.

Sloan, E.T. (2013). Optimal foraging in dry season resident *Connochaetes taurinus* at Enashiva Nature Refuge (Tanzania), School for International Training, Tanzania.

Snaydon, R.W. (1970). Rapid population differentiation in a mosaic environment. I. The response of *Anthoxanthum odoratum* populations to soil. *Evolution*, 14: 257-269.

Yamat, D. (2013). The Enashiva Nature Refuge: A catalyst for community-based conservation in Loliondo (Tanzania), Power Point presentation.