Spring 2024

Rock Hyrax: A study of hyrax energy budget and behavior near Randilen Wildlife Management Area, Tanzania

Alice Thompson
SIT Study Abroad

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Alice Thompson
Academic Director: Dr. Oliver C. Nyakunga
Advisor: Dr. Oliver C. Nyakunga
Co-Advisors: Oscar Paschal, Kaiza Kaganzi, & Jackson Kabeho
University of Vermont
Major: Zoology

Submitted in partial fulfillment of the requirements for Tanzania: Wildlife Conservation and Political Ecology SIT Study Abroad, Spring 2024

Acknowledgements

This project would not have been possible if it weren't for the many people who helped and supported me along the way. First and foremost, I would like to thank Dr. Oliver Nyakunga for being such a supportive academic director. Working tirelessly to make sure things ran smoothly, she not only demonstrated a passion for teaching but was also her dedication to accommodating every student's needs. I next want to extend a big thank you to Kaiza Kaganzi for his role in supporting my writing process and for always making me laugh even through the most difficult times throughout this project. I want to thank Oscar Paschal for being most helpful in refining the focus of my study and for his limitless flow of captivating stories and endless knowledge regarding wildlife. I want to give thanks to Jackson Kabeho for his many jokes, supportive presence, and for working tirelessly around the clock to make sure everyone's needs were met. Many thanks to Mama Juni and Mwima for the many hospital trips and for providing the best emotional support throughout this semester.

I also want to thank the manager of Randilen Wildlife Management Area, Meshurie Melembuki, for hosting me during my data collection period. Additional thanks to our Kiswahili teachers and the rest of the SIT staff with a special shoutout to Mama Angelina for her hard work behind the scenes. Last but certainly not least, I want to thank my fellow students for all their support and for making this journey one I will never forget. I am incredibly grateful for this opportunity and experience to study in such a beautiful country alongside such wonderful people.

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Abstract

Conducted at the gate of Randilen Wildlife Management Area (WMA), the purpose of this study was to contribute knowledge regarding rock hyraxes *(Procavia capensis)* through studying their energy budget and behavior. Rock hyraxes are small mammals belonging to the order *hyracoidea*. Despite being abundant across most of the African continent and parts of the Middle East, these herbivorous animals remain understudied in Tanzania. During the wet season of spring 2024, a total of 70 hours was applied to this research over the course of 10 days (April 7th to April 16th) using both qualitative and quantitative methods. The aspect of energy budget was defined as the hyraxes being in an inactive or active state, and behavior was measured through socializing or isolating behavior. After the data collection period, the data was analyzed for the frequency of each energy state and behavior. The results from this study show that the hyraxes at Randilen WMA spend most of their time in an inactive state which reiterates what previous studies have claimed, however, more research is needed to better understand these creatures. In addition to contributing to the overall understanding of hyrax behavior, studying hyraxes has the potential to aid behavior research in other gregarious species.

Keywords: Rock hyrax *(Procavia capensis),* Energy budget, behavior, Randilen Wildlife Management Area, Tanzania

Chapter I

Introduction

1.1 Background

Hyrax (*Procaviidae*), also referred to as dassies, are the only members belonging to the order *Hyracoidean* which includes three genera: The tree hyrax (*Dendrohyrax),* the rock hyrax (*Procavia), and* the yellow-spotted rock or bush hyrax *(Heterohyrax*). The genus *Dendrohyrax,* further consists of *Dendrohyrax arboreus, Dendrohyrax interfluvialis,* and *Dendrohyrax dorsalis* (Chase, 2012, p. 108). Despite their deceiving rodent-like appearance, the closest relatives to hyraxes have been identified as elephants (*Proboscidea)* and sea cows (*Sirenia*) (Chase, 2012, p. 108). Both descending from the common ancestor *Tethytheria,* hyrax and elephants have similar characteristics regarding their teeth and toes. Like elephants, hyrax have elongated incisors in addition to the feature of hoof-like nails (Karn, 2021). They range in size from 30-56 cm with a lifespan of approximately 12 years (Freeman, 2018, p. 4). Hyraxes have numerous predators including leopards, jackals, hyenas, snakes, and various birds of prey (Mbise, 2015, p. 3). Hyraxes are also known to be hunted by humans and used for their skin or medicinal purposes (Topp-Jorgensen, 2008, p. 64). Tree hyraxes can be found in forests of East, South, and West Africa in elevations up to 4,500 meters. Being solitary nocturnal animals, *Dendrohyrax* are incredibly skittish and difficult to observe (Freeman, 2018, p. 3). They have a plant-based diet that mostly favors the leaves of *Hegenia abyssinica*. *Dendrohyrax* also have distinct territorial calls that most often occur at differing periods during the night (Estes, 1999). In contrast from tree hyraxes, *Heterohyrax* and *Procavia* are diurnal and or crepuscular, living gregariously in colonies of between 25-60 individuals (Bordes, 2022, p. 3). While these two types of rock hyrax are distinct species, they often occur sharing the same space on kopjes (Smithsonian's National Zoo & Conservation Biology Institute). Rock hyraxes have the capacity to tolerate body temperature

shifts of up to 7-8 °C which helps conserve energy in extreme environments (Chase, 2012, p. 109). This ability allows them to inhabit a range of environments including most of Africa and sections of the Middle East (Chase, 2012, p. 109). Due to this range in habitat, rock hyrax are mixed feeders and eat a variety of different plants. During the wet season, grasses are readily available, allowing rock hyraxes to graze more frequently in addition to browsing in trees. Rock hyrax also have the capability to emit a large range of vocalizations with males having more complex vocal communications that "advertise a variety of attributes about the communicator to others; from attracting a mate, displaying the singers' identity, age, social status, and body mass, as well as signaling distress," (Koren & Geffen, 2009; Freeman, 2018, p. 4). *Heterohyrax* and *Procavia* colonies consist of a dominant territorial male with the loose association of peripheral males (Fourie, 1987, p. 91). Dominantly consisting of females, hyrax colonies benefit from a large population size which increases vigilance to predators (Mbise, 2015, p. 3). While foraging, an individual hyrax takes the post of a sentinel, keeping a look out for predators and warning the others of approaching danger with a loud shrieking noise (Chase, 2012, p. 109). They also rotate the position of sentinel to give each individual the opportunity to forage and feed. Limited to the safety of rock crevices and other cavities in which to hide, rock hyraxes can disperse up to 2km from their main shelter due to factors like food availability, and inbreeding and competition avoidance (Mbise, 2015, p. 4). The mating season of rock hyraxes usually spans from March to May peaking in April (Fourie, 1987, p. 95). During this time, territorial males are especially aggressive towards any peripheral male encroaching on the females in the colony. Described in a study of rock hyrax behavior in 1987, "An attempt by a peripheral male to follow a sub-adult female into her area of activity caused the territorial male to charge and chase away the peripheral male" (Fourie, 1987, p. 95). Female hyraxes reach sexual maturity after 16 to 17 months of age while males generally do not attain to puberty until after 28 months (Fourie, 1987, p. 92). Although males may reach sexual maturity earlier than 28 months, they are often prevented from mating by

older or territorial males (Fourie, 1987, p. 92). “At around 17–24 months, adolescent male rock hyraxes will be forced to disperse from the natal group and find their own group or join a bachelor group on the periphery of the natal group” (Freeman, 2018, p. 4). The gestation period of a rock hyrax is unusually long in relation to their size and lifespan, lasting from 6-8 months and resulting in a litter size of 1-3 (Freeman, 2018, p. 4). Although hyraxes are listed as of “least concern” by the IUCN, their occurrence on kopjes results in fragmented distribution which, in anthropogenically modified landscapes, may result in a greater extinction risk (Mbise, 2019, p. 672). Rock hyraxes are also known to use communal latrines, identifiable by the consolidation of fecal pellets and hyraceum which form middens. “Even though many colonies can easily be approached, their latrines (accumulated excrement and urine) are often out of reach in crevices or beneath boulders” (Barraclough, 1997, p. 22). When their latrines are accessible, however, they become remarkable sources for paleoenvironmental archives, as they are often well sheltered from the elements and are substantial in size (Barraclough, 1997, p. 22). Due to the lack of studies on rock hyrax, especially pertaining to Randilen WMA, studying the behavior of Tanzanian rock hyraxes is crucial for bridging existing research gaps and may pave the way for further exploration of their midden’s potential in contributing to climate change research.

1.2 Problem statement

Studies on rock hyrax have intermittently been conducted, in their inhabited regions of most African countries and parts of the Middle East. The studies that have been conducted, particularly in South Africa and Israel, were mainly limited to general hyrax population distribution and social structure (Fourie, 1987; Scott & Bousman, 1989; Chase, 2009; Chase, 2012; Serruya & Eilam, 1996). The few studies of hyrax behavior in Tanzania have mainly focused on the tree hyrax, which have drastically different habits of living (Topp-Jorgensen, 2008). While there have been a couple studies done in the Serengeti regarding rock hyrax (Mbise, 2015; Mbise, 2019), they focused more on presence or absences of populations. In one of the studies executed

in South Africa, it was observed that rock hyraxes spend 95% of their time in an inactive state (Fourie, 1987, p. 92). A later study referenced the previously cited source and made an addition to specify that during their inactive state, hyraxes are mostly found "crouching" and sitting (Serruya & Eilam, 1996). While the above scenario has been observed in other parts of Africa, little research has been dedicated to hyrax energy budget or behavior and it is unknown whether these stated above results are consistent with hyrax colonies residing in or around the Randilen Wildlife Management Area. Considering the species aloof appearance in academia and their ecological potential regarding paleoenvironmental archives, it is imperative to keep a straight documentation of rock hyrax in all known areas they inhabit.

1.3 Scope of the study

This study was conducted during the wet season of spring 2024 just outside of Randilen Wildlife Management. Over the course of 10 full days, data will be collected for 7 hours each day for a total of 70 hours. Despite there being three genera of *Procaviidae,* due to time and budget constraints this study will only focus on *Procavia* behavior.

1.4 Significance

The significance of this study is the contribution of knowledge regarding rock hyrax behavior in Tanzania. Understanding hyrax behavior has the potential to shed light on the environment they inhabit, their role in the ecosystem, genetic divergences in phylogenetic studies, and provide insight into the changing climate of Tanzania through their middens. With the rate and magnitude at which climate change is increasing, it's important not to overlook any possible opportunities such as paleoenvironmental archives that have the potential in leading to a better understanding of how climate change is affecting the world (Chevalier, 2020).

1.5 Justification

Given the significant gap in research regarding rock hyrax in Tanzania and in particular to Randilen Wildlife Management Area, more knowledge needs to be acquired in this location for an overall understanding of hyrax behavior. The knowledge from this study also has the potential to be a reference for future paleoenvironmental archive research and conservation efforts regarding the prioritization of certain environments and species. Since much is still unknown about rock hyrax behavior specific to Tanzania, and thus Randilen, this study is important for bridging the gap of knowledge and potentially discovering new insight into the structure and behavior of rock hyrax and their colonies.

1.6 Objectives

1.6.1 General

To assess the current behavior and energy budget of hyraxes residing on the edge of Randilen Wildlife Management Area (WMA).

1.6.2 Specific

I. To examine the rock hyrax energy budget through their activity states at the gate of Randilen WMA.

II. To assess the social behavior of rock hyrax at the gate of Randilen WMA.

1.7 Hypothesis

Hyrax will spend most of their time in an inactive state, mirroring results of other studies (Fourie, 1987; Serruya & Eilam, 1996).

Chapter II

Methodology

2.1 Study area description

Located in the Monduli District and Arusha Region of Tanzania, Randilen Wildlife Management Area (RWMA) occupies 31,200.68 hectares of land, bordering Tarangire and Lake Manyara. The WMA was established in 2012 and governed by eight local Maasai villages: Lolkisale, Lemoot, Oldonyo, Lengolwa, Mswakini, Nafco, Mswakini Juu and Naitolia. Originally formed by the four villages Mswakini, Mswakini Juu, Lolkisale, and Naitolia, the population of Randilen WMA members is approximately 18,093 with Lolkisale village being the most populated. WMAs are based on the concept of collaboration between local peoples and the government, where local people have rights over wildlife resources and in return the government can use the land to promote wildlife conservation efforts. The purpose statement of Randilen WMA is stated as follows, "To conserve the ecological biodiversity of RWMA as part of the Tarangire-Manyara Ecosystem and though sustainably tourism, benefit RWMA community members and adjacent areas."

2.1.1 Climate

The climate of Randilen is categorized as semi-arid, having an annual rainfall estimate of 500-800mm and a prominent dry season (RWMA Council, 2022). During the period of data collection, the temperature ranged from 64°F to 84°F. Most days were cloudy with periods of rainfall.

2.1.2 Fauna and Flora of Randilen WMA

An abundance of different fauna resides in Randilen including antelopes, elephants, lions, giraffes, leopards, and buffalo, in addition to a variety of bird species. The vegetation in Randilen

WMA consists of various types of woodlands, bushlands, grasslands, and seasonal swamps. This includes specific species of *Acacia tortilis*, *Acacia-Commiphora, Sclerocary birrea (Amarula), Adansonia digitata, and Terminalia brownii* (RWMA Council, 2022).

2.1.3 Study Site

The criteria for selecting this specific site were based in the consideration for the impact of my presence in the colony. The study site is situated at the gate of RWMA, with Google Earth putting the exact location at 3°42'33" S, and 36°5'27" E. This location is subjected to much human activity due to the many rangers and tourists moving around the area. This constant exposure to human presence is reasoned to have caused more acclimation to people than other more remote kopjes, positively effecting the study where physical presence might impact the hyrax's expression of authentic behavior. Additionally, previous studies have concluded that "hyrax population size is positively affected by human premises, possibly caused by fewer predators and higher food availability in these areas" (Mbise, 2015). This is also reason to believe that a larger population of hyrax reside at the RWMA gate, thus implying more opportunities to observe activity states and behavior, resulting in more accurate data. Consisting of a kopje, or large rock mound, and much vegetation coverage, this area is an ideal location for hyrax due to its many crevices and hiding places. The kopje of study stands overlooking RWMA and part of Tarangire National Park with a perimeter of approximately 760.27ft and an area of 45,996.06ft squared (Figure 1.).

Table 1. *Estimated distance from the fixed point of observation to the viewing range end, and to the bottom of the kopje structure*

	From fixed position to….	
Measuring unit	Feet	Meters
End of viewing range	93ft	28.3464m
End of kopje	121ft	36.8808m

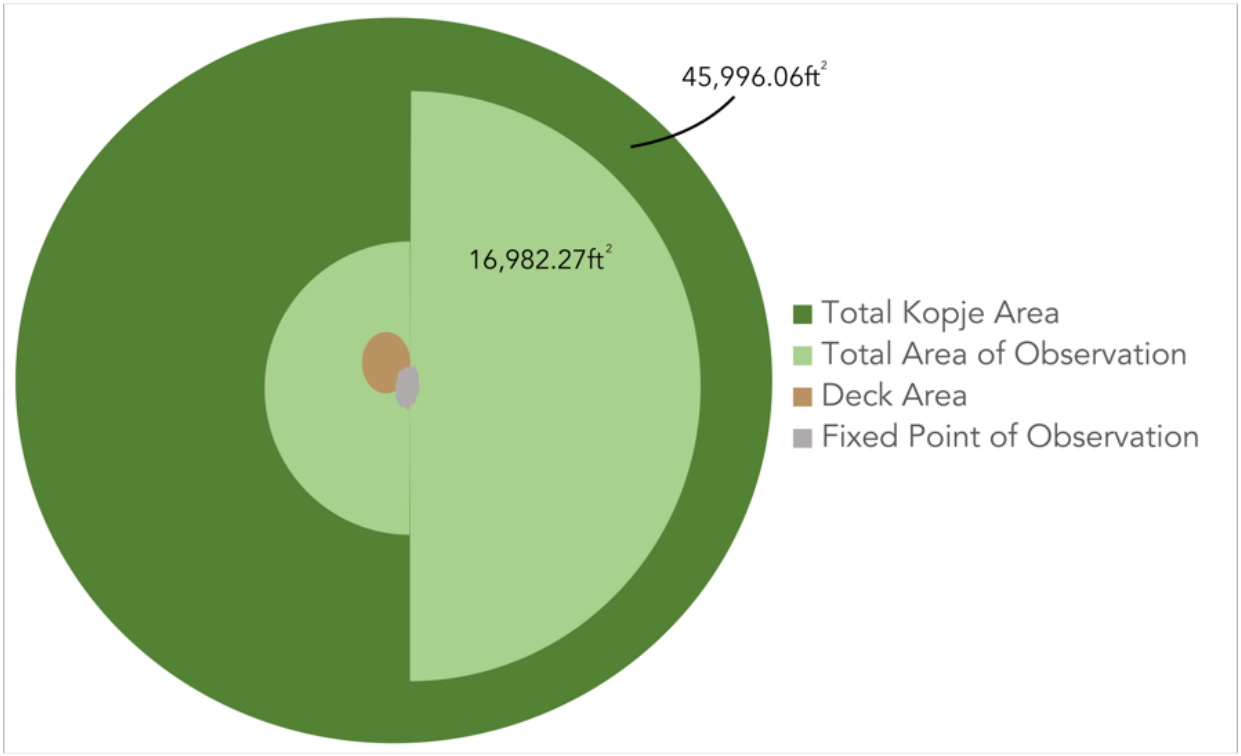

Figure 1. *Estimated area of observation compared to total area of the kopje*

2.2 Study design

This study adapted both qualitative and quantitative observational study design. In this design the rock hyraxes were observed and have their activities and behaviors recorded. The point of observation was chosen due to its convenient location to view the maximum area of the kopje and surrounding vegetation possible at one time. Data was collected over a 10-day period from April 7th, 2024, to April 16th, 2024, with 7 hours of observation each day for a total of 70 hours of data collection. The two categories of data collection were on hyrax's energy budget and behavior in the morning from 6:00am to 11:00am, and in the evening from 5:00pm to 7:00pm. The activity states for the hyrax's energy budget were divided into "Inactive" and "Active". The "Inactive" section included standing, sitting, and laying down, while the "Active" section included running, walking, and climbing. The behaviors were again divided into two groups: "Socializing" and "Isolating". Within the "Socializing" category there were playing, huddling, mating, eating,

basking, and resting, while the "Isolating" section only included eating, basing, and resting. Adult and juvenile hyraxes were distinguished by estimating relative size.

2.3 Methods

2.3.1 Observational method

The hyraxes were observed from a fixed position at the highest point of the kopje. This position was determined during the ISP Prep-week. The observer was situated in the approximate center of the hyrax's habitat due to lack of functional positions distant from the kopje in which to observe the colony. This position allowed for maximum observation of the hyraxes at various elevations on the kopje and provide a sufficient view of surrounding trees in which the hyraxes climb in. Ethograms were used to categorize and distinguish the energy budget and behavior of the hyraxes (see Table 1. & Table 2.). Adults and juveniles were distinguished based on the size differences and behavior. Juveniles were significantly smaller than the adults and often observed near an adult female or other juveniles. While it was originally planned to record the data in relation to male versus female hyrax, due to the limitation of the fixed observation point and large dispersion area, it was deemed unnecessarily challenging to efficiently distinguish between the two genders.

2.3.2 Scan Sampling

The method of scan sampling through participant observation was used to observe the hyrax colony's behavior near RWMA. "In this technique, an observer records the behavior of a group of individuals during a specific time interval, at fixed time points, regardless of the activity or location of the individuals being observed" (Beaton, 2023). Scanning from left to right, the visible area of the kopje and its surrounding vegetation were surveyed every 5 minutes and the hyrax's activity states and behaviors were recorded in a predetermined data collection table. The scan sampling technique allows for the observer to watch multiple different behaviors displayed

by multiple group members at the same time. This method can also capture the frequency of studied behaviors, allowing for further understanding about what behaviors are performed most often. Although this technique can limit the capturing of more infrequent behaviors, this study compensated by additionally recording unincluded behaviors in the "Notes" section at the bottom of the data table.

***Table 2**. Description of inactive and active states of being for the energy budget*

Energy States:		Description:
Inactive	Standing	In a standing position, the stomach is not in contact with the ground surface (Serruya & Eilam, 1996)
	Sitting	In a sitting position, only the pelvic or rear area is in contact with the ground (Serruya & Eilam, 1996)
	Laying	In a laying position, the stomach is fully in contact with the ground surface, with or without the addition of the chin in contact with the ground surface (Serruya & Eilam, 1996)
Active	Running	In a running state, the two front and back legs are somewhat fixed parallel to each while the hyrax rapidly moves forward (Personal observation, 2024)
	Walking	In a walking state, there is alternation between all four limbs while the hyrax moves forward (Personal observation, 2024)
	Climbing (vegetation)	In a climbing state, the hyrax is moving at a walking or running pace up or down trees (Personal observation, 2024)

Table 3. *Description of socializing and isolating behaviors.*

Behaviors:		Description:
Socializing	Playing	Playing is identified as two or more hyraxes, rapidly jumping over each other, chasing each other (running), mock mating (only juveniles), or running in circles (Fourie, 1987; Personal observation, 2024)
	Huddling	Huddling is identified as two or more hyraxes standing, sitting, or lying next to (in contact with) each other (Personal observation, 2024)
	Mating	Mating is identified as two adult hyraxes with one mounted on the other's back (Fourie, 1987)
	Eating	Eating is identified as visibly consuming (chewing) vegetation (Personal observation, 2024)
	Basking	Basking is identified as sitting or lying in direct sunlight or, in the case of cloudy weather, an area that would be in direct sunlight (Personal observation, 2024)
	Resting	Resting is identified as sitting or lying in indirect sunlight/shade or, in the case of cloudy weather, an area that would be in indirect sunlight/shade (Personal observation, 2024)
Isolating	Eating	Eating is identified as visibly consuming (chewing) vegetation (Personal observation, 2024)
	Basking	Basking is identified as sitting or lying in direct sunlight or, in the case of cloudy weather, an area that would be in direct sunlight (Personal observation, 2024)
	Resting	Resting is identified as sitting or laying in indirect sunlight/shade or, in the case of cloudy weather, an area that would be in indirect sunlight/shade (Personal observation, 2024)

2.3.3 Data collection instruments

For quantifying the study area, an ariel image of the kopje from Google Earth was used. The "Path or Polygon" feature of the website was utilized to estimate the parameter and area measurements of the kopje. A pair of binoculars was occasionally used to aid observation from fixed position. Additionally, a 100-meter tape measure was used to estimate the area of the deck and approximate height of kopje.

2.4 Sampling techniques and procedure

The sampling procedure was convenient and purposive non-probability due to previously being informed of the hyrax's presence at the RWMA gate. Although there is another known hyrax colony residing at Vilima Vitatu inside RWMA, focusing on one colony allows for more conclusive data.

2.4.1 Sample size

Despite the presence of multiple hyrax colonies, only a colony close to the Randilen WMA area was studied due to the scope and budget of the study. Nonetheless, focusing on one colony allowed for a more thorough evaluation of the hyrax's behaviors. Although it is possible there were multiple colonies residing on the same kopje at the gate, for the purpose of simplicity in the study it was assumed that the kopje was inhabited by one colony. To estimate the total colony's population, the average number of hyraxes observed at once over the course of all 10 days was calculated along with the highest and lowest number.

2.5 Data analysis

Using the behavioral information collected over the course of 70 hours, the data was synthesized into the frequency of "Inactive" and "Active" states, and "Social" and "Isolating" behaviors for adults, juveniles, and both combined. These more general categories of "Inactive" and "Active" states were determined by the frequency of observed hyrax standing, sitting, and

laying, and running, walking, and climbing respectively. The broad groups of "Social" and "Isolating" were determined by the frequency of eating, basking, and resting for both, with the added frequency determination for the behaviors of playing, huddling, and mating. While not explicitly a part of the data collection tables, it will also be noted if these activity states and behaviors occur from hyraxes on the kopje or in a tree/vegetation.

2.6 Ethical considerations

Due to significantly close proximity to the hyrax colony of interest, there was no intentional contact made by the observer regarding the animals. Limited movement of the observer was meant to reduce the sense of threat for the hyrax, as well as making sure ringtones or any potential noises were silenced.

Results

3.1 General population results

Results show between 25 to 38 hyraxes were observed each day with the maximum of 38 seen on April 7th (Figure 2.). When comparing maximum adults vs. juveniles seen, more juveniles were seen at 15 to 32 per day while only 10 to 13 adults were seen per day (Figure 3.).

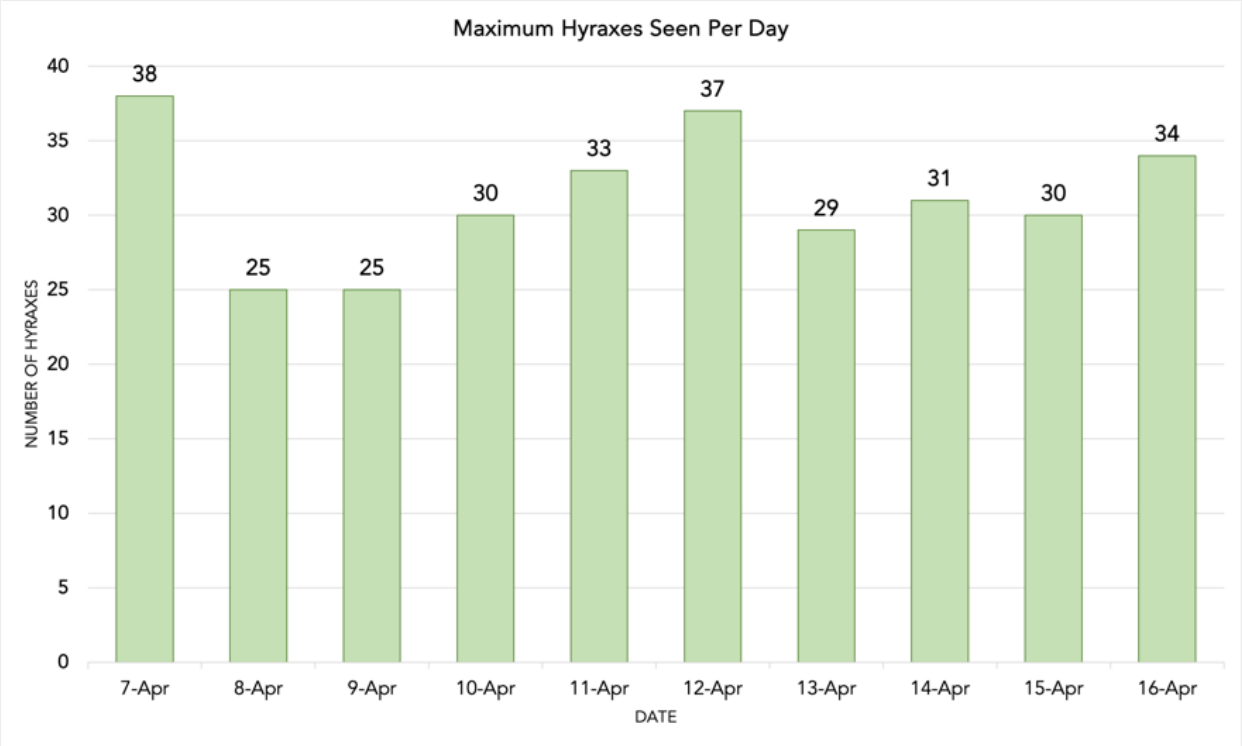

Figure 2. *Maximum number of hyraxes seen at one instance per day from April 7th to April 16th.*

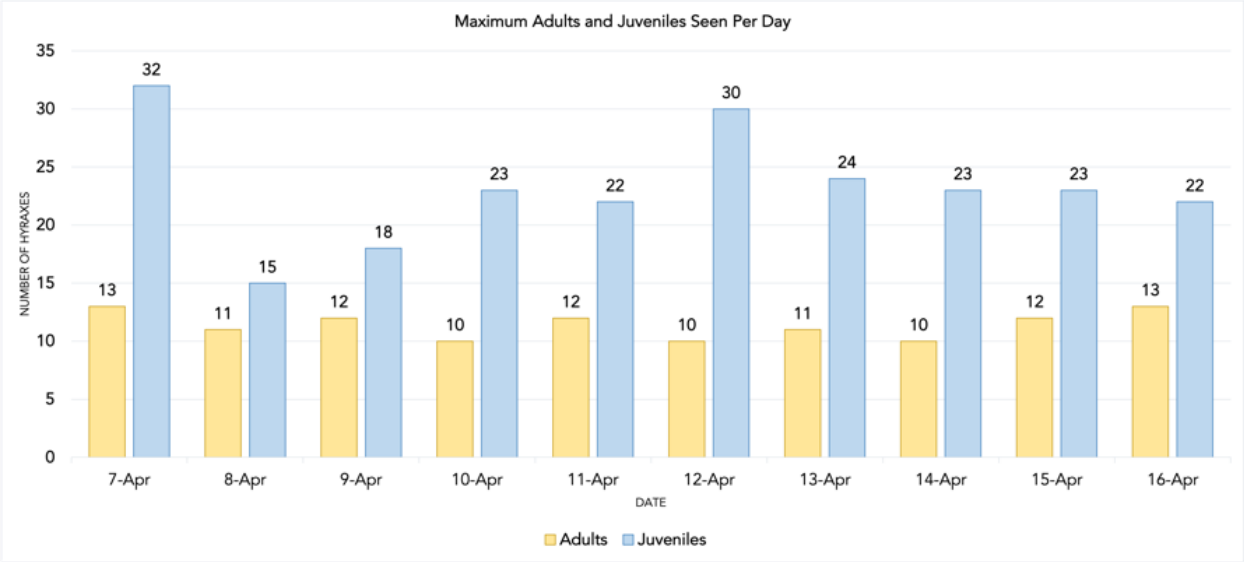

Figure 3*. Combined graphs of maximum adult and juvenile hyraxes seen per day from April 7th to April 16th.*

During the morning session of 6:00am to 11:00am, the maximum hyraxes were seen during the hours of 8:00am and 9:00am with an average of 16 and 14 seen respectively. In the evening session, the most hyraxes were seen during the hour of 6:00pm with an average of 15 (Figure 4.). While more juveniles were seen per hour, both adults and juveniles were most abundant during 8:00am and 9:00am in the morning, and 6:00pm in the evening (Figure 5.).

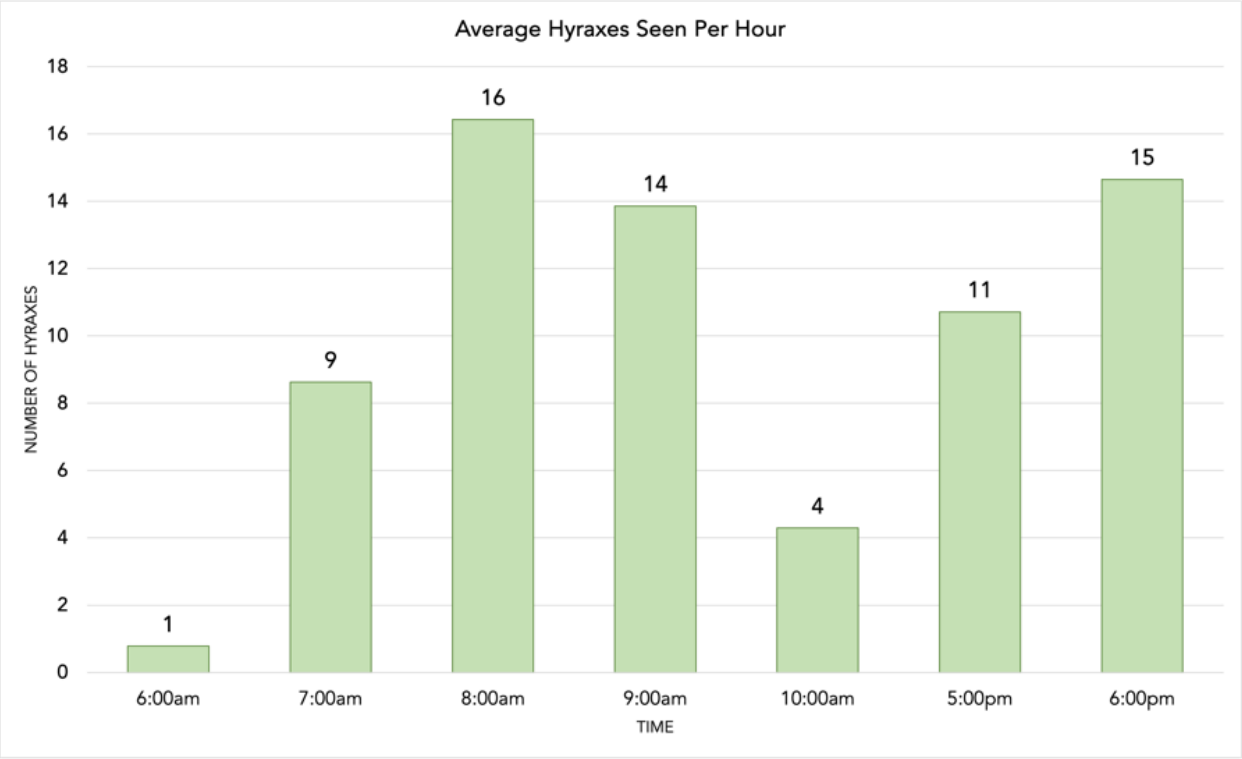

Figure 4*. Average hyraxes seen per hour over the course of April 7th to April 16th.*

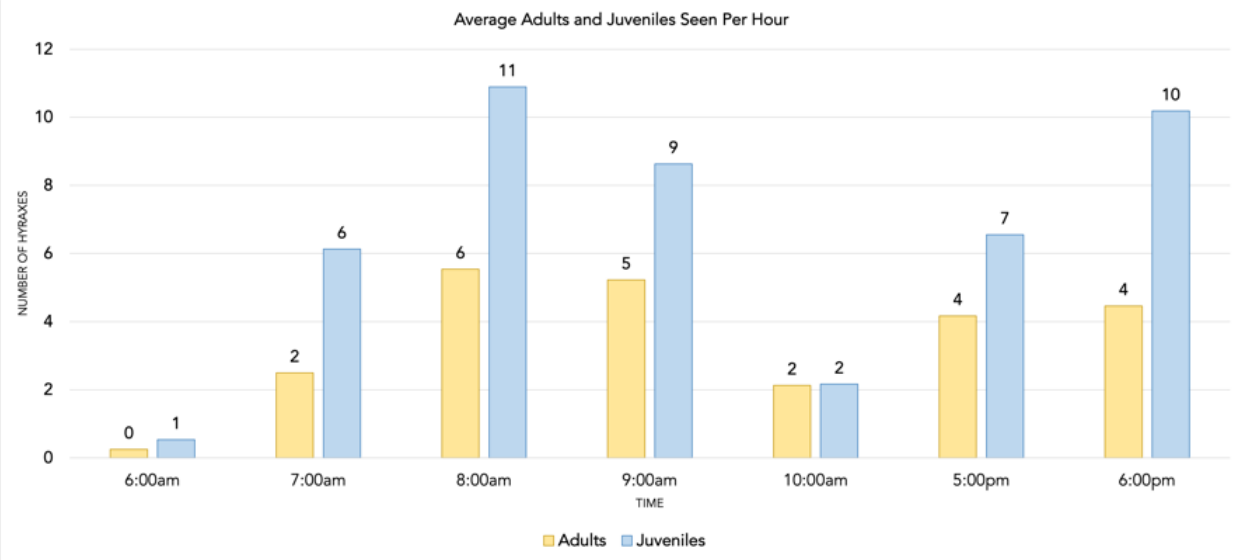

Figure 5*. Combined graphs of average adults and juveniles seen per hour over the course of April 7th to April 16th.*

Based on the maximum hyraxes seen per day in the surrounding area observable from the fixed position, in addition to a scaled approximation of the study area (Table 1. & Figure 1.), an estimate of the total population was calculated (Equation 1.). The calculated estimation for the total hyrax population size was done twice using the highest and lowest values from Figure 2. The

highest value of 38 hyraxes yielded a result of about 103 hyraxes, and the lowest value of 25 hyrax resulted in 68 hyrax as estimates for the total hyrax population at this kopje.

***Equation 1**. Estimating Species Density*

$$N_{est} = N_c\left(\frac{A_{tot}}{A_c}\right)$$

3.2 Energy Budget

For a thorough examination of the hyrax energy budget, the data was divided into the morning and evening session for adults and juveniles separately, and then combined. The combined results for adults and juveniles over the course of all 10 days shows that these hyraxes were inactive for 76.87% vs. being active for 23.13% of the whole day (Table 4.). During their inactive state, the hyraxes were laying down for 59.83%, standing for 21.61%, and sitting for 18.56% of the time (Table 4.). While active, the hyraxes were recorded climbing for 66.38%, walking for 18.24%, and running for 15.38% of the time (Table 4.). The state of playing was included in the energy budget category given that every instance of playing recorded also included the action of running. Although playing is included in the combined data for both adults and juveniles, it's important to note that playing was only recorded occurring amongst juveniles. When comparing the morning and evening session for both adults and juveniles, there are only slight differences, the most of which observed the hyraxes being 5.59% more inactive in the evening hours (Table 4.). Over the course of April 8th, 9th, and 10th, there were 15 instances of adults and 10 instances of juveniles simply laying or sitting in trees for shade. When observed, these hyraxes were counted as resting, while any other times they were seen in trees they were actively climbing.

Table 4. *Summary of the energy budget for both adults and juveniles throughout the whole day, and then specifically the morning and evening session*

Combined Data							
Energy Budget	100%	Inactive	76.87%	Standing	21.61%		
				Sitting	18.56%		
				Laying	59.83%		
		Active	23.13%	Running	15.38%	Playing	39.74%
				Walking	18.24%		
				Climbing	66.38%		
Morning Combined Data							
Energy Budget	100%	Inactive	74.95%	Standing	25.94%		
				Sitting	15.00%		
				Laying	59.06%		
		Active	25.05%	Running	14.86%	Playing	39.59%
				Walking	18.25%		
				Climbing	66.89%		
Evening Combined Data							
Energy Budget	100%	Inactive	80.54%	Standing	14.89%		
				Sitting	24.08%		
				Laying	61.02%		
		Active	19.46%	Running	13.92%	Playing	49%
				Walking	18.77%		
				Climbing	67.31%		

When isolating the data specific to the adult and juvenile hyraxes, their energy budgets follow the general pattern of being mostly inactive, adults with 77.40% and juveniles with 76.63% overall inactivity. While they also both tend to be more inactive during the evening, adults are more inactive in the evening by 2.48%, while juveniles are more inactive in the evening by 6.76% (Table 5. & Table 6.). During the time adults were inactive, they spent 56.91%, 26.19%, and 16.91% of the time laying down, standing, and sitting respectively (Table 5.). Compared to adults, juveniles spent 4.51% more of their time laying down during their inactive state than adults, while sitting for 19.46% and standing for 19.13% of the time (Table 6.). When active, adults spent 62.39% of the time climbing, 25.67% walking, and 11.94% running (Table 5.). Regarding when juveniles were active, they were observed climbing for 68.60%, walking for 14.42%, and running for 17.21% of the time (Table 6.). While the activity of climbing decreased in the evening for adults, going from 63.88% to 59.47%, it increased slight for juveniles, going from 68.25% to 69.38% (Table 5. & Table 6.). For the overall 17.21% of the time juveniles were running, 46.40% of that time was them playing with each other. Juveniles were also observed to increase their

playing in the evening by 15.86% (Table 6.). Although overall juveniles were averaged to be sitting more than standing, they were standing for 24.12% and sitting for 14.93% of their inactive state in the morning vs. their 11.73% standing and 26.16% sitting in the evening (Table 6.). Juveniles were slightly more active in the morning and inactive in the evening than the adults and vice versa (Table 5. & Table 6.).

Table 5*. Summary of the energy budget for only adults throughout the whole day, and then specifically the morning and evening sessions.*

Adult Data							
Energy Budget	100%	Inactive	77.40%	Standing	26.19%		
				Sitting	16.91%		
				Laying	56.91%		
		Active	22.60%	Running	11.94%	Playing	0%
				Walking	25.67%		
				Climbing	62.39%		
Morning Adult Data							
Energy Budget	100%	Inactive	76.50%	Standing	29.13%		
				Sitting	15.12%		
				Laying	55.76%		
		Active	23.50%	Running	11.74%	Playing	0%
				Walking	24.38%		
				Climbing	63.88%		
Evening Adult Data							
Energy Budget	100%	Inactive	78.98%	Standing	21.22%		
				Sitting	19.93%		
				Laying	58.85%		
		Active	21.02%	Running	12.33%	Playing	0%
				Walking	28.19%		
				Climbing	59.47%		

***Table 6**. Summary of the energy budget for only juveniles throughout the whole day, and then specifically the morning and evening sessions.*

Juvenile Data							
Energy Budget	100%	Inactive	76.63%	Standing	19.13%		
				Sitting	19.46%		
				Laying	61.42%		
		Active	23.37%	Running	17.21%	Playing	46.40%
				Walking	14.42%		
				Climbing	68.60%		
Morning Juvenile Data							
Energy Budget	100%	Inactive	74.05%	Standing	24.12%		
				Sitting	14.93%		
				Laying	60.95%		
		Active	25.95%	Running	16.38%	Playing	46.21%
				Walking	15.14%		
				Climbing	68.25%		
Evening Juvenile Data							
Energy Budget	100%	Inactive	80.81%	Standing	11.73%		
				Sitting	26.16%		
				Laying	62.11%		
		Active	19.19%	Running	14.32%	Playing	62.07%
				Walking	12.84%		
				Climbing	69.38%		

Although there was some variation between the data, the hyraxes spent most of their time laying down in an inactive state, and the time spent active was predominantly used for climbing.

3.3 Behavior

The behavior of the hyraxes was broken up into socializing and isolating with the same three categories of eating, basking, and resting for each. Overall, hyraxes socialized 97.64% of the time vs. the 2.36% some were seen isolating from the larger group's common area. The behavior of socializing was spent 76.75%, 18.50%, and 4.75% of the time basking, eating, and resting respectively. Of the 76.75% spent basking, 51.28% of the time hyraxes were huddling together in large piles or smaller groups. Of the 18.50% spent eating, 91.87% of that time was spent while climbing in trees, and 8.13% of eating occurred while the hyraxes stood or sat on part of the kopje. For the 2.36% that was isolating behavior, the hyraxes spent 63.78% of the time resting while basking took up 22.70% and eating was 13.51% of the time. Of the isolating eating behavior, 100% of it was observed while the hyraxes were climbing a tree (Table 7.). When broken down into the morning and evening sessions, the results show that hyraxes spent 20.75% more of

their time eating in trees in the morning than the evening. The behavior of huddling also increased in the evening by 17.04%. In terms of isolating behavior, less than 1% occurred during the evening session with 87.50% of that time spent basking. Isolating behavior also went from predominantly 66.10% resting and 14.12% eating in the morning to 12.50% resting and 0% eating in the evening (Table 7.).

Table 7. *Summary of behaviors for both adults and juveniles throughout the whole day, and then specifically the morning and evening session.*

Combined Data							
Behavior	100%	Socializing	97.64%	Eating	18.50%	In a tree	91.87%
						On a rock	8.13%
				Basking	76.75%	Huddling	51.28%
				Resting	4.75%		
		Isolating	2.36%	Eating	13.51%	In a tree	100%
						On a rock	0%
				Basking	22.70%		
				Resting	63.78%		
Morning Combined Data							
Behavior	100%	Socializing	96.35%	Eating	18.99%	In a tree	97.75%
						On a rock	2.25%
				Basking	77.72%	Huddling	44.60%
				Resting	3.29%		
		Isolating	3.65%	Eating	14.12%	In a tree	100%
						On a rock	0%
				Basking	19.77%		
				Resting	66.10%		
Evening Combined Data							
Behavior	100%	Socializing	99.73%	Eating	17.73%	In a tree	77.00%
						On a rock	22.24%
				Basking	75.22%	Huddling	61.64%
				Resting	7.05%		
		Isolating	0.27%	Eating	0%	In a tree	0%
						On a rock	0%
				Basking	87.50%		
				Resting	12.50%		

The socializing behaviors of adults vs. juveniles was observed to be similar however, only adult hyraxes were ever observed to isolate from the group, making up an overall 6.83% of their behavior (Table 8.). When socializing adult and juveniles spent most of their time basking, adults 75.72% and juveniles 77.78% of the time. Their next most frequent behavior was eating at just over 18% for both, with adults eating 85.62% and juveniles 94.05% of the time in trees. Although huddling behavior was also displayed 2.81% more amongst juveniles than adults throughout the day, their huddling behavior both increased during the evening session, adults by 12.34% and

juveniles by 18.90% (Table 8. & Table 9.). Specifically for adults, their isolating behavior was spent mostly resting in the morning and basking in the evening with 14.12% eating in the morning and 0% eating in the evening (Table 8.). While eating amongst socializing adults increased during the evening hours by 2.54%, eating decreased for juveniles by 3.13%.

Table 8. *Summary of behaviors for only adults throughout the whole day, and then specifically the morning and evening sessions.*

Adult Data							
Behavior	100%	Socializing	93.17%	Eating	18.73%	In a tree	85.62%
						On a rock	14.38%
				Basking	75.72%	Huddling	46.20%
				Resting	5.54%		
		Isolating	6.83%	Eating	13.51%	In a tree	100%
						On a rock	0%
				Basking	22.70%		
				Resting	63.78%		
Morning Adult Data							
Behavior	100%	Socializing	89.72%	Eating	17.75%	In a tree	95.62%
						On a rock	4.38%
				Basking	77.59%	Huddling	41.50%
				Resting	4.66%		
		Isolating	10.28%	Eating	14.12%	In a tree	100%
						On a rock	0%
				Basking	19.77%		
				Resting	66.10%		
Evening Adult Data							
Behavior	100%	Socializing	99.19%	Eating	20.29%	In a tree	67.84%
						On a rock	32.16%
				Basking	72.78%	Huddling	53.84%
				Resting	6.93%		
		Isolating	0.81%	Eating	0%	In a tree	0%
						On a rock	0%
				Basking	87.50%		
				Resting	12.50%		

Table 9. *Summary of behaviors for only juveniles throughout the whole day, and then specifically the morning and evening sessions.*

Juvenile Data							
Behavior	100%	Socializing	100%	Eating	18.39%	In a tree	94.05%
						On a rock	5.95%
				Basking	77.26%	Huddling	49.01%
				Resting	4.36%		
		Isolating	0%	Eating	0%	In a tree	0%
						On a rock	0%
				Basking	0%		
				Resting	0%		
Morning Juvenile Data							
Behavior	100%	Socializing	100%	Eating	19.60%	In a tree	98.37%
						On a rock	1.63%
				Basking	77.78%	Huddling	41.89%
				Resting	2.62%		
		Isolating	0%	Eating	0%	In a tree	0%
						On a rock	0%
				Basking	0%		
				Resting	0%		
Evening Juvenile Data							
Behavior	100%	Socializing	100%	Eating	16.47%	In a tree	85.93%
						On a rock	14.07%
				Basking	76.42%	Huddling	60.79%
				Resting	7.10%		
		Isolating	0%	Eating	0%	In a tree	0%
						On a rock	0%
				Basking	0%		
				Resting	0%		

Besides the fact that juveniles exhibited 0% of isolating behaviors, adult and juvenile's behaviors were predominantly socializing while basking. Additionally, adults and juveniles spent more of their time browsing in trees rather than from standing or sitting on the kopje. While the juveniles of the group were always in close proximity to each other or to an adult, there were a few that seemingly preferred to slightly distance themselves from the larger group, for example sitting alone rather than in a huddle with others.

4.0 Discussion

Discussion

The hyraxes residing at the gate of Randilen Wildlife Management Area are inactive 76.87% of the day while behaving socially for 97.64% of their time. While the findings of their mostly inactive state and social behavior are consistent with past research, these data show that the hyraxes spent more time in an active state than expected (Millar, 1971). Since diurnal hyraxes are known to be gregarious (Bordes, 2022, p. 3), the predominant social behavior is not surprising. Given all isolating hyraxes were observed to be adults, this suggests that these hyraxes were peripheral males that only hovered around the outskirts of the group. The general pattern of activity and behavior observed each day started with the hyraxes basking and huddling in the morning and then dispersing to feed and seek shade as the day becomes hotter. At the beginning of the evening session, the hyraxes were mostly climbing and eating which they soon abandoned to huddle together again as the sun went down. The hyraxes being abundant most during the morning hours of 8:00am and 9:00am reiterates how they seek shade and shelter before hottest point in the day (12:00pm) and to avoid detection from many predatory birds that are most active after those times. When laying down in a basking or resting inactive state, most hyraxes would keep their eye open while only a few would close their eyes completely. This behavior was most likely used as a precautionary measure for possible approaching predators and displayed the advantages of gregarious living. Similar to the previously described role of sentinel hyraxes while feeding, few hyraxes would stay alert while the others slept so as to alert the group of any imminent danger.

The fact that huddling behavior increased during the evening session is also consistent with how hyraxes use huddling to conserve body heat when the sunsets and the day starts to cool off. It was observed that during chillier, cloudy, and sometimes rainy periods, the hyrax would puff themselves up and seemingly prefer to huddle while standing, contrasting from behavior during warm and sunny periods where the hyrax would pile on top of each other or stretch out to full

length on the kopje or deck. Apart from the predetermined behaviors, these hyraxes were also observed to use rocks and the wooden beams of the deck as scratching posts. On many occasions they were observed enthusiastically rolling on to their backs or sliding up and down the rocks to scratch themselves. Despite a claim about hyraxes not blinking (Marks, 2018), these hyraxes were observed to blink not with their eyelids but rather a seemingly white translucent membrane of sorts that briefly incased their eye in a motion perpendicular to the motion of their eye lids.

While mating was included in the data collection tables, there were no instances of mating observed except for mock mating behavior amongst juveniles, which was recorded as playing (Fourie, 1987 pg. 94). Mock mating behavior was differentiated from what is assumed as real mating because both male and female observed juveniles took turns mounting each other. While there were not significant instances of conflict, any fighting that occurred was usually between juveniles playing, or on a couple instances, adults seemingly kicking juveniles out of a huddling group after which the juvenile would find a different spot in the group to huddle in. It was also during these moments of mock mating or slight conflict when the hyraxes were heard to vocalize the most. The hyraxes involved in these moments made a combination of chirping and higher pitched purring noises, pushing each other around with their noses. The other instances of hyrax noises were heard while the hyraxes were out of sight under the kopje. Clearly distinguishable from the numerous surrounding bird calls, these noises were again a higher pitched purring-rumbling sound, similar to that of a guinea pig.

Limitations

When calculating the estimated total hyrax populations, two different values resulted. The first value of 103 hyrax was calculated from the maximum number of hyraxes seen at one time over the course of the 10 days. Compared to outside sources, this result exceeds the general estimated number of individual hyraxes expected to live in one colony by a significant amount (Ben-Moshe, 2020, Figure A1.). While the result of 103 hyrax is still completely possible, it seems

unlikely due to what is known about hyrax colonies. The second value of 68 was calculated using the lowest maximum number of hyraxes seen at one time which was 25 hyraxes. In addition to closely aligning with other population estimates, it is reasoned that during the days 25 hyrax were the maximum seen, the hyraxes were more evenly dispersed across the kopje, and given the nature of the equation calculating for density (Equation 1.), the result of approximately 68 hyrax total is more plausible than 103. Additionally, the tallest and most exposed areas of the kopje to sunlight were within the range of observation. Since the social basking was the leading behavior during the peak hours of 8:00am to 9:00am, and 6:00pm, and the time the maximum number of hyraxes observed per day falls within these hours, it is probable that most hyraxes in the colony were already present. From these results and reasonings, it is concluded that the hyrax colony residing at the gate of RWMA has a population of somewhere between 38 to 68 individuals. Although this range of individuals is supported by other research (Ben-Moshe, 2020), the possibility of only observing 55.88% of the total hyrax colony may have had a significant effect of data accuracy.

Many of the days during the data collection period were cloudy with periods of rain before and after the designated morning and evening sessions. This could be attributed to the factor of Tanzania experiencing the wet season which is predicted to drastically effect the observed behavior of the hyraxes. While the hyraxes were not active during periods of heavy rain, they didn't seem to mind a light sprinkling rain. In one instance, following a heavy rain period, a juvenile was observed laying down in and drinking from a puddle that had formed on the kopje. Despite the negative effect weather may have on data collection, it also presents as an opportunity to make observations beyond the structure of the study. Another limitation that affected the study as a whole, was the time frame in which data was collected. Only observing the hyrax for 10 days contrasted significantly from the other studies previously mentioned, that were able to research for multiple months (Serruya & Eilam, 1996). Although these limitations posed a challenge, substantial data was still able to be collected.

5.0 Conclusions and Recommendations

5.1 Conclusion

Succeeding the 70 hours of data collection, it was observed that the hyraxes spent most of their energy budget regulating body temperature while in an inactive state throughout the day accordingly. These findings based on the data collected, support the hypothesis of the hyraxes being in a predominantly inactive energy state. As a gregarious species, hyraxes at the edge of Randilen WMA behave in a social manner with a few peripheral males residing at a distance from the larger group of juveniles and presumed female adults. Compared to other studies regarding rock hyraxes, the findings from this research resulted in a higher percentage of activity recorded amongst the hyraxes. While the reason for this discrepancy is unclear, it is likely that proximity to human activity, in addition to possible limiting factors of observed population and weather influences, influenced the resulting data.

5.2 Future Research

While this study at Randilen WMA continued to affirm previous hyrax studies conducted elsewhere, there are many more directions future researchers could pick pertaining to this hyrax colony. This study examined the general hyrax energy budget and behavior during the wet season; however, it is predicted that their behavior might vary in correlation to both Tanzania's wet and dry season. Although this study provides a starting point for hyrax behavior during the wet season, the ability to compare multiple wet season data to just as much data throughout the dry season will yield more accurate results about the hyraxes. In addition to their energy budget and behavior, acquiring knowledge about their preferred diet in this specific location could assist researchers in understanding changing vegetation patterns and thus effective conservation methods for multiple species. Additionally, despite these hyraxes depositing their waste in multiple locations across the kopje, there were a couple midden locations that seemed significantly larger than others, prompting

the querying of if there is a pattern or reason for these midden locations. As previously mentioned, hyrax middens have caught scientists' attention for their potential in aiding climate change research through acting as paleoenvironmental proxies and providing data about changing vegetation in the target area (Ryner, 2008 pg. 584). To reiterate the study of hyrax social interaction by Bordes in 2022, the behavior of hyraxes during night hours may significantly influence their behavior during the daytime. Regarding this specific hyrax colony, studying their nighttime behavior could provide insight into individual hyrax behavior and help to further understand reasons why, for example, certain juveniles preferred to bask alone, in pairs, with an adult, or in a pile, and why some adults seemed to reject the juvenile's presence near them personally, but not to the whole group. Although this study serves as a starting point to rock hyrax research in Tanzania and more specifically Randilen WMA, more research is needed to improve the understanding of the hyrax's niche in this habitat and the even larger environment.

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Appendix A

Raw Data

Table 10. *Raw Data (April 7th, 2024)*

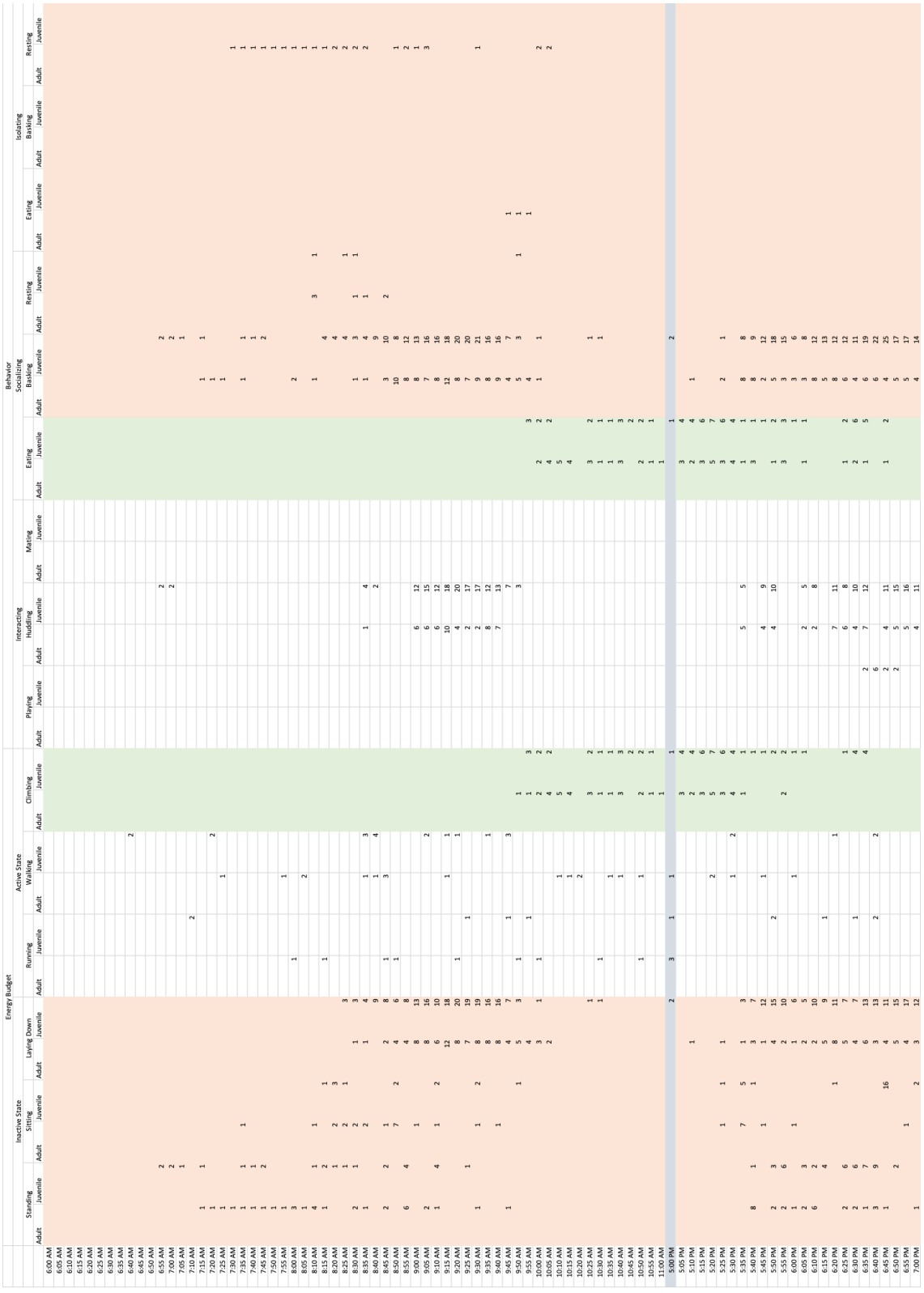


Table 11. *Raw Data (April 8th, 2024)*

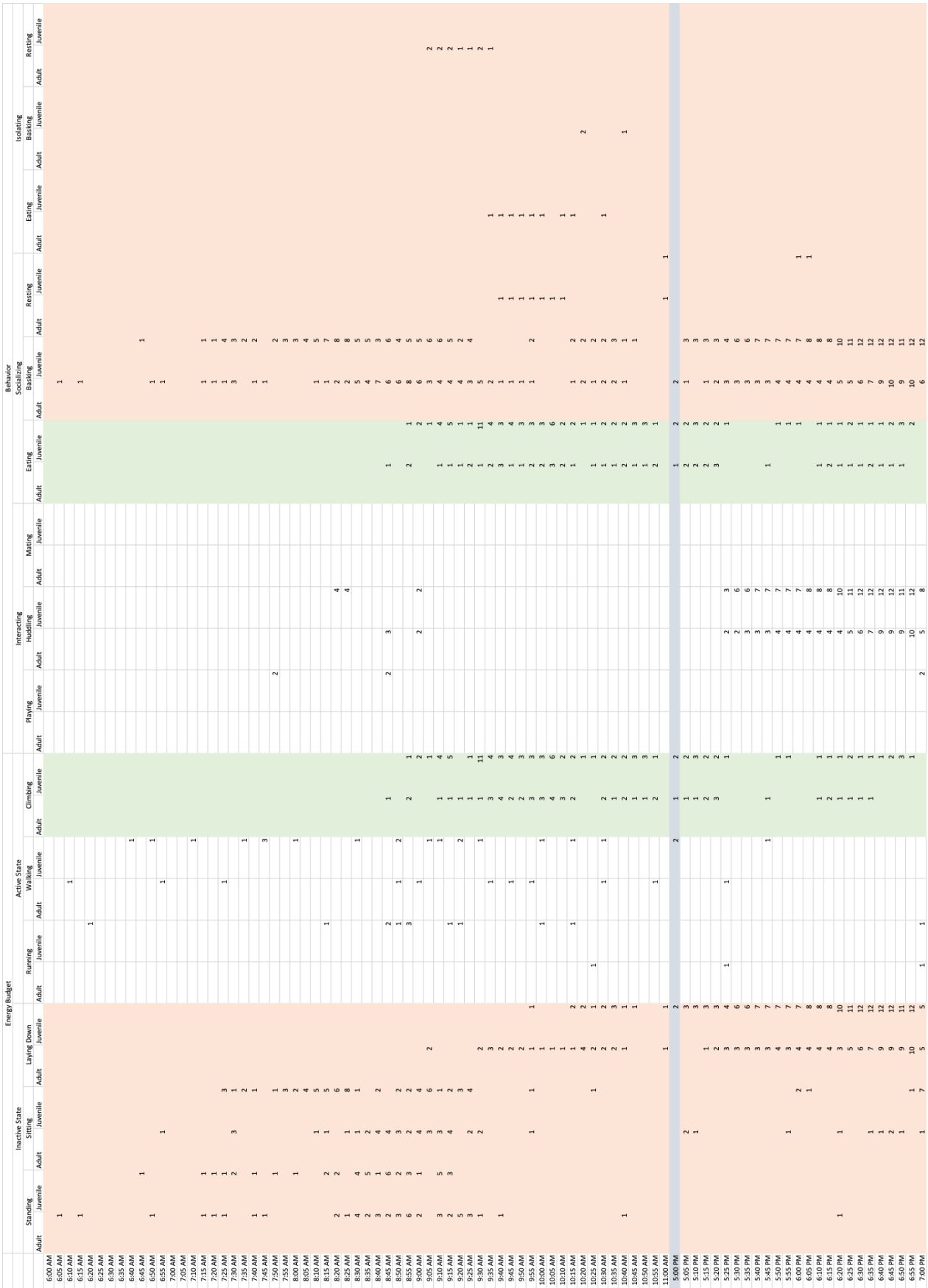


***Table 12**. Raw Data (April 9th, 2024)*

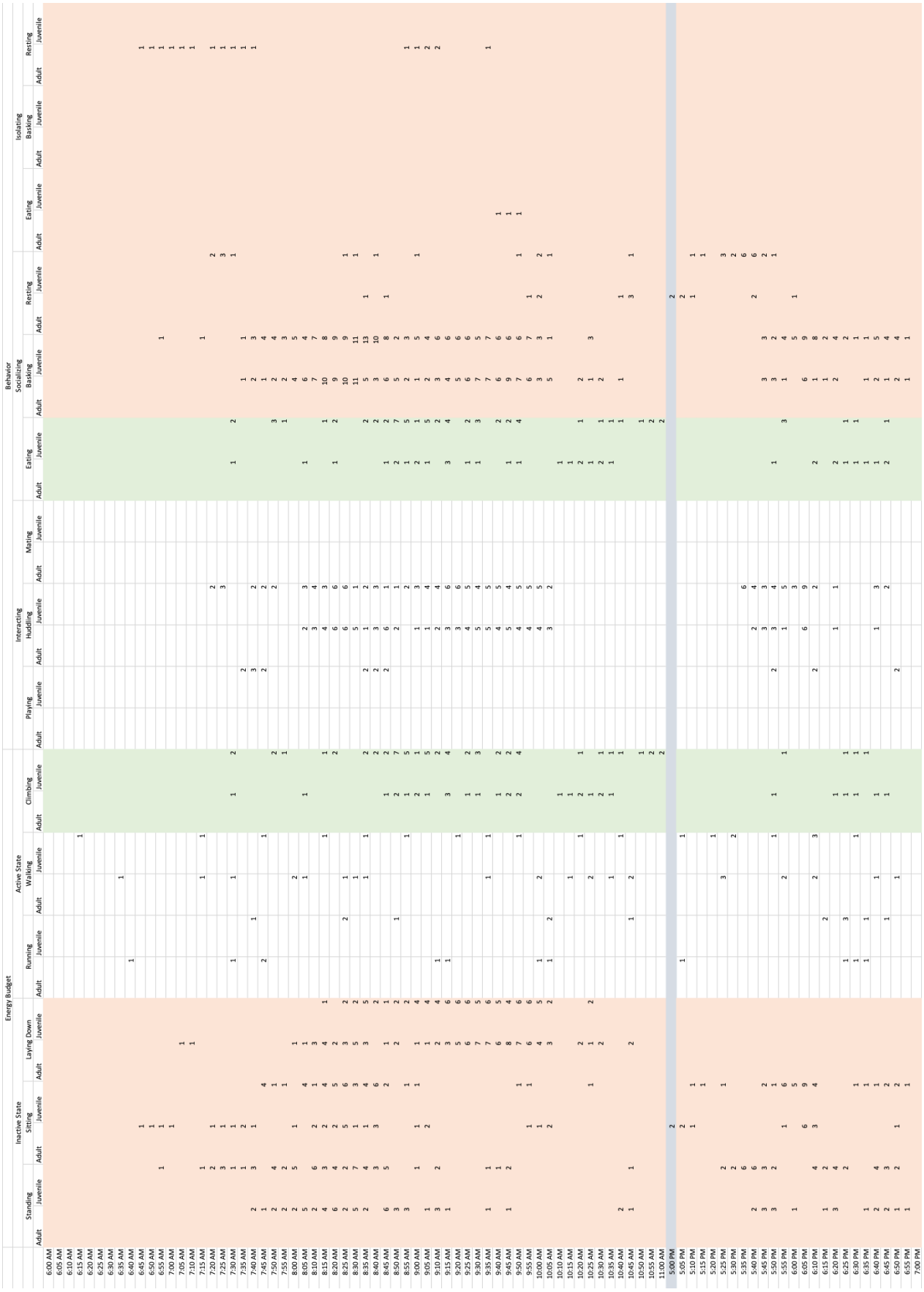


Table 13. *Raw Data (April 10th, 2024)*

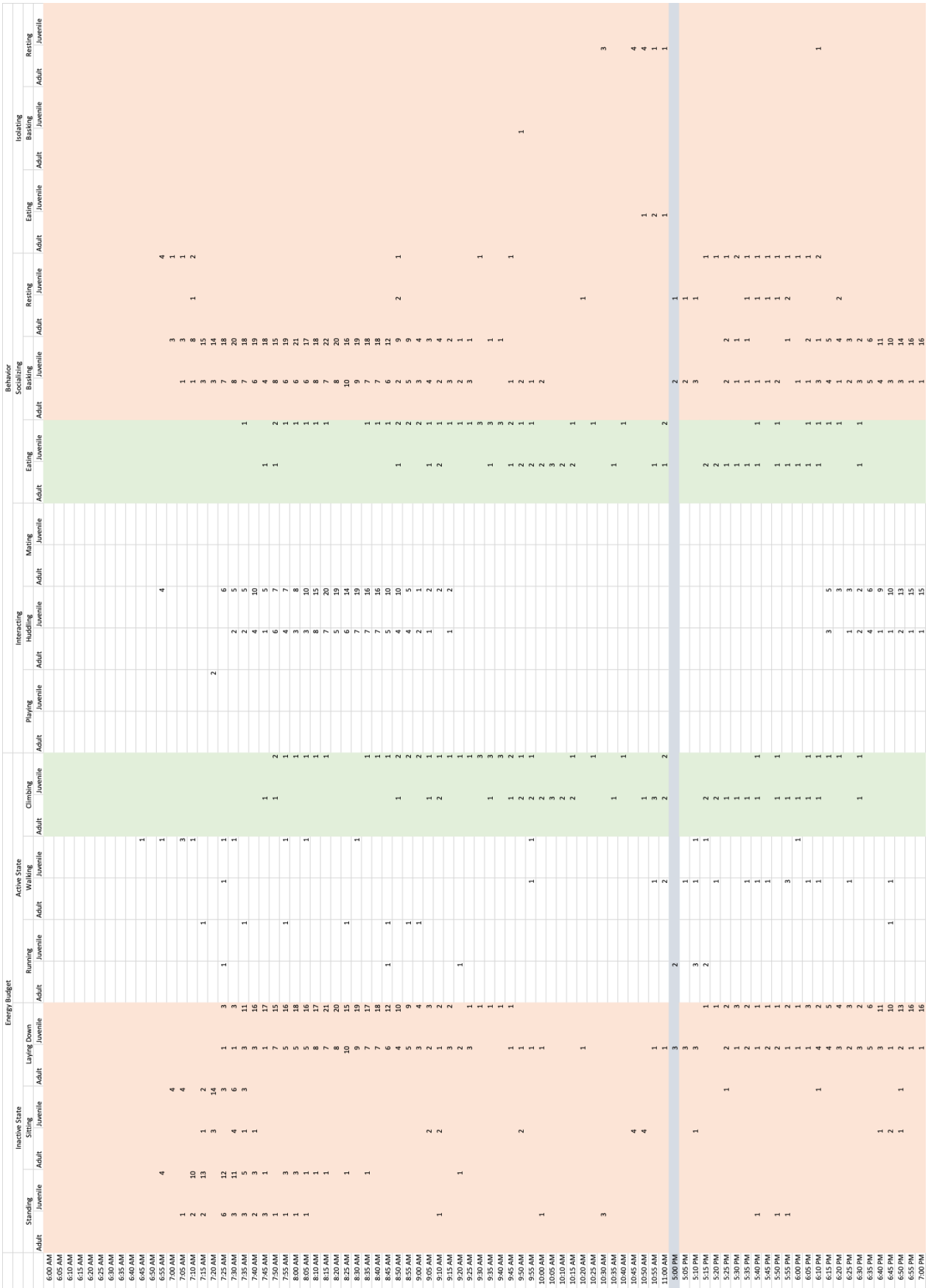


***Table 14**. Raw Data (April 11th, 2024)*

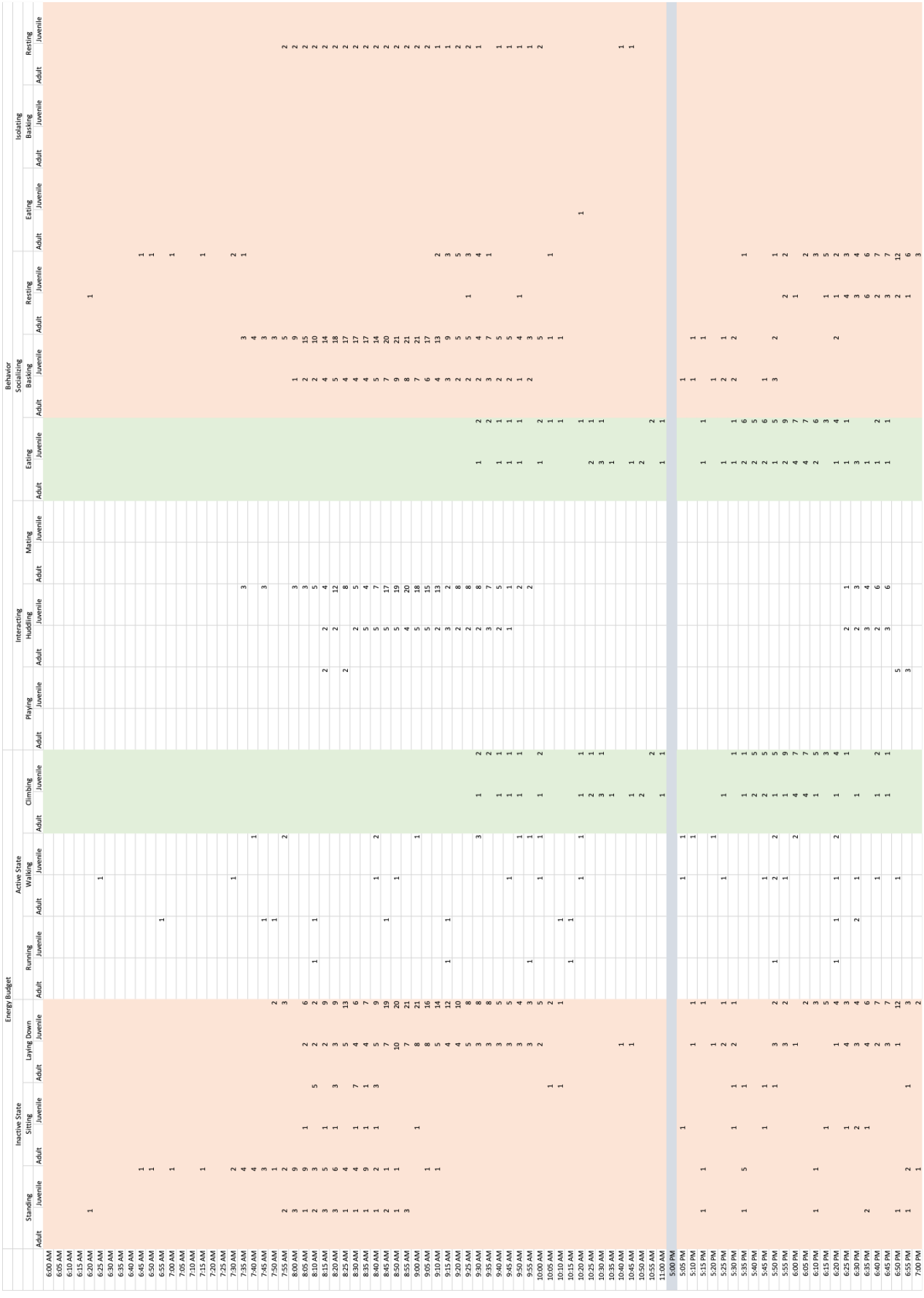


Table 15. *Raw Data (April 12th, 2024)*

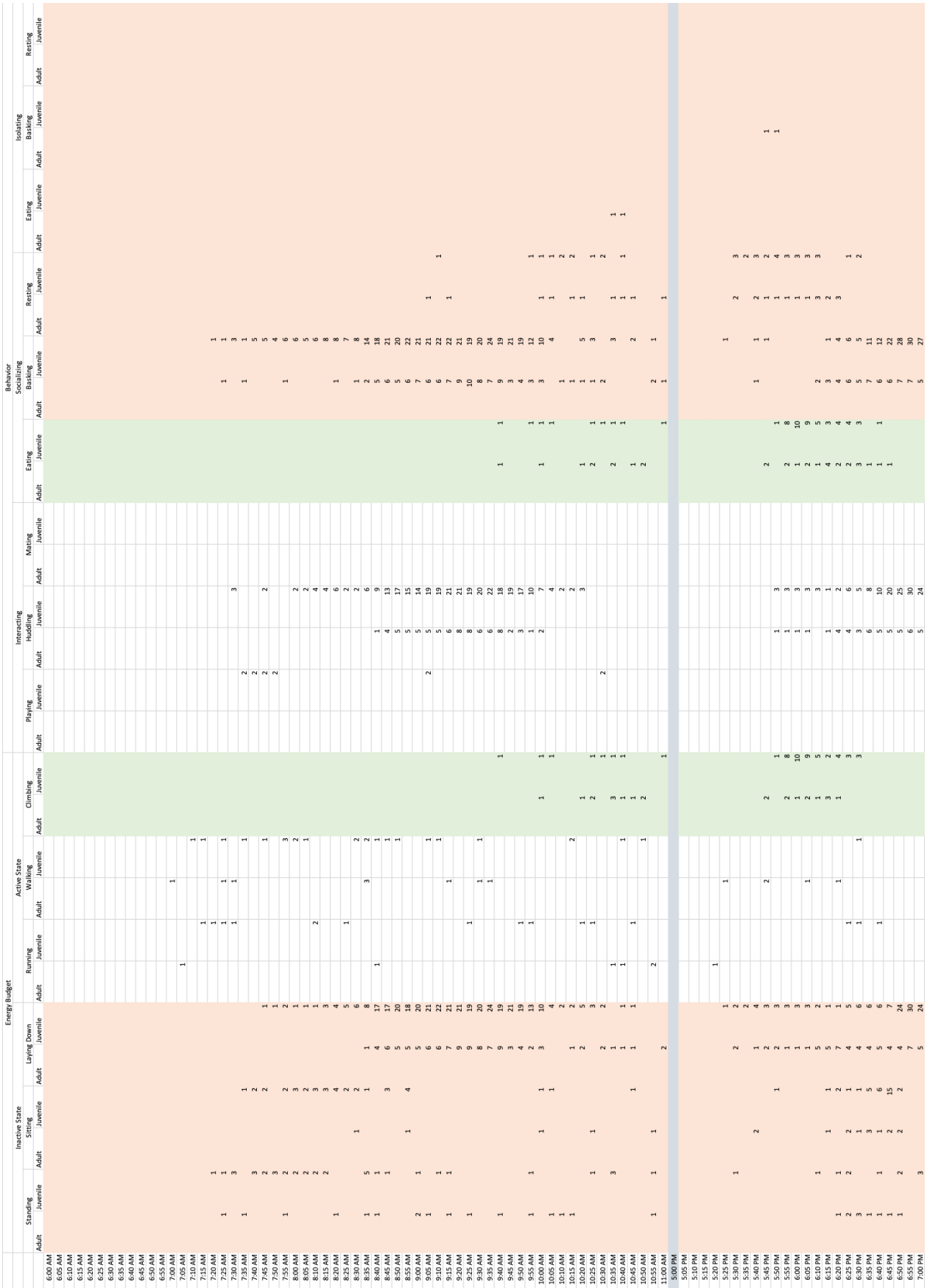


***Table 16**. Raw Data (April 13th, 2024)*

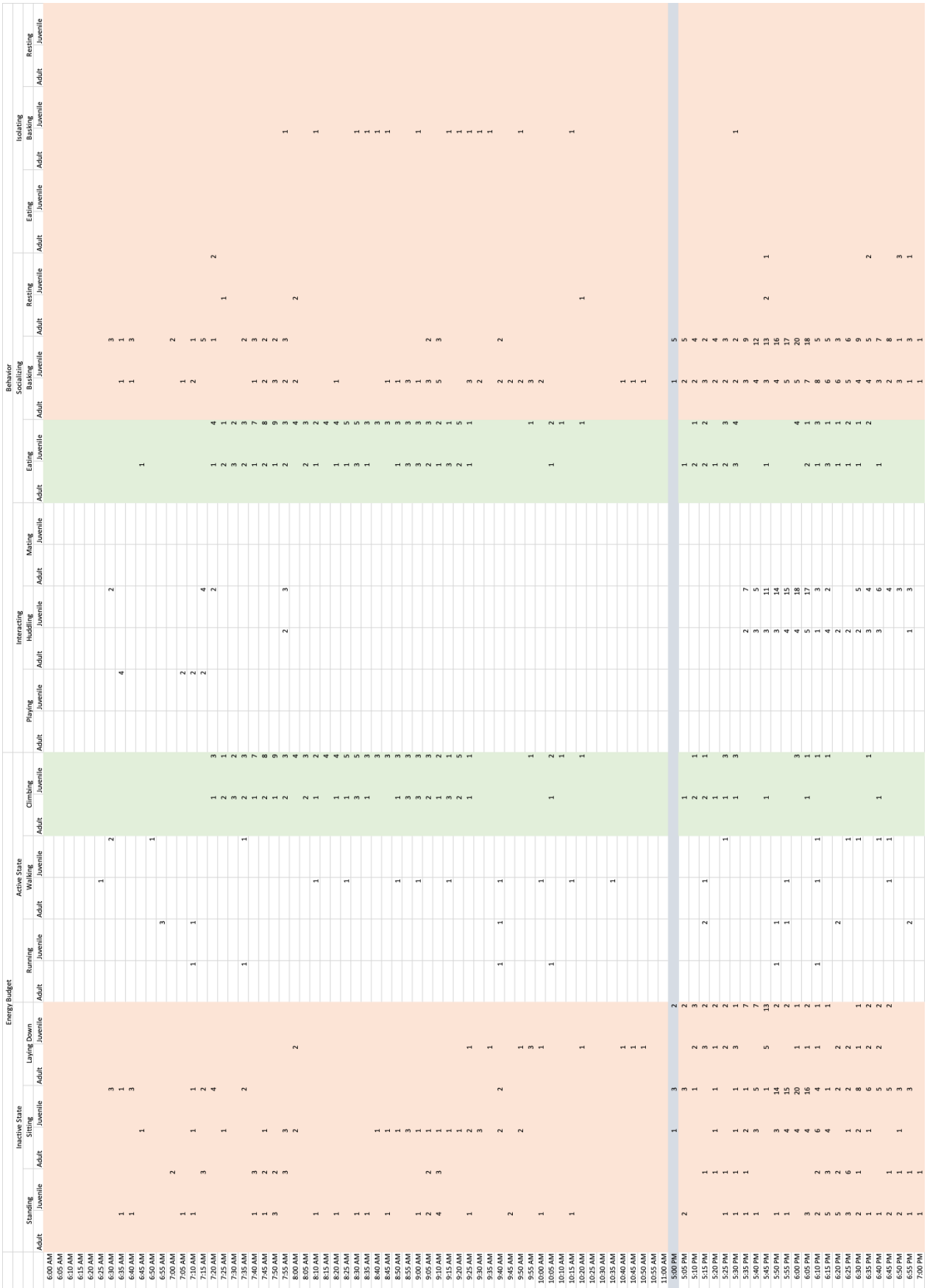


***Table 17**. Raw Data (April 14th, 2024)*

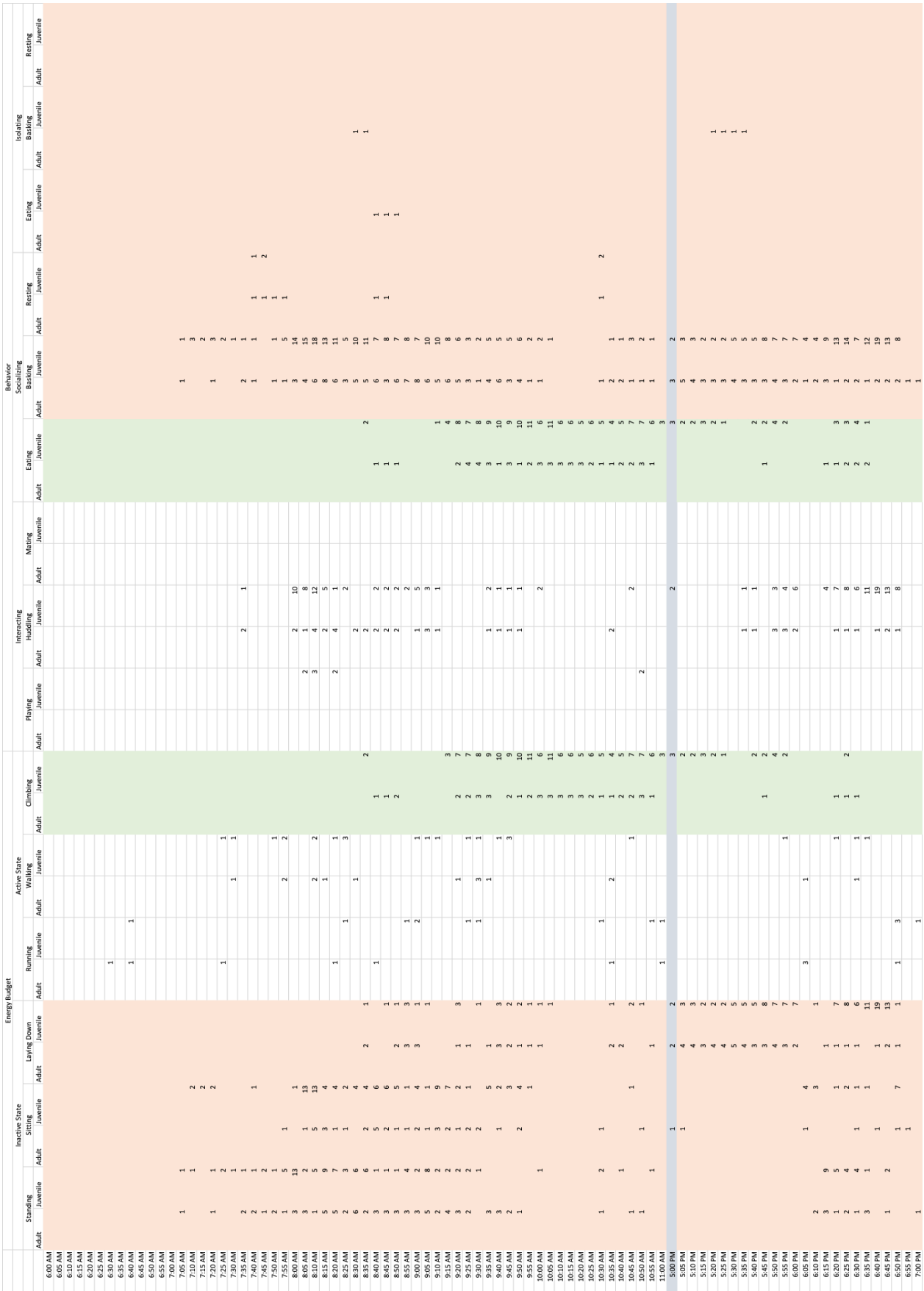


***Table 18**. Raw Data (April 15th, 2024)*

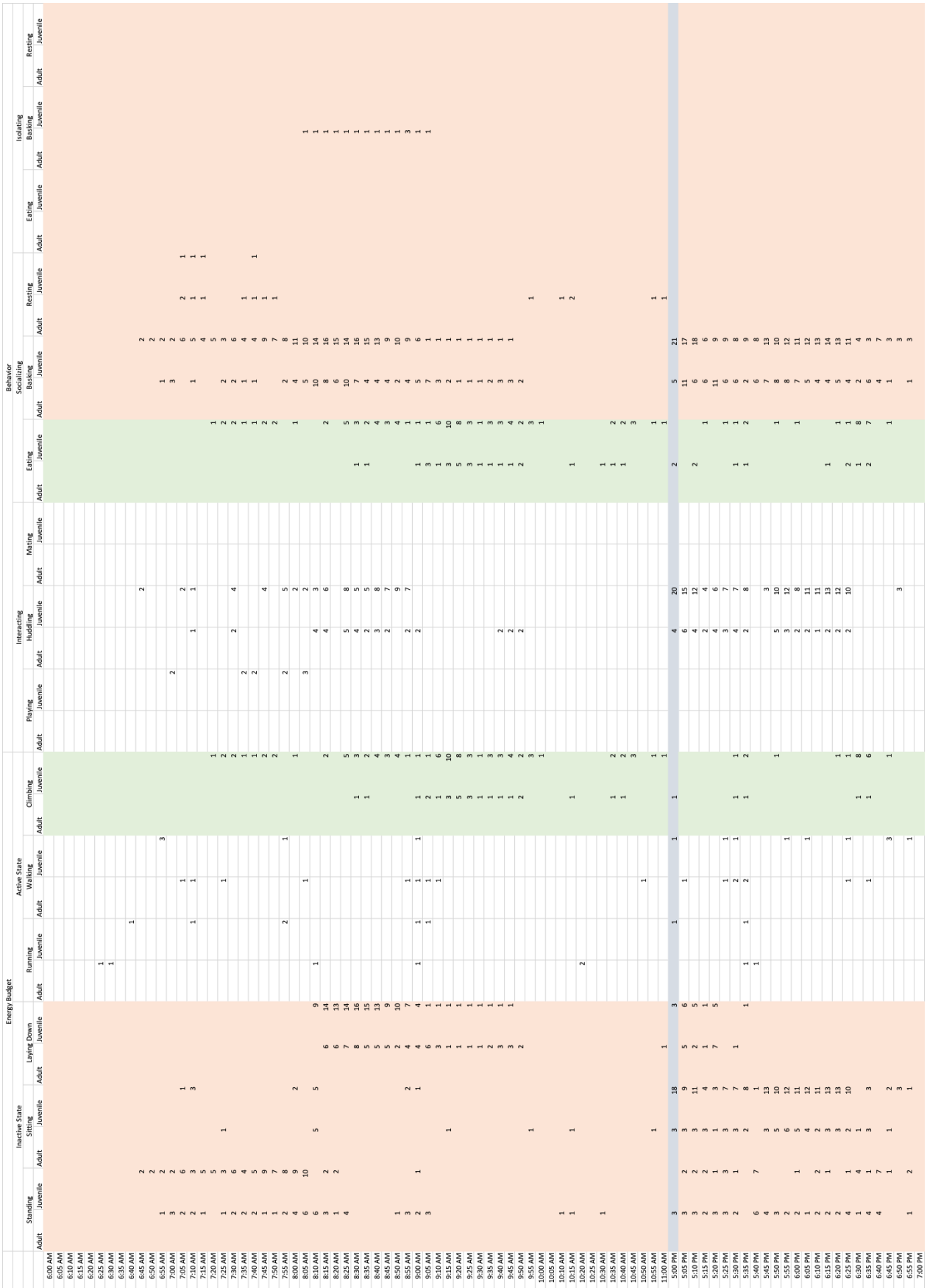
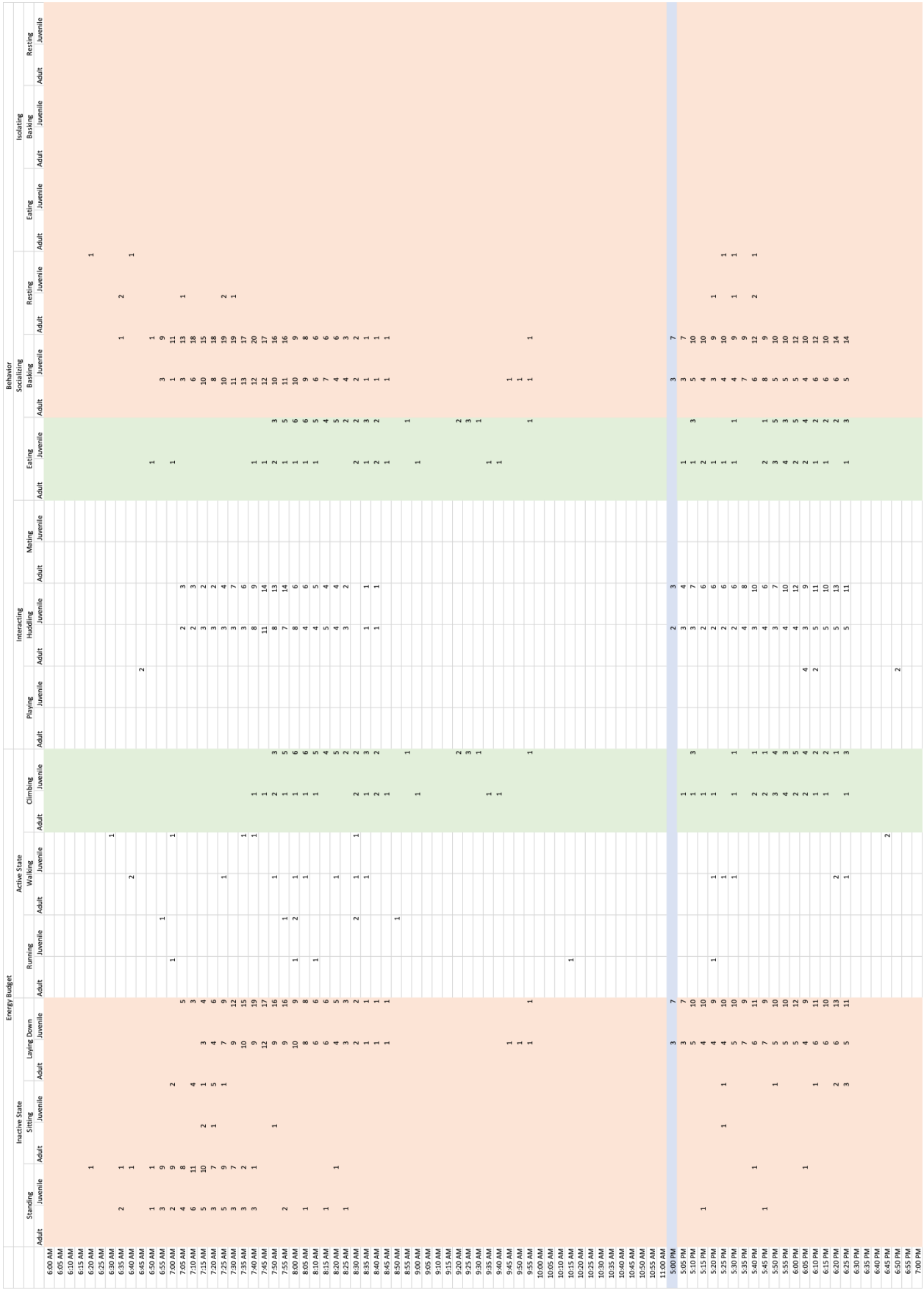


***Table 19**. Raw Data (April 16th, 2024)*



Appendix B

Work Plan

Proposal Writing	Proposal Submission	Research Proposal Marking	Data Collection	Data Analysis & Report Writing	Research Paper Submission

April/May

	01 Mon	02 Tue	03 Wed	04 Thu	05 Fri	06 Sat
		Submit Final ISP Proposal @ 2:00pm	Research Proposal Marking	Research Proposal Marking	Research Proposal Marking	Travel to Randilen
07 Sun	**08 Mon**	**09 Tue**	**10 Wed**	**11 Thu**	**12 Fri**	**13 Sat**
Day 1 (of data collection)	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
14 Sun	**15 Mon**	**16 Tue**	**17 Wed**	**18 Thu**	**19 Fri**	**20 Sat**
Day 8	Day 9	Day 10 (last day)	Travel to Mto Wa Mbu	Data Analysis	Data Analysis	Data Analysis
21 Sun	**22 Mon**	**23 Tue**	**24 Wed**	**25 Thu**	**26 Fri**	**27 Sat**
Data Analysis	Data Analysis	Travel to Arusha	Report Writing	Report Writing	Report Writing	Report Writing
28 Sun	**29 Mon**	**30 Tue**	**01 Wed**	**02 Thu**	**03 Fri**	**04 Sat**
Submit ISP Report for Review	Revise ISP Report	Revise ISP Report	Revise ISP Report **Submit** Work Journal	ISP Presentations	**Submit** Final ISP Report	
05 Sun						

Budget

Total : 1,600,000 shilingi			
Description	**Quantity**	**# of Days Needed (20 days for ISP)**	**Total costs (TZE)**
Accommodations: Camping (near main gate)	N/A	10 nights	$15 per night x 10 nights = $150 = 390,000
Food/water: • Food • Water • Gas (cook stove)	• Food - Ramen - Pasta - Beans - Fruit - Tomatoes - Corn • Water 4-5x (big jugs) • Gas (cook stove) = 1 tank	10	• Food @ Randilen = 68,850 • Water 4x = 34,000
Transportation: • To Randilen • To Mto Wa Mbu • To Arusha	2 (Bus and Boda boda)	3	1. To Randilen = 0 2. To Makuyuni = 1,000 3. To Arusha = 5,000
Ranger?: (I don't think I'll need a ranger)	1	1	N/A
Data collection materials:	1	1	(From office)

- 100m Tape-measure			
Advisor(s): Advisor: Dr. Oliver C. Nyakunga Co-Advisors: Oscar Paschal & Kaiza Kaganzi	2-3	(TBD)	(N/A)
Printing of data tables: Black and White	2 sheets per day (double sided)	10	Black and White double sided = 500 per page + extra = 13,000 total (set aside 7,000 incase of damage)
Extras/Asantes:	(TBD)	(TBD)	16,000
Totals:	**1,600,000** **@ Randilen** Airbnb rent = 76,000 Printing data collection tables = 13,000 Data (41GB) = 85,000 Food = 68,850 Water = 34,000 Camping (x10 nights) = 390,000 Asante = 16,000 Makuyuni bus = 1,000 Arusha bus = 5,000 **@ Arusha** inDrive to office = 10,000 Eagle's Lair = 280,000 Food = 109,000 **Total Spent = 1,087,850**		