Influence of Diet on Activity Patterns of Nonhuman Primates

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Abstract:

Primate activity patterns and diet have been researched separately in the wild; this project aims to examine the relationship between the two by comparing species in captive populations. The zoo setting allows for the control of many variables such as climate, exposure to humans, and the absence of predators. Observational studies were conducted in hopes of understanding the relationship of differences between the activity patterns of frugivores and folivores. It was predicted that folivorous species would be less active than frugivorous species with regard to three activity categories: scale (micro or macro), intensity (vigorous or calm), and sociality (social or solitary). Focal-follows and group-scans were conducted to record behaviors of different species at the Oregon Zoo, including two folivorous and seven frugivorous species. The results from the group-scans of these species were compared to identify a relationship between diet and activity patterns. I found that folivores performed a larger percent of behaviors that were calm and micro than frugivores. There was no correlation between sociality and diet type. The results support the hypothesis originally predicted. This study does not imply that diet dictates behavior, rather, this information can help to provide zoos with plans for providing proper enrichment for each species. Post hoc analysis led to the comparison of enrichment with the activity categories and found that vigorous and macro behaviors were observed significantly more when food or other objects were provided.

Introduction:

This research aims to understand the relationship between different diets and activity patterns among primates. The research involves observational sampling from zoo enclosures of different species. The diets and nutrient contents of those diets for each species will be examined comparatively. The activities and behaviors of these animals will be recorded and also compared to each species. This analysis will provide an insight into whether or not different species' metabolic rates might be related to their diet. As other studies performed have not fully done a comparative study between species, this study hopes to fill in gaps about primate activity patterns that have been left from other research studies.

There are three main categories of food consumption into which primates are typically divided. The first two include the consumption of plant parts. These categories are separated because of a large variance in the nutrients that different parts of the plant provide. In general, the categories are broken into fruit eaters and leaf eaters. Frugivores are primates that consume mostly fruit but the parts or manner can vary, affecting the nutritional content: "Fruit-eaters sometimes consume only the pulp and spit out the seed, or they might consume the whole fruit and digest the pulp and seeds or pass the seeds intact in the feces. Some fruit is consumed only for the seeds, and the pulp and pod or husk are discarded. Gumnivores (gumeaters and sap-eaters) tend to feed heavily on one or a few species of trees," (Committee, 2003). A diet consisting mostly of fruit or sap is high in sugar, which produces high amounts of energy. An average medium sized banana for example, contains 105 kcal and 14.43 g of sugar, bananas are one of the orangutans favorite foods (Basic Report). Diets consisting of fruit are marked by large increases in

the amounts of glucose in the body during feeding time. This sugar gives the primates spikes of energy. It is hypothesized that these primates will be very active at times of food consumption, especially in comparison to leaf-eating primates. Frugivorous primates are also predicted to be more active than folivorous, or primarily leaf-eating, primates because they have to travel more in order to acquire food. Fruits are often available in patches while leaves are abundant and evenly distributed. Fruit also tends to be available seasonally while leaves are more often abundant year-round. Restrictions of food resources like this may cause wild frugivorous primates to travel more than wild folivorous primates.

Although folivory is typically thought of as consuming only leaves, a wide variety of plant structures are consumed, just as with frugivores. The range that includes "young leaves, mature leaves, petioles, shoots, and other plant parts are eaten with various degrees of preference," (Committee, 2003). It is predicted that folivorous species will show calm behaviors because these plant parts do not contain high amounts of sugar as do fruits. One species of folivore is the black howler monkey (*Alouatta pigra*). Pavelka and Knopff found that black howlers are "typical of howler monkeys in showing high levels of inactivity, normally associated with a highly folivorous diet," (2004). Their study documents the food consumed by a population of black howlers, noting that howlers are often thought of as the most folivorous new world monkeys, and they are notorious for being energy-minimizing and having an inactive lifestyle (Pavelka & Knopff, 2004). Black Howlers are one of the species that will be observed for this study.

High levels of fiber in a folivorous diet causes several problems for folivores since this material takes longer to digest. One of the adaptations that folivores exhibit is a larger gut with longer intestines. Colobine monkeys, for example, have a more complex and enlarged stomach than most other species. They also have pouch like formations in their stomach that allow for increased surface area and compartmentalization. The colon and caecum are also very enlarged. Microbial fermentation occurs in the stomach and is the most expanded in colobine monkeys (Davies & Oates, 1994). There are several different digestive strategies of folivorous primates. Descriptions of gut modifications include those of the fore gut and hind gut along with symbiotic bacteria that produce energy by microbial degradation of food particles. Colobine monkeys have fore guts that house bacteria: "Anaerobic cellulolytic bacteria and other microbial symbionts in the saccus produce enzymes that degrade plant cell walls and promote access to the cellular contents," (Committee, 2003). This information has been helpful in understanding why folivores may be more lethargic than species that eat fruit or insects.

Although this study will not be addressing the third category of diet type due to lack of accessibility, it is important to understand faunivorous primates and how their diet differs from those observed. Faunivory often refers to the consumption of vertebrate tissue or carnivory (McGrew, 2000). "Primate faunivores, which tend to be small and nocturnal, feed primarily on invertebrates but can supplement their diet with plant materials," (Committee, 2003). There are several different ways that insects can be incorporated into a diet; they can be consumed as staple, complementary, supplementary, or replacement foods (Rothman et al., 2014). Small and nocturnal species are often

classified as having insects as the staple of their diet. Complementary food supplies nutrients for the consumer that would not otherwise be available in sufficient quantities; for example, marmosets, tamarins, capuchins, and patas monkeys often consume insects as a crucial protein source to complement the energy they consume from fruit (Rothman et al., 2014). A supplementary food is similar to complementary in that they are necessary to provide nutrients, but supplementary is to a smaller degree as only a single essential nutrient is provided. These foods are often consumed on occasion and in small quantities. Gorillas and colobus monkeys are thought to consume insects for trace elements (Rothman et al., 2014). Food replacements are the final category and include the consumption of insects when there is a high amount available such as seasonally (Rothman et al., 2014). These different categories of insectivory demonstrate how different diets may consist of different amounts of protein and other nutrients.

Faunivores tend to be small, quick primates, which is required because insects are very fast and require high levels of coordination to catch. Since the prey is quick moving, this implication caused for selection of higher metabolism and better eyesight. For faunivores, "it is quite possible that preying upon and including certain hard-bodied insects as a significant portion of the diet also required a locomotor shift in the earliest euprimate ancestors," (Rothman et al., 2014). In order to capture quick moving insects, the primates would also have to be very quick moving with fast reaction time, which favors small-bodied primates. It would be difficult for larger species to gain access to insects because of "prohibitive pursuit-and-handling time involved in capturing widely dispersed small prey or anatomical and locomotor constraints on the kinematics of arthropod capture," (Hawes & Peres, 2013). Such a large portion of small insects would need to be consumed in order to provide a substantial diet to large primates that it would simply not be feasible. This is one aspect in which it is the activity patterns of a primate that cause certain diets to be favored and others to be ruled out.

The relationship between diet and activity patterns has been studied in the past to some extent. In non-human primates, the diets of species are well known, but methods and recording procedures are very inconsistent. There also is a bias toward more accessible species that are populous and easily habituated to researchers. This creates gaps in data, as explained by researchers: "Sampling effort by primatologists, however, has been unequally distributed, hampering quantitative comparisons of primate diets," (Hawes & Peres, 2014). There also are few direct comparisons of diet and amounts of activity in primates. One study observed the effects seasonal changes had the relationship between diet and activity. Pavelka and Knopff (2004) compared the diet and activity patterns of black howlers. The study compared two separate time periods where the main diet components varied. From January to March, the howler monkeys consumed mostly leaves. During the warmer months of April-July, the population took advantage of increased access to fruit, and the howlers' diets consisted mostly of fruits. No difference was found in activity between the two different time periods; the howlers were equally as inactive throughout all months. When the data were pooled they found variations in diet that were immediately apparent, "corresponding variation, however, is not seen in the monthly activity budgets," (Pavelka & Knopff, 2004). This study suggests that diet alone may not cause changes in different activity patterns. Instead, taking more of an

evolutionary standpoint may give rise to reasoning that the sudden increase in fruit consumption was not a long enough time period to cause changes in instinctive behavior.

The application of the findings from comparison of diet and activity patterns may be important for zoos in terms of providing enrichment to primate species and others alike. Many studies have evaluated the negative and positive effects captivity has on the behavior of a species. Cooke and Schillaci (2007) address the effects zoo environments have on the behavior of gibbons and siamangs. They looked into how the visitors of zoos affect the apes. Sound meters were used to detect changes in noise with comparison to group size and presence or absence of children. It was found that noise level had significant effects specifically on the males' activity patterns as increased noise levels resulted in decreased activity patterns. Cooke and Schillaci did document, however, that some of the males would occasionally display territorial behaviors when zoo visitors were present (2007). If the increased sound level is decreasing behaviors, different preventative measures could be taken to either decrease the noise for the primates, or to provide distractions that return activity levels to normal. Enrichments including food could provide a distraction to the primates. Frugivores, for example, could be given items containing fruit to provide energy that may return activity patterns to their normal state. Feeding at times of high visitor traffic could also be beneficial by drawing the primates out where the crowd can observe them while also distracting the primates from the visitor's presence by occupying them with food.

Enrichment for captive populations is an environment that provides stimulation that encourages behaviors typical for that species. Enrichment can be provided in a combination of different ways in order to maximize animal welfare. For this study enrichment was considered to be food and other objects in the cage that were not permanent but the individual interacted with. This included blankets, shirts, cardboard boxes, toys, and other assorted novel objects. Stimulation can also be increased by simply placing food or novel objects in areas that are more difficult to access. Faunivorous primates must catch their prey in the wild, which requires talent and learned skill. Although pellet food may meet nutritional requirements, it does not provide this aspect of hunting for food. Dickie describes how important food manipulation can be for providing stimulus to primates. Zoo enclosures with netting on ceilings that food must be retrieved through is one such way. "It is also important to consider the times at which primates are fed. Old World primates may forage from first light to dusk in the wild, so providing one large feed each day is far from adequate," mentioned Dickie (1998). Viewing activity patterns relative to feeding times during this research may reinforce this statement and how important it is.

For each species, all individuals that were observable were viewed at the same time and the behavior was recorded according to three different classifications: intensity, scale, and sociality. The first parameter is calm vs. vigorous. Behaviors done aggressively, quickly, or with emphasis were coded as vigorous. Slow, steady, or relaxed behaviors were considered to be calm. The second parameter is micro vs. macro behaviors. A behavior is considered to be micro if the individual is not moving outside of it's body length with performing a task. A behavior that requires the individual to move

across the enclosure was coded as macro. The final parameter of the three is social vs. solitary behaviors. If an individual was interacting with another then the behavior was considered to be social, otherwise the behavior was solitary. Whether or not an individual was interacting with some sort of enrichment was also recorded. These enrichments included food, blankets, cardboard boxes, clothing, or a combination of items. After the first day of observations, whether or not an individual was sleeping or awake was also recorded. This was done because sleeping was recorded as micro and calm but differs from calm, micro behaviors performed while awake.

Expected Results and Significance:

Several studies have addressed both topics of diet and activity patterns in primates. These studies predict that a lower quality diet will be associated with a lower amount of activity throughout the day. This hypothesis will be tested by comparing the frequencies of the different categories of activity for folivores and frugivores. It is hypothesized that frugivores will exhibit more vigorous and macro activity patterns than folivores who are predicted to have micro and calm behaviors. Folivorous primates are also thought to be less social than frugivores because they do not need to compete for food as much and may not need to form as strong of alliances. The social intelligence hypothesis states that increased social skills and intelligence have been selected for by the pressure of social challenges; this increase is often correlated with highly encephalized primates (Perry et al., 2004). It is often a high energy cost for species to have the brain activity associated with this complex social cognition. Folivorous species may not possess the extra energy needed for this nor have been influenced by the same selection that frugivorous species have to become more social. This is why it is hypothesized that frugivores are more social in comparison to folivores. It is also expected that by observing enrichment provided, this study will show that frugivores would benefit the most from enrichment out of the two dietary categories.

Unlike most existing studies, this research involves a cross-species comparison of many different categories of primates. The zoo setting for this research helps to eliminate the effects that different variables found outside of a zoo might have on the three activity categories being studied. For example, variable temperatures, seasonal changes, lack or predators, and exposure to humans will all be constant for each species since they are in the same zoo. Although this research aims to establish a correlation between diet and activity patterns, it is expected that the relationship between the two cannot ultimately be termed causation because too many factors still remain.

Methods:

For this observational research project, focal follows along with group follows were performed. In past studies, both methods have been used in the wild as a way to quickly document behaviors and observations. The focal follow, or focal-animal observation, described by Susan Perry in her book *Manipulative Monkeys* is similar to what was conducted for this study. “The primary data collection protocol involves following a single monkey for ten minutes,” and all social, foraging, and self-directed

behaviors were recorded (Perry, 2008). A second form of observational research described by Perry is a group scan, in which the activity of each monkey visible is recorded along with the spatial relationship of that individual to other monkeys within 10 body lengths of it (Perry, 2008). This method is only feasible when observing a few, easy-to-see behaviors (Committee, 2003). In order to aid in quickly documenting behaviors, a general ethogram was created including behaviors that were seen across species as has been done in previous studies (Nishida et al., 1999). With these methods, time spent on activities was transferred into a percentage of the entire day.

For this research project, observations were conducted at the Oregon Zoo. Ten different species of primates were observed including: colobus monkeys (*Colobus guereza*), 2 species of orangutans (*Pongo abelii* and *Pongo pygmaeus*), white-cheeked gibbons (*Nomascus leucogenys*), mandrillls (*Mandrilllus sphinx*), chimpanzees (*Pan troglodytes*), De Brazza's monkeys (*Cercopithecus neglectus*), cotton-top tamarins (*Saguinus Oedipus*), white-faced saki monkeys (*Pithecia pithecia*), and black howler monkeys (*Alouatta caraya*). For the purposes of this study, data from both species of orangutans was pooled. These species were separated into two categories of diet patterns: folivores: colobus monkeys, black howler monkeys; and frugivores: orangutans, gibbons, mandrillls, chimpanzees, De Brazza's monkeys, and Cotton-Top Tamarins (Committee, 2003). Initially a focal follow detailing each behavior performed was used to gain a general basis for how that species behaves. Specific focal follows were conducted during data collection to categorize the behaviors based on activity patterns.

A sample observational study was done as a trial. Since accessing the zoo beforehand was not feasible, the video "RX Feb 12 2008 part 1" by Susane Perry was used (Perry, 2009). This is a 3-minute focal follow of a capuchin. A sample ethogram was created for recordings and is presented below. The results from two separate observers (myself and my advisor) are presented to provide a comparison. Based on the review and comparison of our recordings, it was decided that my methods were accurate and behavioral observations could begin at Oregon Zoo. During the observational studies for this research, the behaviors recorded were broader than seen in the example.

Individuals present:
RX (Rumor): focal animal
OD (Odin): alpha male
CI (Curie): infant

Ethogram:

Code	Behavior	Brief Description
EF	Eats Food	Bring food to mouth, one hand, no manipulation
GF	Grabs Food	Catches a bug to eat
LA	Looks Around	Looking around either at observers or at surroundings
SP	Searches for Prey	Looking for bug
TH	Threatens	Hunched position and threatening behavior toward another
BT	Bares Teeth	Shows teeth while threatening toward another
CU	Climbs Upward	Moves up a tree
CA	Climbs Across	Moves from tree to tree
PB	Peels Bark	Peels away bark in order to search for bug

1st observer recordings:

Time	Observations
0-1:00	RX SP; RX GF; RX EF; RX LA; RX SP; RX TH CI + OD; RX BT;
1-2:00	RX SP; RX PB; RX SP; RX GF; RX CU; RX EF; RX LA; RX CA
2-3:00	RX CA; RX CU; RX CA; RX CU

2nd observer recordings:

Time	Observations
0-1:00	RX GF; LA; CU; CA; TH
1-2:00	RX CU; EF (long time); CA
2-3:00	RX CA; CU; CA

A recording such as this, done prior to focal follows and group scans, was helpful for identifying basic behaviors. When observations began, primarily focal follows were done. An example of a table to be filled out during a focal follow is provided as Table 1 below. Tables were printed as sheets and filled out during observations.

Species:			Individual:				Zoo:			
Enrichment: Pre During Post							Date:			
Time (sec)	Social				Solitary				Visitor near glass	More than 10 visitors
	Vigorous		Calm		Vigorous		Calm			
	Micro	Macro	Micro	Macro	Micro	Macro	Micro	Macro		
10										
20										
30										
40										
50										
1 min										
1:10										
1:20										
1:30										
1:40										
1:50										
2 min										
2:10										
2:20										
2:30										
2:40										
2:50										
3 min										
Description of Enrichment:										

Table 1: Data table used to record focal follows. Information was filled out at the time of each observation and recordings were made using a stop-watch.

For the first few observations, the chart above was used to record focal follows. This method proved to be rather inefficient, though, because only one individual was being recorded at a time. It was also not very effective because, many times, individuals would not move for the entire observation period. To improve data collection methods, group scans became the primary method of recording. The observations recorded as focal follows were then transcribed into the same format as the group scans to make data consistent.

Table 2 below shows an excerpt of the table filled out during group scans. For each observation id number, every individual of that species was observed. Behaviors were recorded in regards to intensity, scale, and sociality. Enrichment and alertness were also recorded. If an individual of the species currently being observed was not present, then the boxes were left blank.

Before any observational studies began, the Institutional Animal Care and Use Committee at Washington State University was contacted to ensure that no animal harm could be caused by this research. The committee approved of the research proposal and gave the following guidelines for observational data collection:

1. You should not wear perfume or bright/scented cosmetics.
2. Don't make eye contact with the animals, especially the alpha males, who might become aggressive and redirect their aggression at subordinate females in the enclosure.
3. Wear subtle clothing in greys/browns, and greens so you blend in with the scenery.
4. Move your observation position randomly around every 15-30 minutes.
5. Don't eat or drink in front of the animals.
6. Don't have a loud or distracting device make sounds, and don't text or talk on the phone (cell phone, etc.).
7. Use a writing tablet and pen that are grey, brown, or green (non-distracting).

These guidelines were followed during data collection in order to be in accordance with the committee.

Observation-ID	Date	Time	Species	Individual-ID	Intensity	Scale	Social	Enrichment	Alert
43	6/23/15	12:50:00 PM	Orangutan	3	Calm	Micro	Solitary	No	sleeping
43	6/23/15	12:50:00 PM	Orangutan	4	Calm	Micro	Solitary	No	Sleeping
44	6/23/15	14:35:00 PM	Saki	19	Calm	Micro	Solitary	No	Awake
44	6/23/15	14:35:00 PM	Saki	20	Calm	Micro	Solitary	No	Awake
45	6/23/15	16:25:00 PM	Saki	19	Calm	Micro	Solitary	No	Awake
45	6/23/15	16:25:00 PM	Saki	20	Calm	Micro	Solitary	No	Awake
46	6/23/15	16:30:00 PM	Saki	19	Calm	Micro	Solitary	no	Awake
46	6/23/15	16:30:00 PM	Saki	20	Calm	Macro	Solitary	no	Awake
47	6/23/15	12:35:00 PM	Mandrill	14	Calm	Macro	Solitary	Yes-Food	awake
47	6/23/15	12:35:00 PM	Mandrill	15	Calm	Macro	Solitary	Yes- Food	Awake
47	6/23/15	12:35:00 PM	Mandrill	16					

Table 2: Example of data table for group scans. Information was filled out and then entered into a spreadsheet using Microsoft Excel Software.

Results:

The three parameters focused on for this research were scale, intensity, and sociality. The graphs below depict the data collected from Oregon Zoo. The width of each species column represents the proportion of observations that were done for each species in comparison to each other. For example, Figure 1 below shows a graph of scale by species and the orangutans have a much wider column than saki monkeys because there were more total observations done for orangutans than there were saki monkeys. This increase is due partly to the fact that there were four orangutan individuals and only two saki monkey individuals. The difference in observation number is also due to the fact that some species were more accessible than others and easier to view. The y-axis of these graphs is separated into two categories, Figure 1 shows micro vs. macro distribution. The columns are broken along this axis to represent what percentage of observations were macro and what percentage was micro. All data analyses were done using R Statistical Analysis Software and Microsoft Excel. All graphs were created using this software as well.

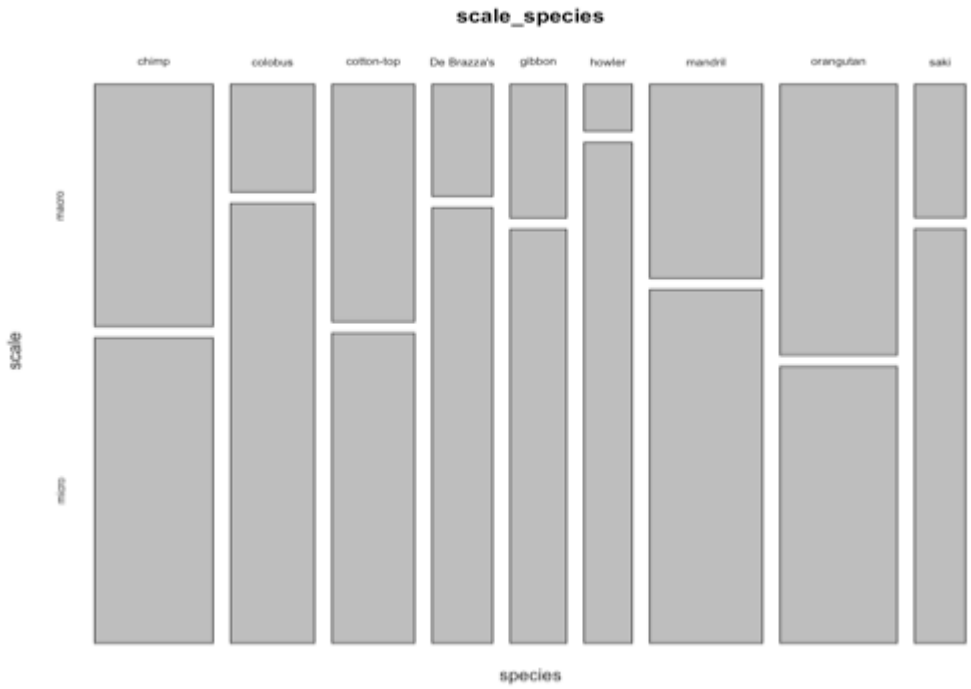

Figure 1: Scale vs. Species. Comparison of scale with each species conveying total percentage of micro and macro behaviors.

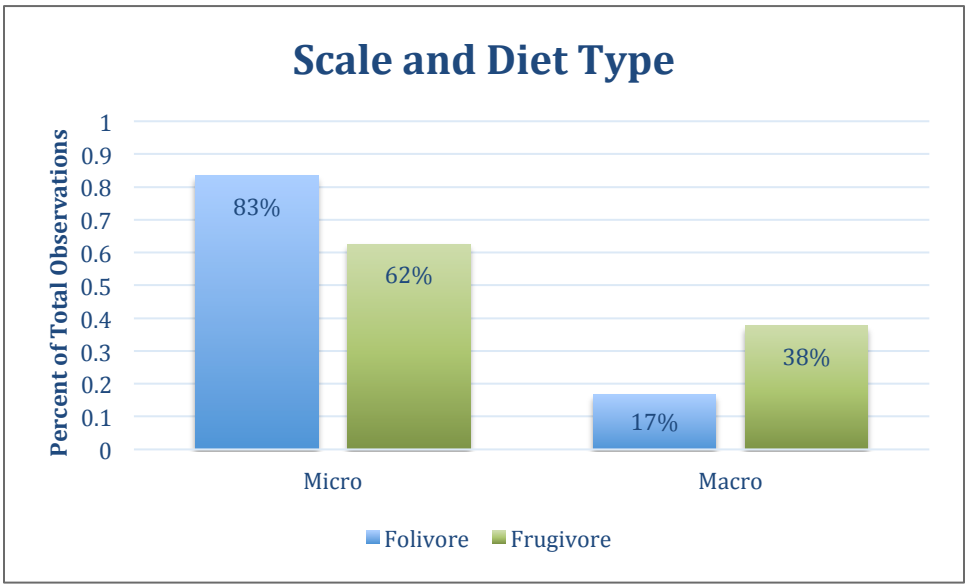

Figure 2: Scale vs. Diet type. Comparison of average percent of scale of behavior for folivorous and frugivorous diet types.

A difference was found between folivores and frugivores in terms of behavioral scale. To do this, first statistical analysis of the data from Figure 1 was done to calculate a p-value of 7.293 x 10^-6. A p-value less than 0.01 is considered to be highly significant, and indicates that these results would not be found by chance. This means that there was a strongly significant difference among species in terms of micro and macro behaviors. In order to determine if diet type had a significant difference, the species were grouped into folivores and frugivores and then statistical analyses were run again. These data are represented in Figure 2 above, and have a p-value of 0.01665428, meaning there was also a significant difference between folivores and frugivores in how much they performed micro and macro behaviors.

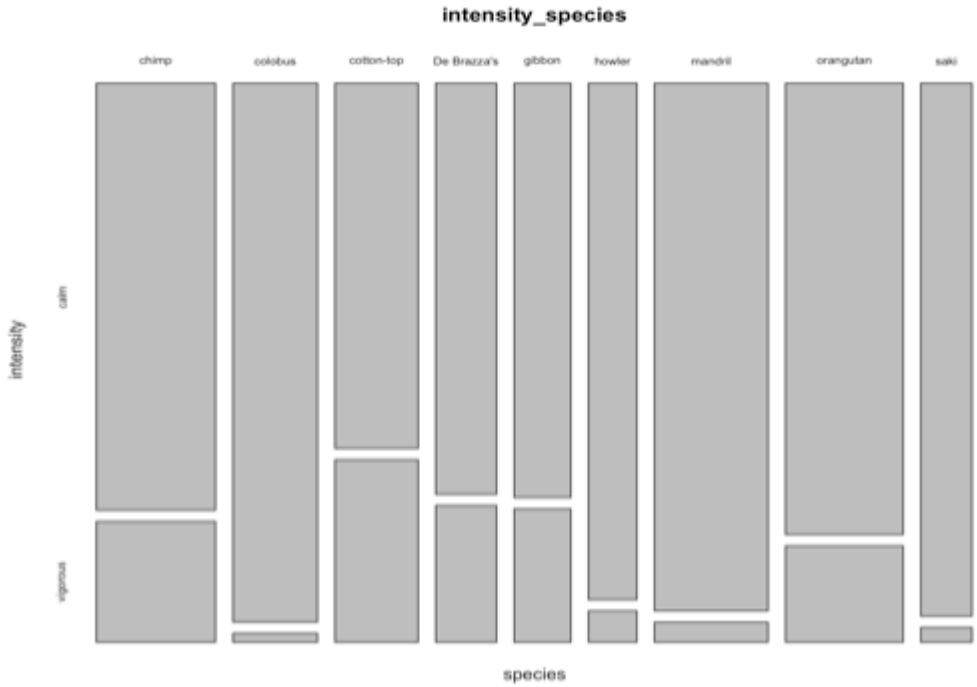

Figure 3: Intensity vs. Species. Comparison of intensity with each species conveying total percentage of vigorous and calm behaviors.

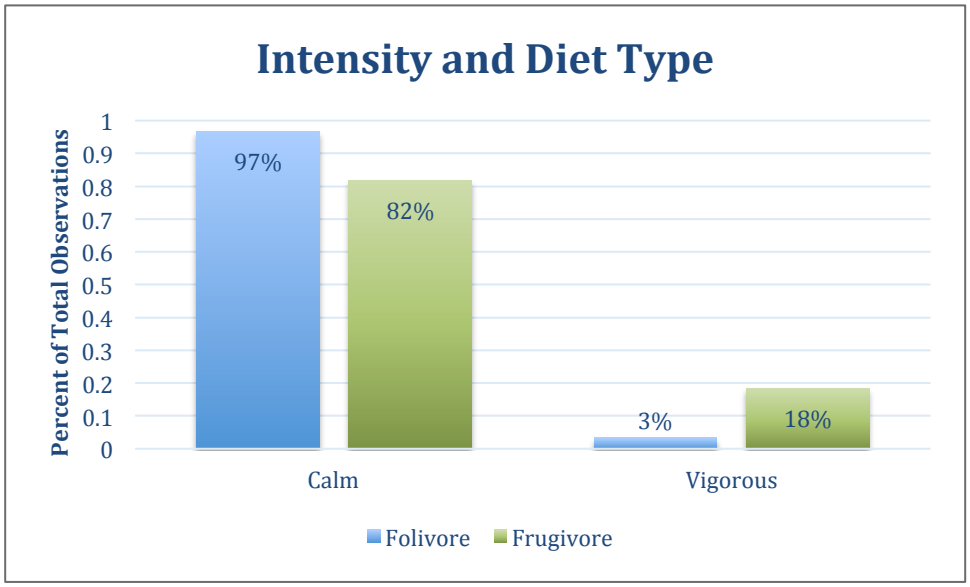

Figure 4: Intensity vs. Diet Type. Comparison of average percent of intensity of behavior for folivorous and frugivorous diet types.

The intensity of behavior for each species is shown graphically in Figure 3. The data analysis of this comparison gave a p-value of 8.714 x 10^-8. This means that there was again a significant difference among species. When the species were grouped into

their diet types, there was again a significant difference in the behaviors. The folivores were more likely to be calm than the frugivores. This data gave a p-value of 0.0478128 which means there was a statistically significant difference between vigorous and calm behaviors based on diet type.

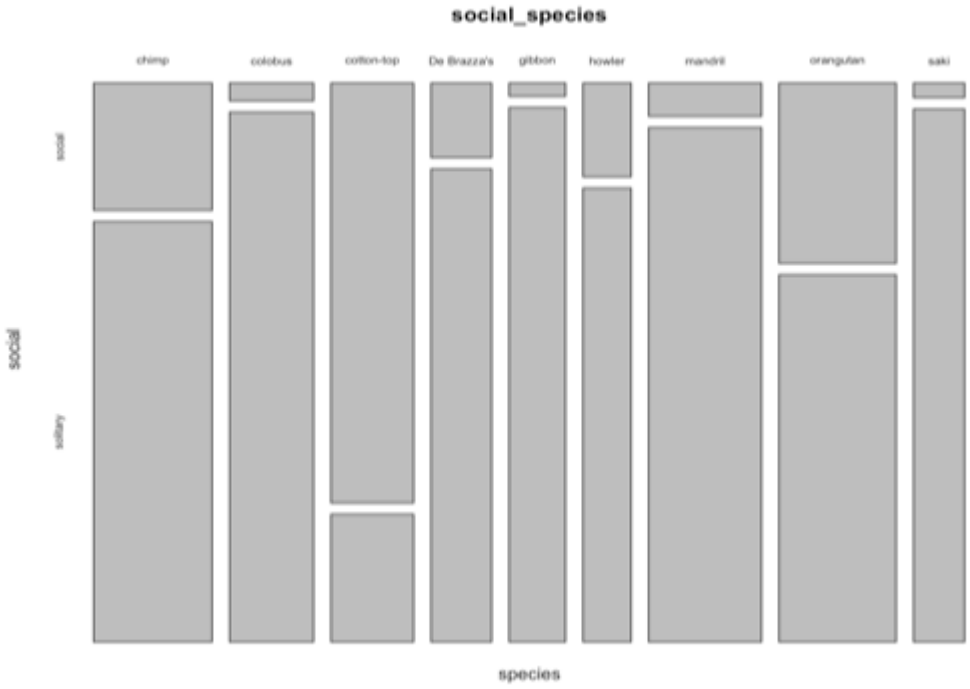

Figure 5: Sociality vs. Species Comparison of sociality for each species conveying total percentage of social and solitary behaviors.

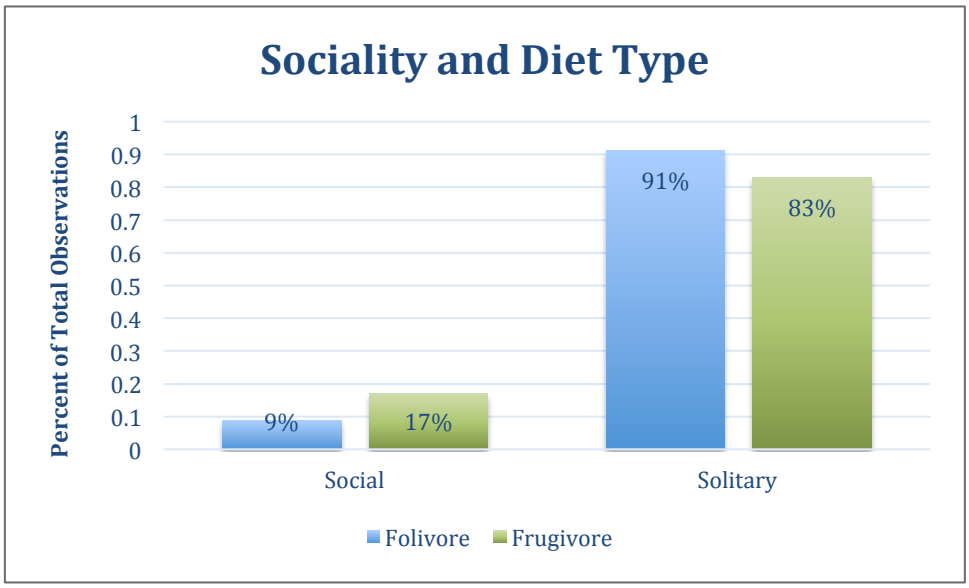

Figure 6: Sociality vs. Diet Type. Comparison of average percent of sociality of behavior for folivorous and frugivorous diet types.

Socaility of behaviors was also compared to determine if behaviors were social or solitary. Data analysis revealed that there was significant variance of levels of social interaction among species with a p-value of 9.906 x 10^-30. However, data analyses also showed there was no difference in levels of social interactions between folivores and frugivores, indicated by a p-value of 0.590828. This shows that there was no significant difference for sociality based on diet type.

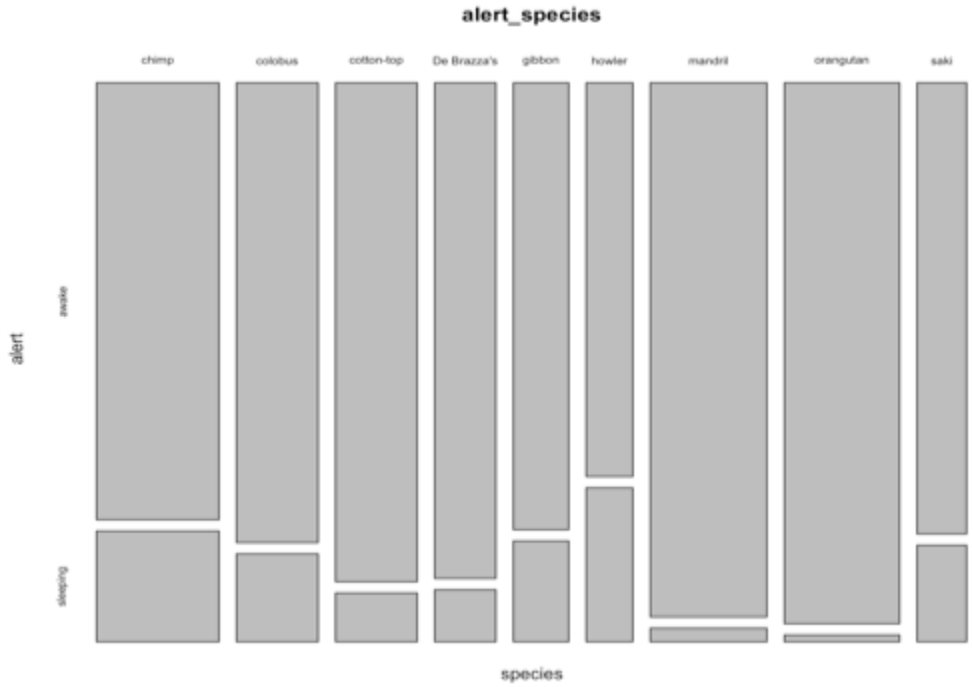

Figure 7: Alertness vs. Species. Comparison of sociality for each species conveying total percentage of awake or sleeping.

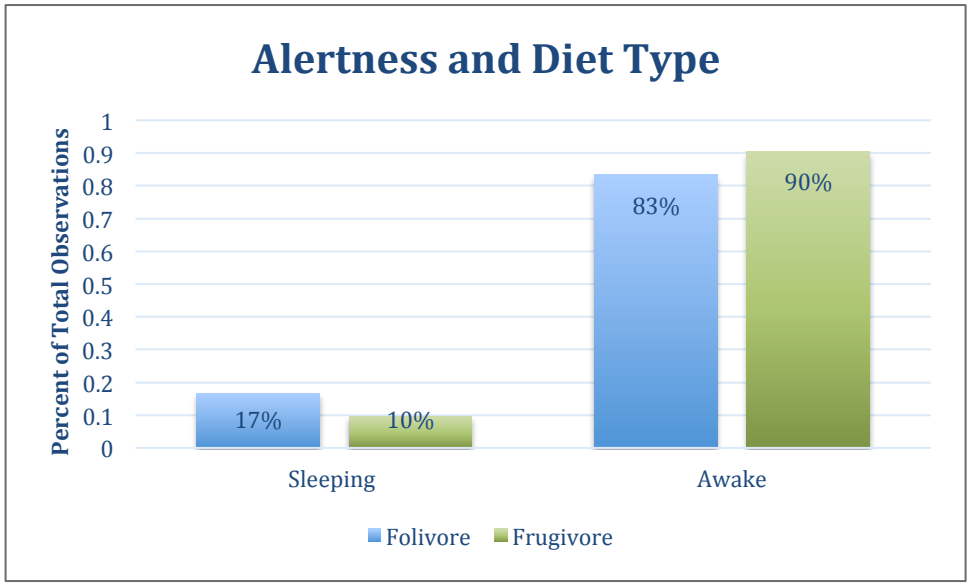

Figure 8: Alertness vs. Diet Type. Comparison of average percent of sociality of behavior for folivorous and frugivorous diet types.

Alertness was also compared for each species to see if folivores slept more than frugivores. Data analyses showed there was variance in time spent sleeping across species, indicated by a p-value of 6.354 x 10^-5. When analyses were done comparing frugivores and folivores though, there was no significant difference since a p-value of 0.13122 was given. That is, folivores did not sleep a significant amount more than frugivores.

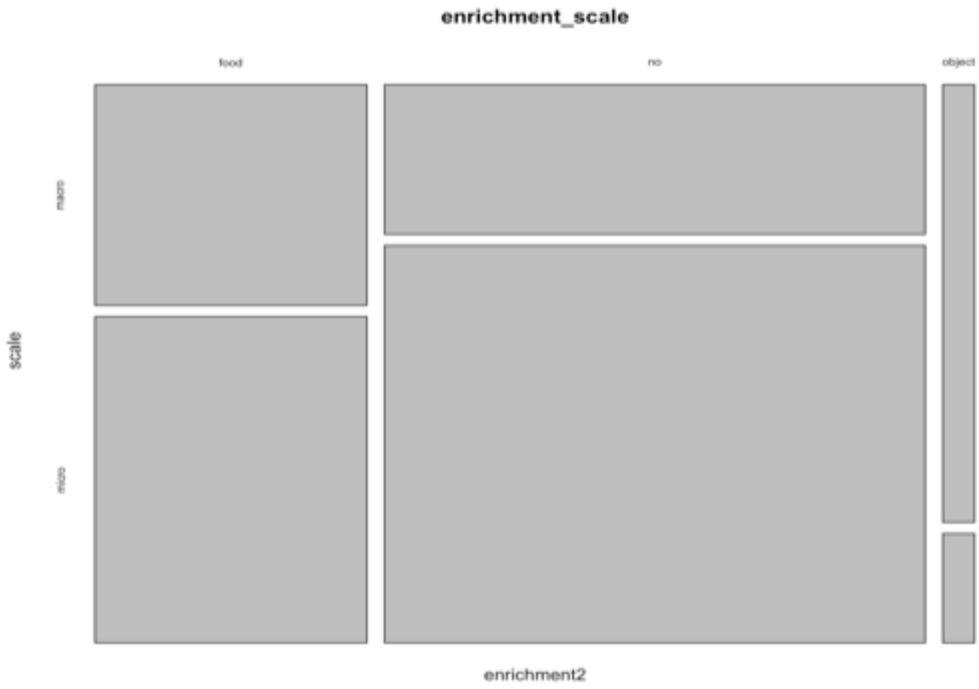

Figure 9: Scale vs. Enrichment. Comparison of scale of behavior and type of enrichment: either no enrichment, food, or novel object. Graph conveys total of micro or calm behaviors when these enrichment conditions applied.

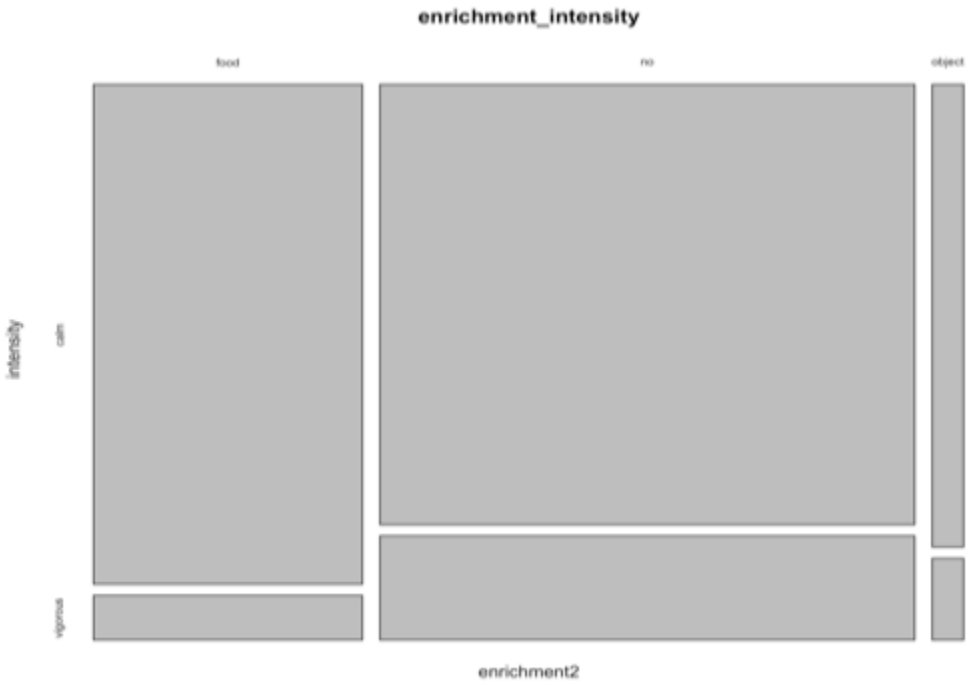

Figure 10: Intensity vs. Enrichment. Comparison of intensity of behavior and type of enrichment: either no enrichment, food, or novel object. Graph conveys total of vigorous or calm behaviors when these enrichment conditions applied.

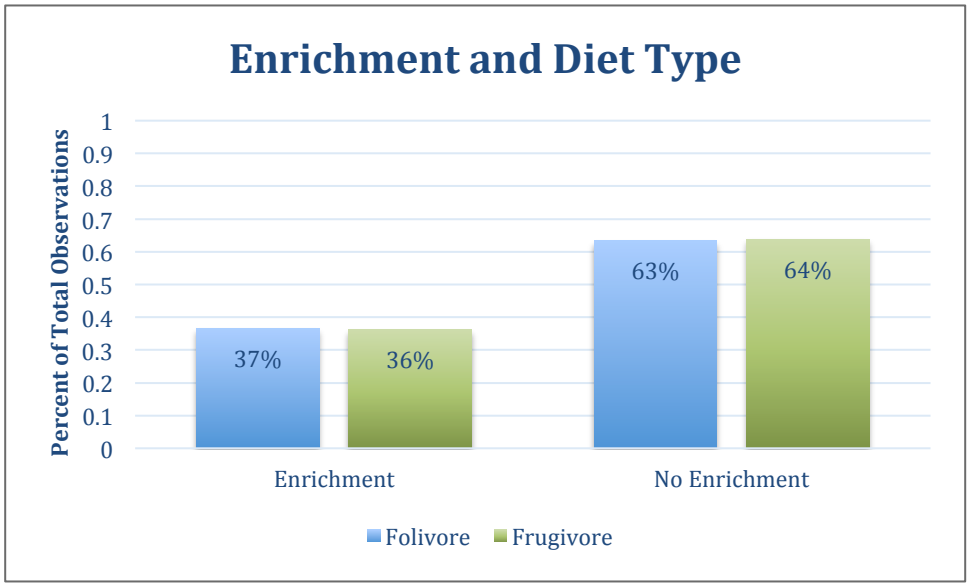

Figure 11: Enrichment vs. Diet Type. Comparison of average use of enrichment for folivorous and frugivorous diet types.

Intensity and scale were also compared to use of enrichment provided. Figure 9 shows the comparison of scale of behavior with enrichments provided. The data gave a p-value of 5.652 x 10^-7 meaning there is a highly significant difference in the scale of behaviors. This means that behaviors were more likely to be macro when enrichment was

provided. This is especially true when novel objects were provided as enrichment. Figure 10 shows the comparison of intensity with enrichment. The data gave a p-value of 0.00548 meaning there was a significant difference in the intensity of behaviors. When enrichment was provided, behaviors were more calm. Figure 11 above shows that there is no significant difference in the use of enrichment for the different diet types. Statistical analysis gave a p-value of 0.75759 meaning there is not a significant difference of enrichment use between folivores and frugivores.

Discussion:

The main focus of this research is on non-human primate behavior and is centered around three basic parameters of activity patterns: scale, intensity, and sociality. The purpose of addressing how activity differed among species was to find if there was correlation with diet type. Diet types were divided into three categories, two of which were accessible for this study, comparisons were made to see if there were any significant differences between them. Having observational studies conducted at Oregon Zoo allowed for other variable factors to be controlled and considered null in the process of data collection and analysis.

The first activity pattern addressed was scale, and behaviors were categorized based on micro or macro movement. If an individual remained in one spot during the group scanning, it was categorized as micro. However, if an individual was moving across an enclosure, the behavior was categorized as macro. This classification was important because it allowed for observation of the range of activities performed. It was found that there was a significant difference in the scale of behaviors not only between species but also between folivores and frugivores. Folivores performed micro behavior about 83% of the time in comparison to frugivores that performed micro behaviors about 62% of the time. This means that frugivores have larger movements 20% of the time.

The difference in frugivore and folivore activity could be important in considering what type of enclosures are more appropriate for frugivorous species that spend closer to half of their time mobile and moving around their enclosure. This data is not surprising as primates in the wild have also exemplified these same patterns. Wild frugivorous primates are required to travel to their food source and may feel more pressure to forage a larger range than folivorous primates. Due to the seasonality of fruit, some species species need to travel in order to optimize their nutrient intake. Aquado and Teichroeb (2016) found that vervet monkeys would chose high-reward food sites even if there were other food sites closer in proximity. This instinct to travel to acquire food may help explain why the frugivorous primates in this study showed more macro behaviors than folivorous species.

It is important also to note that vertical and horizontal movement were coded as macro and no distinction was made between the two. Observational studies of each species and their vertical or horizontal movements would also be beneficial information for zoo, rescue, rehabilitation, and sanctuary centers. Knowledge of activity patterns of each species could help when considering how large an enclosure should be and what

kind of enrichment objects, either large trees or small toys, should be provided, and how the exhibit design could be optimized for each individual species. Choo et al. (2001) observed orangutans at Singapore Zoo and found that visitor proximity, number, and activity can have behavioral effects on orangutans. They also found that enclosure design and habituation to visitors could ease some of the effects caused by visitors, suggesting that zoos should reconsider the design of enclosures to improve the welfare of captive animals. Further research could also look into a correlation of feeding time and peak times of macro movement for frugivorous species. Since frugivores have a diet higher in sugar than folivores, they are more likely to experience bursts of energy that may be short lived. Having increased feedings of smaller meals may encourage individuals to move around the enclosure more often and therefore be more active throughout the day.

The second aspect of activity patterns categorized behaviors based on intensity. This classification was a bit more difficult to discern during a group scan, as behaviors done on a micro scale could be difficult to observe. If an individual was doing something quickly and intensely, the behavior was considered vigorous. A behavior done slowly, steadily, or in a relaxed manner was considered calm. For example, an individual sitting still would have a behavior coded as micro and calm since they were not moving across the enclosure, and they were not performing a task vigorously. There were cases where individuals might be sitting still and using just their hands to perform a task such as food manipulation in a vigorous manner. There was one instance where an individual repeatedly rubbed a stone against the rock ledge on which he was sitting. This behavior was coded as micro and vigorous. It was important to see whether there was a difference in the intensity of behaviors performed between the two diet types because this could reveal if individuals were performing as expected based on observations done in the wild, and if different enrichment objects might be preferable to different species. It was found that there was a slightly significant difference between the two diet types in terms of intensity. As expected, folivores showed calmer behaviors than frugivores. In fact, folivores showed calm behaviors almost 97% of the time. As addressed earlier, folivores have a lower metabolism and take longer to process their food through their large guts. Along with information on black howler monkeys provided by Pavelka and Knopff, the observational studies made it clear that this species, and likely other folivores, were extremely lethargic and energy-conserving (2004). Findings of this study may again be important for future improvement of enclosures for species. For example, a future study on the peak times of vigorous movements in comparison to feeding times may indicate increased vigorous activity when food items are present.

The third parameter of activity pattern addressed was sociality. Any behavior that involved interaction with another individual was considered to be social. It was predicted that frugivorous species would be more social than folivorous species since in the wild frugivores would be congregated around seasonal food supplies. The data, however, showed that, while there was variance among species, this was not correlated with diet type. There was no significant difference in the number of social interactions between folivores and frugivores, so this finding did not support the original hypothesis that frugivores would be more social. Some of the limitations of this study may have affected

this result and further research would provide more concrete evidence in favor or disproval of the original hypothesis.

One additional parameter of behavior recorded was whether or not the individual appeared to be sleeping when the observation was done. This was done because folivores were predicted to be more lethargic than frugivores so alertness was recorded to see to what extent they were sleeping while being lethargic. It was found that when alertness and diet type were compared, there was no significant difference between how much each diet type slept. Folivores have a poor diet that may cause them to eat throughout the day and be awake even though they aren't showing macro or vigorous activity.

During the observations, use of food or novel objects provided was recorded as enrichment. This was done in order to understand if folivores and frugivores responded differently to enrichment provided in their enclosures. It was found that the use of enrichment did not vary between the two diet types. Both folivores and frugivores interacted with food or another object about 36% of the time. When the use of enrichment was compared to the previous parameters measured, behaviors seemed to be more calm when enrichment was provided, especially when food was the enrichment source. Statistical analyses of enrichment and scale of behavior showed there was a significant increase in calm behaviors when enrichment was provided. There was also a correlation between enrichment and scale; behaviors tended to be more macroscopic when enrichment was provided. Statistical analyses of enrichment and intensity of behavior showed a significant increase in macro behaviors when enrichment was provided. Although most of the time food was the source of enrichment provided, there were several different times when a blanket, sheet, cardboard box, clothing, toy, or other object was provided in the enclosure. Blankets, burlap sacks, and sheets, for example, were often used by the orangutans to cover themselves up. One individual in particular was often observed walking around with a sheet tied like a cape on his back. A way that this data could have been improved would have been to take better note of what enrichment was being provided. There were several times enclosures were rearranged and it is assumed that this helps stimulate the primate's senses, keeping them interested in their environment, but this was not noted.

Having access to primate species at the Oregon Zoo was essential for the observational studies and data collection for this research. With this setting, species were viewable most times and information about each individual could be known thanks to the zoo staff. In speaking with zoo keepers, information about individual ages and time spent at the zoo was known. This information gave light to some of the limitations of this research. One of the limitations noticed early on in the project was sample size. The number of individuals for each species was not equal. The number of species for each diet type was also not equal. Data may be skewed because there were only two folivorous species. Also, with only a small number of individuals available of each species, the data may have again been skewed. One such problem was age of the individuals. For example, there were two white-cheeked gibbon individuals and the female of the pair was much older. A zoo keeper remarked that she used to be much more active and interact more with the male but had slowed down with her older age and now spent much of the

afternoon napping on her favorite ledge. This situation occurred also with De Brazza's monkeys as the pair was made up of a mother and son. Like the female white-cheeked gibbon, she also spent most of her time napping or calmly observing her son as he bounced around the enclosure very energetically. With these limitations in mind, a subsequent study with a larger and equally dispersed sample size would be able to provide more reliable data.

Another situation that caused an obvious disturbance to a few individuals was the introduction of two new orangutans to the Red Ape enclosure. Typically, the white-cheeked gibbons would periodically be allowed in the outdoor enclosure with the orangutans. This was not being done, however, because the zoo was introducing the two new orangutans to the two existing ones at the zoo. When observations began for this research, the newest orangutan, Kitra, was kept separate from the others they were learning about each other by viewing each other through windows. This introduction of a new group-mate could have caused a large increase in the amount of behaviors displayed by the orangutans. The limitations of this study therefore again include the sample size and individuals that were provided by Oregon Zoo. A final limitation of this study was that faunivorous species were not observed. Oregon Zoo did not have any faunivorous species at the time this study was conducted and therefore could not be compared to the activities of folivores and frugivores.

Conclusion:

Non-human primates showed to have some correlation between diet types and activity patterns. The study showed that for the primates observed at Oregon Zoo there was a correlation between diet type and scale of activity. Intensity of activity was also found to be correlated with diet type. The hypothesis that folivorous species of primates would have more micro behaviors than frugivores was supported. The hypothesis that folivorous species would also have calmer behaviors than frugivores was also supported by the data. It was found that there was no correlation between sociality and diet type for these species and the original hypothesis that frugivores would be more social was not supported. The hypothesis that frugivores would use enrichment items more than folivores was not supported. Although there was no correlation of use of enrichment with diet type, there was a correlation of enrichment with scale and intensity of activity patterns. Enrichment use correlated with more macro and calm behaviors. The findings of this research suggest that enclosure designs could be specified for each species to improve animal welfare. Enrichment use could also be individualized to peak the interests of each primate. Further research would bring more light to the correlation of diet and activity patterns.

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