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Section I

My project began on my flight from Long Island, New York to Northfield, Minnesota. I have always been a highly curious person, drawn to new knowledge and understanding of any topic. Yet, as I sat on that plane, beginning to read about the latest research in the behavioral biology of baboons, I did not realize Primatology would become a passion.

My high school's Social Science Research Program required that I submit a project to the Intel Science Talent Search. I searched through various social science research journals, looking for ideas that would spark my interest. Although I have always been fascinated by animals, studying animal behavior for my project never occurred to me until I was accepted to the Carleton College Summer Science Institute where the behavioral biology of baboons was a topic of study. My three week journey to Carleton College in Minnesota to study "baboonology" was serendipitous; as was my newfound appreciation for the ability of mathematics to bring science into light.

At the Carleton College Summer Science Program I studied under Professor Annie Bosacker, the mentor for my Intel project. Before the program, Dr. Bosacker recommended books and journal articles for me to study so that I had a preliminary background on the subject. I soon began to develop ideas for my research project. Through Dr. Bosacker I was given access to an extensive data set, entitled GomDem04, collected for over forty years at Gombe National Park, Tanzania. This data set represented the demography of hundreds of wild olive baboons from various different troops that inhabit Gombe National Park. It provided essential information such as the

name, birth date, number in birth order, sex, age at death, and mother's name and age for each baboon.

At first, the data sheet appeared to be an enormous, overwhelming mass of numbers and empirical information on thousands of baboons, without much study on their actual behavior. I could not see how I would be able to conduct a research project on behavioral biology through analyzing a set of numbers. Yet, through Dr. Bosacker's vast knowledge of the topic and entertaining stories about her time at Gombe National Park, Tanzania, she brought the data to life. She encouraged me to find the stories hidden in the numbers as the data captured so much of baboon life. Dr. Bosacker's research collected in Tanzania was the key to creating my hypothesis. Without her research I would not have the data to conduct my study. With her guidance, I soon narrowed my focus to studying birth order in relation to age of death. Recalling a process of linear regression that my Junior Year math teacher, Mr. Bozzone, had taught me I sifted through the data with new direction. Through analyzing the data set I drew connections between the research I had done and the data at hand in order to form my hypothesis as to the effects of birth order on survival.

First, I grouped the female baboons in the data set by birth order number. Through doing this I was able to analyze how birth order affected maturation by comparing the ages of females of different birth orders at the date of their first swelling and first menstrual cycle. However, I found that birth order has no significant effect on the average rate of maturation in female baboons. In order to further analyze the effects of birth order more specifically on mortality rate, I rearranged the data set, grouping by mother. From this data set I then extrapolated each mothers' total number of offspring,

the number of offspring that died before age 5 and the birth order of each dead offspring. By then analyzing the total number of dead children and their birth order I was able to determine how many "first born" children, middle children and "last born" children died. In order to analyze the effects of total amount of offspring on overall mortality and survival rates I performed linear regression analysis between total number of children and total number of dead children and between total number of children and total number of surviving children.

The empirical data encapsulated the behavioral data. From this vast set of numbers a vivid picture of baboon life emerged. Consistently, the data set revealed that in a majority of families, determined by a common mother, first born and last born children died more often than middle children. Perhaps because of behavioral tendencies of offspring or because of quality of maternal care, it became clear that there is a relationship between chance of infant survival and the order in which they are born.

My project would not have been possible without the use of mathematics and statistical analysis. Through the use of statistics in graphing and manipulating the data I was able to support my hypothesis. Before beginning my project I did not have much experience in working with statistics, especially in the case of research study. While conducting preliminary research prior to studying at Carleton I was challenged by forms of math I had not been exposed to before. I was unaware of "P-values" and the purpose advanced regression analysis. This project made these practices tangible and worthwhile. Combining not just math and science but math and many scenarios can expose or support undiscovered patterns in the real world. Through my project I was not just exposed to a new passion in Primatology but an appreciation for the purpose of statistics.

Section II

Overall my project focused on the effects of birth order on infant survival into adulthood of *Papio Cynocephalus Anubis*, wild olive baboons. In my preliminary research I found that in most advanced mammals and many other species during the period of infancy the quality of a mother's care is the foundation for the offspring's survival into childhood and adulthood. For roughly a year to sixteen months after birth the baboon offspring remains completely dependent on its mother for nutrients and protection (Cheney, Seyfarth 50-51). It is a crucial, difficult and highly stressful time for both mother and infant. The level of care which a mother devotes during this period is a deciding factor in the survival or death of her offspring. The dependency of a mother's offspring is physically costing and greatly impacts her behavior and lifestyle (Altmann 32).

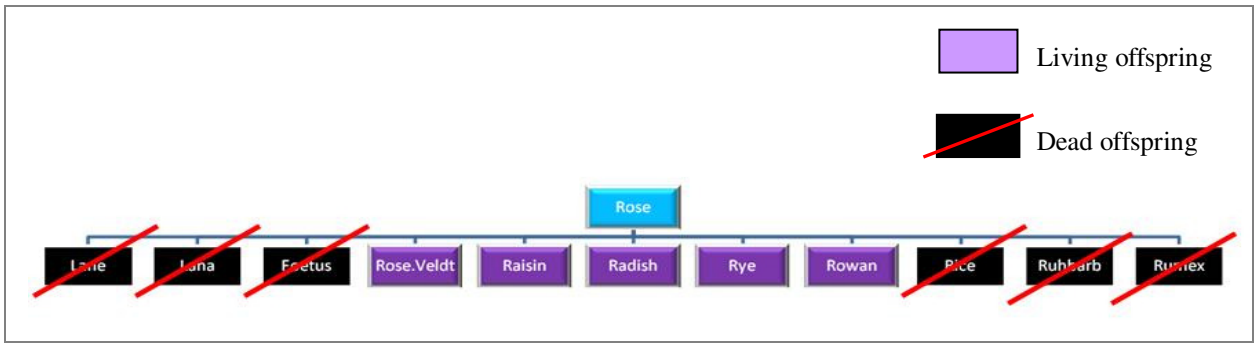
In order to ensure survival for herself and her child, it is beneficial for the mother to have both the physical capacity and experience to properly care for her young. Thus, two main factors, experience and age of the mother, play an integral role in the survival of an infant. The level of a mother's experience is often defined by the effectiveness and speed of a mother to alleviate the cause of her infant's distress (Nyugen). It has been observed that at times first time mothers do not know how to respond to their infant's distress calls while experienced mothers do (Altmann127-128).

Yet, at the same time, it was found that older mothers had a higher mortality rate than younger mothers and thus, more offspring of older mothers subsequently died as well (Altmann 36). Therefore, I hypothesized that because experience and age are overt

factors in maternal care capability, middle offspring are born at the best possible time and thus, survive more often. I also assessed the correlation between a mother's total number of offspring and the amount of that offspring that died and survived in order to determine whether it was more beneficial for a mother to have a greater or smaller number of total offspring.

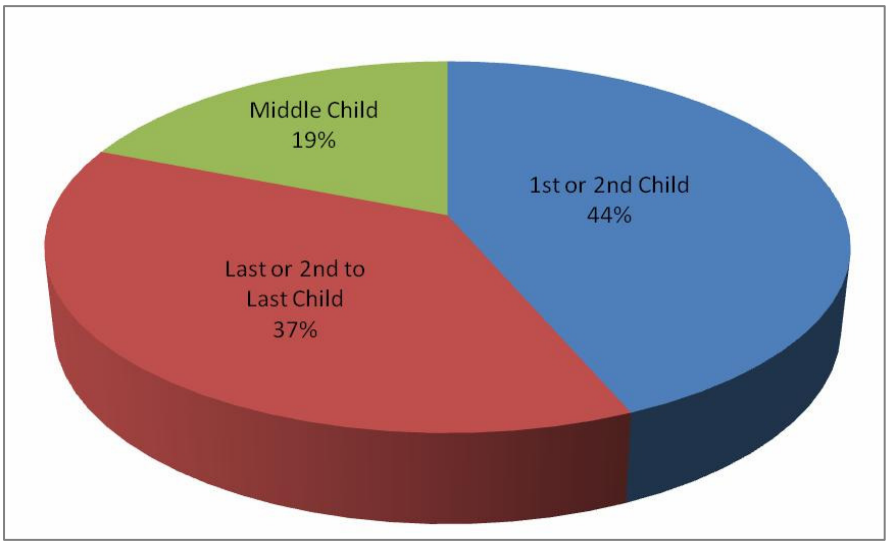
In analyzing GomDem04 I recognized trends in the data which suggest my hypothesis to be true. Figure 1 exemplifies a typical family; a mother's first and last children die but her middle children survive.

Fig. 1 Model of Mother and Offspring



In total, 291 of the analyzed offspring in the data set died. 127 were first or second in birth order, 109 were last or second to last in birth order, while only 55 were middle in birth order. Through comparing the birth order of all the dead offspring, it was clearly demonstrated that middle children survive more often. As demonstrated in Figure 2, 44% offspring that die were first or second born had, 37% were last or second to last, and 19% offspring were middle in birth order.

Fig 2. Mortality of Children Based on Birth Order



Of the total 153 mothers in the data set, 36 mothers had eight or more children. Eight children was the lowest number of offspring that would successfully show the differences in mortality rates based on birth order. Figure 3 displays the percentages of mothers whose last children died, middle children died and/or first children died. As can be seen in the graph the percentage of mothers that had last children die (94.0%) and the percentage of mothers that had first children die (91.6%) was greater than that of mothers that had middle children die (66.0%).

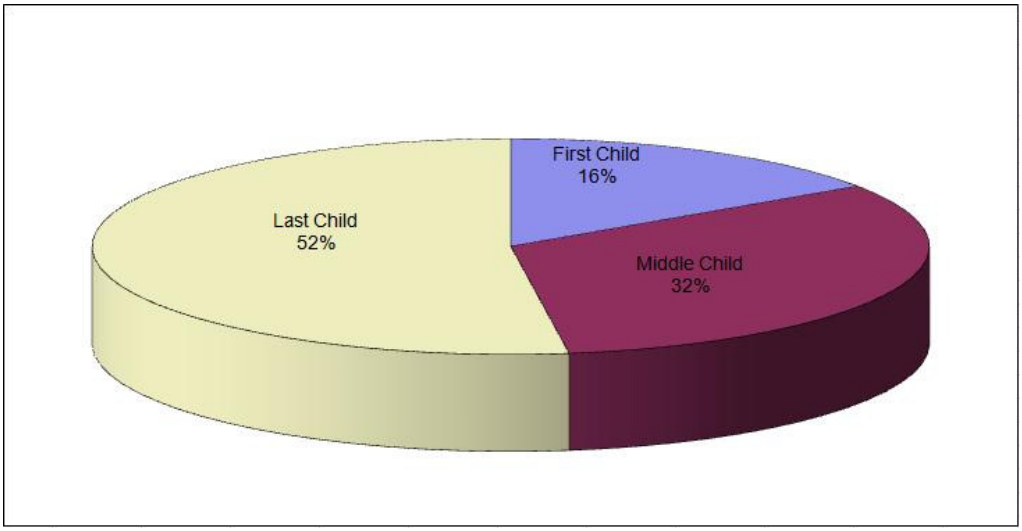
Fig. 3 Morality Risk Based on Mothers with Eight or More Offspring

Similarly, Figure 4 displays the percentages of mothers whose last children survived, middle children survived, and/or first children survived. This graph demonstrates the same trend: middle children survive significantly more often. As seen in the graph, 61% of mothers had their middle children survive where as only 16.6% had their last children die and 38.8% had their first children die.

Fig. 4 Survival Based on Mothers with Eight or More Children

Additionally, in analyzing the mortality risk of last born children, I recognized a tendency for older mothers to miscarry. Thus, children born later in birth order are more likely to either be miscarried fetuses or still born. As represented in Figure 5, I found that of the total 90 miscarriages, represented in the data set as "FEOTUS," 47 were last born children while only 14 were first born and 29 were middle children

Fig. 5 Miscarriage in Relation to Birth Order



Through linear regression, as seen in Figures 6 and 7, I found that there is a clear correlation between the total number of offspring and the survival of those offspring. However, it is not clear whether it would be more beneficial to have a greater or less number of total offspring. As seen in Figure 6, the relationship between total number of offspring and number of those offspring that die is direct with a strong correlation of .8038. The more offspring a mother has the more dead offspring she will have. Yet, Figure 7 shows that the relationship between total number of offspring and survival of that offspring is also direct with a correlation of .7864. The more offspring a mother has the more surviving children she will have. This indicates that although mothers who have a greater number of total offspring also have a greater number of those offspring die, they are also left with a greater number of surviving offspring. For example, Semonlina had a total of 11 children. While a majority (6) of them died, she was still left with more surviving offspring (5) than a mother who only had 5 children and less than a majority (2) of them died.

Fig. 6 Mortality Based on Total Number of Offspring

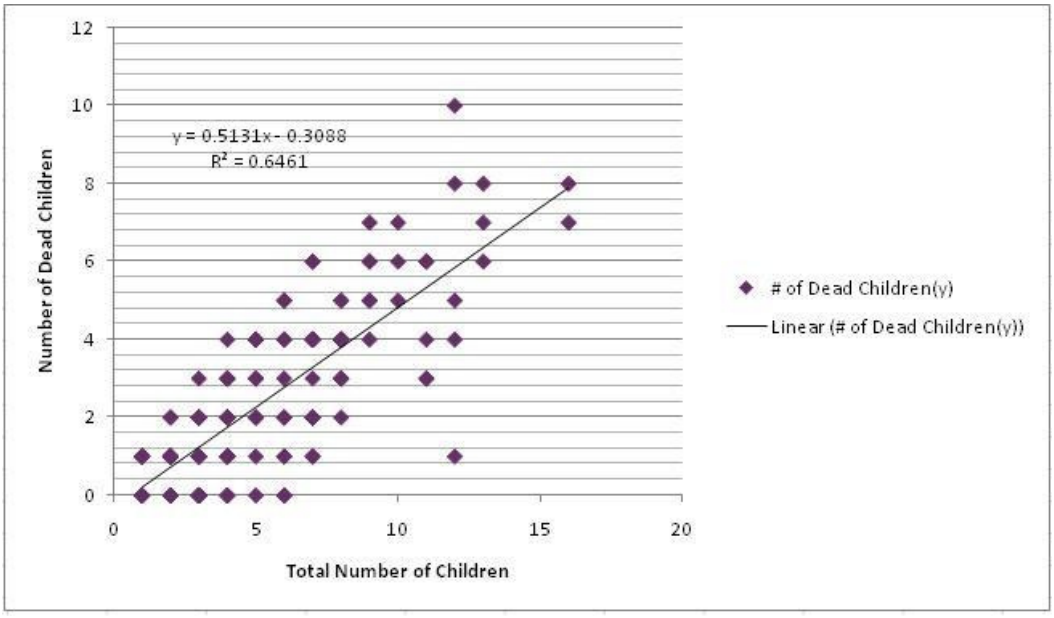
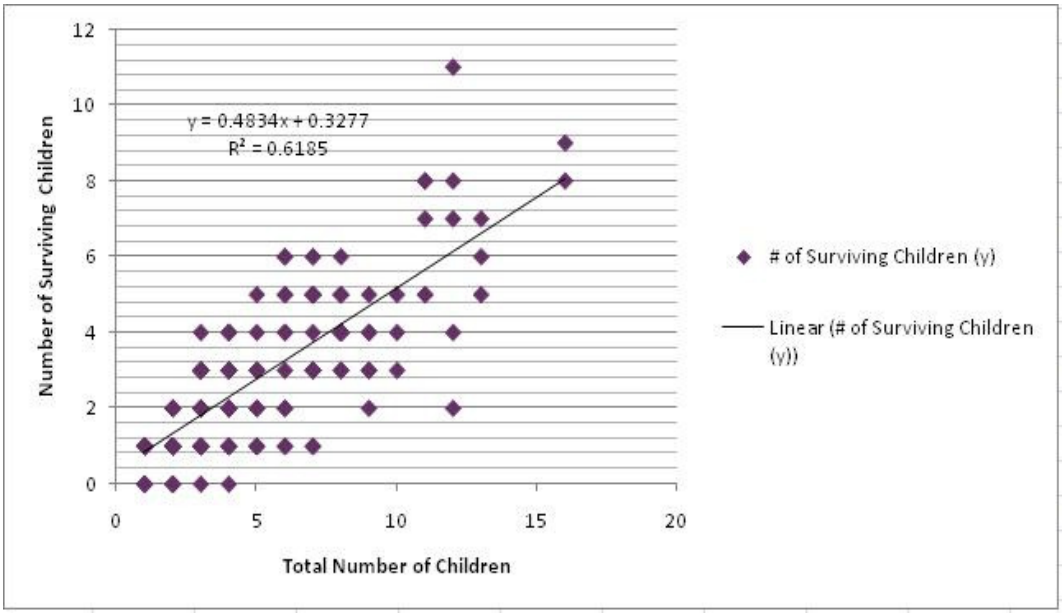


Fig. 7 Survival Based on Total Number of Offspring



The results of this study suggest that birth order affects the survival of baboon offspring during the period of infancy through childhood such that first born children and

last born children tend to die more often. This provides evidence for the assertion that birth order is a significant factor in the survival or mortality of baboon offspring during the early years of life. The experience and age of a mother as both factors seem to play an integral role in the infant experience could give reason to the tendency for middle born children to survive more often. Furthermore, the direct correlations between the total number of offspring and the mortality or survival of those offspring suggest that for a baboon mother it is beneficial to have more children; for, while having more children does lead to a higher mortality rate of her offspring, she is still left with a significantly larger pool of surviving offspring.

Through my project I was not just exposed to a new passion in Primateology but an appreciation for the purpose of statistics. My project also brought me into direct contact with an incredibly important field. By observing and studying the behavior of our closest animal relatives we can learn a great deal about human nature. Until the research of leading primatologists within the last forty years it was not commonly believed that animals possess a high level of intelligence. We now have discovered that most primates, especially the Great Apes, indeed possess a much higher degree of intelligence than at first presumed. Even baboons, a lesser ape than the chimpanzee, have overt intelligence as can be observed through the strong kinships and strategic alliances that they form in order to improve survival.

Furthermore, many of our closest ancestral relatives such as the Cross River Gorilla (*Gorilla gorilla diehli*) and the Sumatran Orangutan (*Pongo abeli*) are endangered. In fact, these two species are among the twenty-five most endangered primates. Deforestation and pollution caused by humans have endangered increasing

number of primates. Study in the field of behavioral biology in primates can help us learn how to better keep these species alive and flourishing. By understanding the aspects that play a role in the survival of primates, or any animal in general, we can help their overall survival and reproduction.