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Meta-Analysis on Zoonotic Infectious Diseases Between Humans and Non-Human Primates

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META-ANALYSIS ON ZOONOTIC INFECTIOUS DISEASES BETWEEN HUMANS AND NON-HUMAN PRIMATES

by

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ABSTRACT: Due to genetic similarity, non-human primates are often the focus of zoonotic infectious disease research. The objective of zoonotic disease research can vary depending upon whether the study is focusing on human health or the health of wild non-human primate populations. Research with non-human primates is often associated with their use in medical laboratories for the benefit of human health. However, other studies focus on both the health of wild non-human primate populations and human interactions. This study reviews zoonotic disease research published in three main primatology journals: *American Journal of Primatology*, *International Journal of Primatology*, and *Primates*. Reviewing journals from within the field of Primatology establishes common trends and sets a baseline for further research to work off of. To find these common trends each article was categorized based off of the research's primary objective in question. Furthermore, this study looks at how zoonotic disease impacts primate conservation and whether or not current research is looking into this. As anthropogenic habitat destruction increases, humans and non-human primates interact more, which leads to an increase in disease transmission. Zoonotic disease negatively impacts both human and non-human primate populations. Many non-human primate populations are endangered and disease transmission further affects conservation efforts.

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INTRODUCTION

Zoonotic disease is defined as any disease that can be transmitted between humans and animals. These diseases can come from viruses or the taxonomic kingdoms of Bacteria, Animalia, Protista, or Fungi (Centers for Disease Control and Prevention, 2013; Wolfe et al., 1998). Due to genetic similarity, research of zoonotic diseases often focuses on disease transmission between humans and non-human primates. Many academic disciplines including the medical community, epidemiology, and primatology study the wide array of zoonotic disease impacts. Initially research within zoonotic disease focused on the medical community and bettering human health. Most information regarding zoonosis comes from understanding the disease within humans, however more recent research shifts the focus of zoonotic disease onto the transmission between human and non-human primate populations. More knowledge can be gained towards the understanding of pathogen virulence and transmission, if better understanding of a disease's natural reservoir or a disease's natural bridge exists (Locatelli et al., 2013; Wolfe et al., 1998). Zoonotic disease research within primatology aims towards this understanding by researching wild primate populations.

Many disease epidemics seen in human populations such as HIV, ebola, and tuberculosis can be traced back to wild primate populations. Primates act as a bridge between the natural reservoir of the disease and humans; because of this wild primate populations can also act as an indicator of ecosystem health (Rouquet et al., 2005; Wolfe et al., 1998). Conducting disease surveillance within a primate population could indicate transmission risk and therefore allow better management of outbreaks (Travis et al., 2006; Wallis and Lee, 1999).

Besides analyzing disease risk and understanding transmission, zoonotic disease can also impact conservation. The endangerment status of primates is affected by numerous different threats including, but not limited to, habitat encroachment and/or deforestation, bushmeat trade, exotic pet trade, medicinal usage, and zoonotic diseases (Nunn and Altizer, 2006; Woodford et al., 2002). Current research aims to determine whether or not infectious disease can cause primate species to go extinct. Previously the International Union for Conservation of Nature (IUCN) did not list disease as the primary cause for any primate endangerment, however other non-primate species have become endangered and have even become extinct due to infectious disease (Nunn and Altizer, 2006). Furthermore, zoonotic disease could impact primate endangerment and extinction even more since over 60% of primate populations are already threatened and decreased in size. This reduction in population size increases susceptibility to zoonotic disease (Nunn and Altizer, 2006; Woodford et al., 2002).

Since zoonotic disease research within primatology can take on many different forms, this study reviews the research published in three main primatology journals to find common research trends within the field. Common research trends then establish a baseline for further research to work off of. Furthermore, this study looks at how zoonotic disease impacts primate conservation and whether or not current research is looking into this.

METHODS

Criteria for Selection-

This meta-analysis reviewed academic articles from three main scientific primatology journals. These journals included *American Journal of Primatology*, *International Journal of Primatology*, and *Primates*. These three academic journals were chosen to gain a broader scope on zoonotic research within the entire discipline of primatology rather than just limiting data to one specific journal. In order to standardize search methods for locating articles within these journals, the phrase "zoonotic disease" was the only search term entered into the search bar to find journal articles for the meta-analysis. This phrase produced 52 results within American Journal of Primatology, 19 results within International Journal of Primatology, and 11 results within Primates. By only using this key phrase, we were able limit the amount of articles; however, we applied further sampling criteria to narrow down the articles for the specific aim of the study. To regulate the type of research articles that this study analyzed we created a set of criteria that each article had to follow. The specific selection criteria for the articles are as follows:

1. We only analyzed full-length research articles. This excluded published abstracts, conference notes, and book reviews.
2. Sampled articles represented only primary research. Many search results were review articles that summarized various cases of zoonotic disease found in different primates. These studies were not included because the research did not present any new research data. An example of this was Wolfe's study on tuberculosis in great apes (Wolfe et al., 2014).
3. In sampled articles, the focus of zoonotic disease transmission was only between humans and non-human primates. Zoonotic disease can be characterized as transmission between any two species of animals (Centers for Disease Control and Prevention. 2013), however this study specifically looked at disease transmission between humans and non-human primates.
4. Each sampled research article identified the specific primates down to the genus level that the study analyzed. Some articles that appeared on the data search only

mentioned using "primates" as their study subject and did not further specify the species or even the taxonomic super family in which the primates belonged to.

After reviewing each article for the specific criteria, we found that five out of the 11 article results in *Primates* and seven out of the 19 results in *International Journal of Primatology* matched the criteria pertaining to the study. Originally, the study was going to analyze the first ten articles from each journal, however *Primates* and the *International Journal of Primatology* did not produce this many articles. We were able to collect the first ten articles from *American Journal of Primatology* that matched the established criteria for the study. Looking back we should have reviewed all 52 results from the *American Journal of Primatology* to see how many articles matched the criteria, however due to time limitations that was not possible in this study.

Furthermore, another limiting factor to article searches was the availability of access that Utah State University had to each journal. The Merrill-Cazier Library at Utah State University subscribes to all three journals, but the electronic access to each journal is limited from a certain year. For online access to the electronic version of *American Journal of Primatology*, Utah State University has subscribed to all journals from the year 1996 to present day. Subscription for the electronic version of *International Journal of Primatology* is from 1997 to present day and the subscription for the electronic version of *Primates* is also from 1997 to present day. This meta-analysis only looks at research from the year 2000 to present day.

Methods for Categorization-

Once the criteria were established for selecting articles, categories were also established for analyzing trends within the research. The study consisted of 25 different categories looking at various trends within each research article. Since the goal of this meta-analysis is trying to gain a broader picture of zoonotic disease research within primatology, many of the categories consisted of broader questions to establish an overall survey of the types of research conducted with regards to zoonotic disease rather than a specific analysis. The categories are presented in Figure 1.

Figure 1: Analysis Categories

General Article Information:
Year Article was Published
Journal (which journal the article was found in)

Main Associated University
Primate Research Center (correlated with the study)

General Study Information:
Methods

Location (country/region)
Remote (Wild), Rural, Urban

Interaction with Humans

Species Information:
Primary Species

Secondary Species

Other Species
Superfamily of Primary Species
Type of Population Studied

Disease Information:

Disease Type 1

Disease Type 2
Other Disease Type
Disease Code
Reservoir, Bridge, Affected
Type of Transmission
Form of Transmission

Research Purpose Information:

Objective

Secondary Objective

Conservation Information:
Conservation Mentioned?
Disease Affect on Conservation
Endangerment Status

The category General Article Information consisted of questions regarding when and what facility was conducting the research. We looked to see if there was any primate research center associated with the university to see whether or not these centers were conducting more research than universities without research centers.

General Study Information consisted of categories looking at where research was being conducted and the proximity of humans to the specific study location. Our thought behind asking how much interaction there was between the primate and human populations was that with more interaction more zoonotic transmission would occur (Chapman et al., 2006; Howells et al., 2011;

Koalewski et al., 2010; Rovirosa-Hernandez et al., 2013; Sá et al., 2013; Vitazkova et al., 2006; Weyher et al., 2006).

The categories within Species Information were set up to see what types of primates were being studied. Although the initial goal was to identify the study population down to species level, we decided to also look at the taxonomic group of superfamily to see broader trends. The categories of "secondary species" and "other species" were added in addition to primary species because research will often focus on more than one primate population resulting in multiple species within the study.

The categories within Disease Information were established so that we could see if any particular disease is more common to zoonotic disease transmission and zoonotic disease research. The category of Disease Code indicates what taxonomic kingdom the disease falls under. We wanted to see if bacteria, viruses, protists, or parasitic animals were more common within zoonotic transmission.

Research Purpose Information categories were created to answer the main questions behind this meta-analysis. By looking at the different objectives within each research article we can analyze the driving causes behind zoonotic disease research and whether research is aimed at human health, primate conservation, or a combination of both. In order to do this we established four different categories of research objectives that each article fell under. These objectives are as follows:

1. Public Health/ Wild Reservoir: The non-human primate is the reservoir for the zoonotic disease and the study focuses on human population health. This objective is often closely linked to Cross-species Transmission Patterns because the research will often want to further investigate how disease is being transmitted

between populations. However, this objective is more a general survey of health within human or primate populations for the sole benefit of human health.

2. Population and Ecosystem Health: The study focuses on the health of the non-human primate population. The objective may also look at the impacts of anthropogenic habitat disruption on zoonotic disease susceptibility.
3. Cross-species Transmission Patterns: the research looks at disease patterns seen in primate and/or human populations. This can include tracking disease distribution within a habitat and the frequency of contact/interactions with humans.
4. Conservation: The study focuses on how zoonotic disease transmission affects the endangerment status of the specific primate population.

Many times research studies will often have more than one objective so we created the categories of primary, secondary, and tertiary objectives. This allows for our study to analyze the main focus of research but also recognize that research often has more questions in mind for future studies. Differentiation between the primary objective and the secondary objective was based off of the research question and what the study aimed to answer. Secondary objectives were decided on by what future questions the research aimed to further study.

The final categories within Conservation Information were created to see the impact of zoonotic disease on conservation. Even though one of the objective categories is conservation, research will often be aware of the impacts that disease has on conservation without it being the objective of a study. We created the category of Conservation Mentioned to see how many research articles are aware of disease impact on endangerment without actually focusing their study on conservation. The category of Endangerment Status was created so that we could see any correlation between the endangerment status of a primate population and conservation as a research objective.

Methods for Analysis-

For the statistical analyses we used the software programs SPSS and Microsoft Excel. We used SPSS to conduct the chi-squared analysis and Excel to create more general percentage charts.

RESULTS

In order to analyze trends and correlations with zoonotic diseases research, we conducted chi-squared tests and calculated percentages of the different categorical patterns. Our results looked at four main areas of interest that included general trends, disease trends, objective trends, and conservation trends. All of the results came from information gathered out of 22 total research articles within the three primatology journals.

General Trends-

This study aimed at fully understanding zoonotic research trends within primatology. Apart of this understanding comes from analyzing what primate populations research focuses on. We analyzed the superfamily, the type of population, and the level of human interaction of each studied population.

Figure 2 shows the percentage breakdown of which primate super families are being studied. Within the three primatology journals, the most studied superfamily is Cercopithecoidea, although this only constitutes 36% of the research. The least studied superfamily is Lemuroidea with only 9% of research articles studying this taxonomic group. No articles studied the superfamilies of Lorisoidea or Tarsiiformes. One article studied multiple superfamilies making up 5% of the superfamily breakdown (Figure 2). Figure 3 shows the percentage breakdown of the types of studied primate populations. The majority of the articles (77%) studied wild primate populations. Both habituated and domestic primate populations were studied the same amount meaning that each category only had one article studying that particular type of primate population. Figure 4 represent the amount of interaction each primate population had with humans. Human interaction is important to analyze because it shows how much potential there is for Zoonosis. The majority of primate populations had some interaction with humans with only 14% of the articles not mentioning any interaction. Even more note worthy is that of the primate populations studied, 54% had frequent interactions with humans.

Figure 2: Superfamily of Primary Species Studied

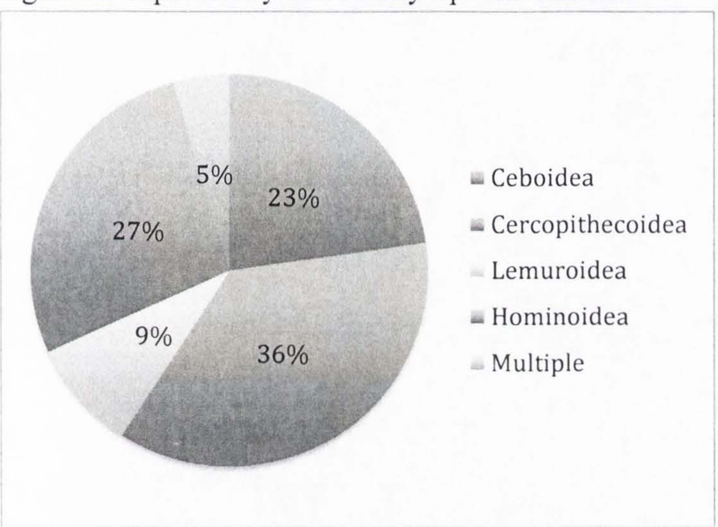


Figure 3: Types of Studied Primate Populations

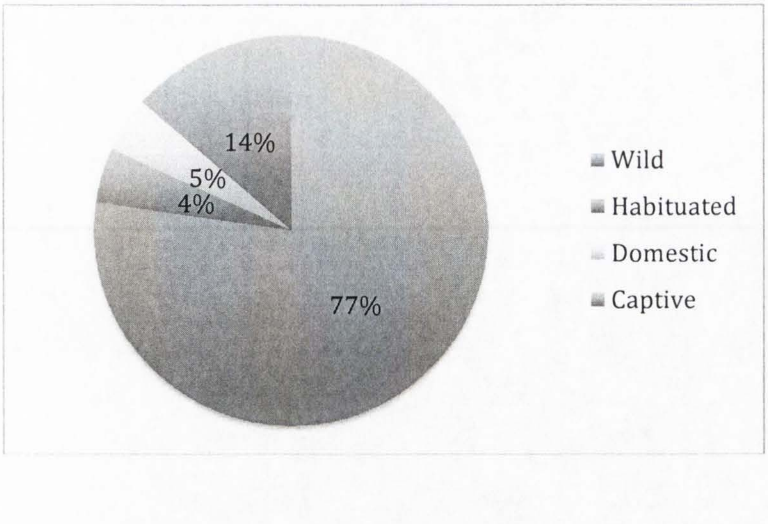
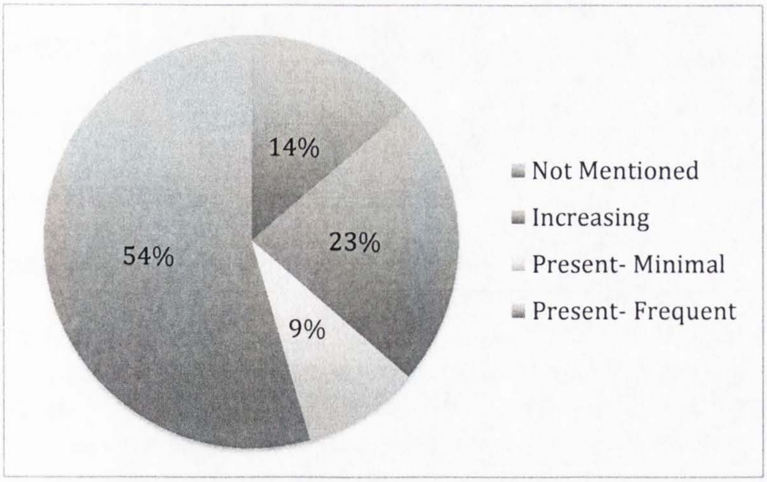


Figure 4: Interaction between Primate and Human Populations



Disease Trends-

Figure 5: Disease Code by Taxonomic Kingdom

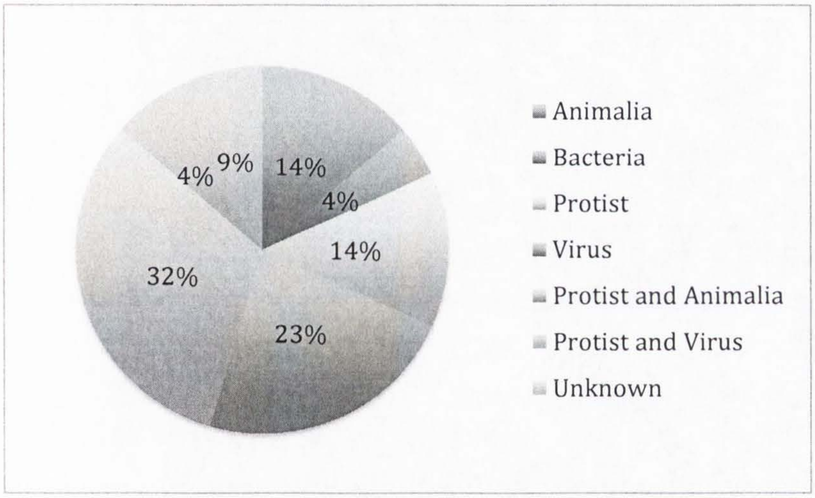


Figure 6: Chi-Squared Test looking at Superfamily impacting Disease Code

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	33.995[a]	24	.085
Likelihood Ratio	30.120	24	.181
N of Valid Cases	22		

a. 35 cells (100.0%) have expected count less than 5. The minimum expected count is .05.

Disease trend analysis included looking at the disease code indicating which taxonomic kingdoms were more prevalent within the research articles (Figure 5). Figure 5 would appear to have a random distribution of different zoonotic diseases affecting primate populations. However, parasitic zoonotic research comprises of the taxonomic kingdoms Animalia, Protista, and Protista and Animalia taken together. Considering this, the three kingdoms make up 60% of the research on zoonotic disease. Viruses then make up the second highest disease prevalence with 23% of the research focusing on viruses (Figure 5).

Another analysis involving disease code classification looked at whether or not the superfamily of the primate population affected the disease being studied. Figure 6 and Figure 7 are the results from a chi squared analysis test preformed to see any correlation between the two categories. The Pearson Chi-Square results in Figure 6 suggest that the correlation significance was .085. This is not enough to prove statistical significance, however it is approaching statistical significance with alpha set to .05.

We were also interested in any correlation patterns between the disease code and the impact of the disease on the endangerment status of the primate population. Figures 8 and 9 show the chi-squared test analyzing whether or not any particular disease has more of an impact on primate endangerment. As seen in Figure 9 there is no statistical relationship between certain types of disease and primate endangerment.

Figure 7: Chi-Squared Test analyzing the impact the Superfamily has on the Disease Code

Super_Family * Disease_Code Crosstabulation

			Disease_Code							
			Protist	Bacteria	Virus	Animalia	Protist and Animalia	Protist and Virus	Unknown	Total
Super_Family	Ceboidea	Count	2	0	0	0	2	1	0	5
		% within Super_Family	40.0%	0.0%	0.0%	0.0%	40.0%	20.0%	0.0%	100.0%
		% within Disease_Code	66.7%	0.0%	0.0%	0.0%	28.6%	100.0%	0.0%	22.7%
		Std. Residual	1.6	-.5	-1.1	-.8	.3	1.6	-.7	
	Cercopithecoidea	Count	1	0	1	3	3	0	0	8
		% within Super_Family	12.5%	0.0%	12.5%	37.5%	37.5%	0.0%	0.0%	100.0%
		% within Disease_Code	33.3%	0.0%	20.0%	100.0%	42.9%	0.0%	0.0%	36.4%
		Std. Residual	-.1	-.6	-.6	1.8	.3	-.6	-.9	
	Lemuroidea	Count	0	1	1	0	0	0	0	2
		% within Super_Family	0.0%	50.0%	50.0%	0.0%	0.0%	0.0%	0.0%	100.0%
		% within Disease_Code	0.0%	100.0%	20.0%	0.0%	0.0%	0.0%	0.0%	9.1%
		Std. Residual	-.5	3.0	.8	-.5	-.8	-.3	-.4	
	Hominoidea	Count	0	0	2	0	2	0	2	6
		% within Super_Family	0.0%	0.0%	33.3%	0.0%	33.3%	0.0%	33.3%	100.0%
		% within Disease_Code	0.0%	0.0%	40.0%	0.0%	28.6%	0.0%	100.0%	27.3%
		Std. Residual	-.9	-.5	.5	-.9	.1	-.5	2.0	
	Multiple	Count	0	0	1	0	0	0	0	1
		% within Super_Family	0.0%	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%	100.0%
		% within Disease_Code	0.0%	0.0%	20.0%	0.0%	0.0%	0.0%	0.0%	4.5%
		Std. Residual	-.4	-.2	1.6	-.4	-.6	-.2	-.3	
Total		Count	3	1	5	3	7	1	2	22
		% within Super_Family	13.6%	4.5%	22.7%	13.6%	31.8%	4.5%	9.1%	100.0%
		% within Disease_Code	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Figure 8: Chi-Squared Test analyzing the impact Disease Code has on the Disease Impact on Endangerment

Disease_Code * Disease_Affect_on_Conservation Crosstabulation

			Disease_Affect_on_Conservation			
			Unknown/ Not Mentioned	Minimal	Present	Total
Disease_Code	Protist	Count	1	2	0	3
		% within Disease_Code	33.3%	66.7%	0.0%	100.0%
		% within Disease_Affect_on_Conservation	14.3%	20.0%	0.0%	13.6%
		Std. Residual	.0	.5	-.8	
	Bacteria	Count	0	0	1	1
		% within Disease_Code	0.0%	0.0%	100.0%	100.0%
		% within Disease_Affect_on_Conservation	0.0%	0.0%	20.0%	4.5%
		Std. Residual	-.6	-.7	1.6	
	Virus	Count	1	2	2	5
		% within Disease_Code	20.0%	40.0%	40.0%	100.0%
		% within Disease_Affect_on_Conservation	14.3%	20.0%	40.0%	22.7%
		Std. Residual	-.5	-.2	.8	
	Animalia	Count	1	2	0	3
		% within Disease_Code	33.3%	66.7%	0.0%	100.0%
		% within Disease_Affect_on_Conservation	14.3%	20.0%	0.0%	13.6%
		Std. Residual	.0	.5	-.8	
	Protist and Animalia	Count	3	4	0	7

		% within Disease_Code	42.9%	57.1%	0.0%	100.0%
		% within Disease_Affect_on_Conservation	42.9%	40.0%	0.0%	31.8%
		Std. Residual	.5	.5	-1.3	
	Protist and Virus	Count	1	0	0	1
		% within Disease_Code	100.0%	0.0%	0.0%	100.0%
		% within Disease_Affect_on_Conservation	14.3%	0.0%	0.0%	4.5%
		Std. Residual	1.2	-.7	-.5	
	Unknown	Count	0	0	2	2
		% within Disease_Code	0.0%	0.0%	100.0%	100.0%
		% within Disease_Affect_on_Conservation	0.0%	0.0%	40.0%	9.1%
		Std. Residual	-.8	-1.0	2.3	
Total		Count	7	10	5	22
		% within Disease_Code	31.8%	45.5%	22.7%	100.0%
		% within Disease_Affect_on_Conservation	100.0%	100.0%	100.0%	100.0%

Figure 9: Chi-Squared Test analyzing the impact Disease Code has on the Disease Impact on Endangerment

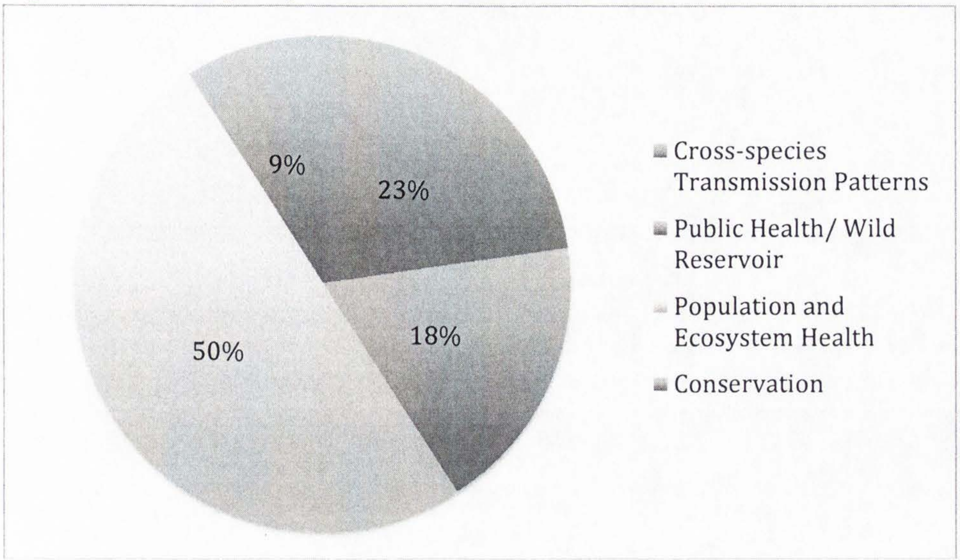
Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	17.283[a]	12	.139
Likelihood Ratio	18.869	12	.092
N of Valid Cases	22		

a. 21 cells (100.0%) have expected count less than 5. The minimum expected count is .23.

Objective Trends-

Figure 10: Primary Objectives for Research Articles



In order to see the focus of zoonotic disease research in primatology, we first had to analyze research objectives and see which objective is more common within the field. Figure 10 shows the breakdown of research objectives within primatology. The Population and Ecosystem Health objective is the main focus with 50% of zoonotic research studying this as a main objective. The other three categories are then distributed from there with Cross-species Transmission Patterns and Public Health/Wild Reservoir objectives receiving similar amount of focus with 23% and 18% respectively. Conservation as a main research objective was seen in 9% of research (Figure 10).

Figure 11: Chi-Squared Tests analyzing how Endangerment Status impacts Primary Objectives

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	16.420[a]	9	.059
Likelihood Ratio	11.461	9	.245
N of Valid Cases	22		

a. 15 cells (93.8%) have expected count less than 5. The minimum expected count is .09.

Endangerment_Status * Primary_Objective Crosstabulation

			Primary_Objective				
			Cross-Species Transmission Patterns	Public Health/ Wild Reservoir	Population and Ecosystem Health	Conservation	Total
Endangerment_Status	Least Concern	Count	2	3	4	0	9
		% within Endangerment_Status	22.2%	33.3%	44.4%	0.0%	100.0%
		% within Primary_Objective	40.0%	75.0%	36.4%	0.0%	40.9%
		Std. Residual	.0	1.1	-.2	-.9	
	Vulnerable	Count	1	0	0	0	1
		% within Endangerment_Status	100.0%	0.0%	0.0%	0.0%	100.0%
		% within Primary_Objective	20.0%	0.0%	0.0%	0.0%	4.5%
		Std. Residual	1.6	-.4	-.7	-.3	
	Endangered	Count	2	1	7	1	11
		% within Endangerment_Status	18.2%	9.1%	63.6%	9.1%	100.0%
		% within Primary_Objective	40.0%	25.0%	63.6%	50.0%	50.0%
		Std. Residual	-.3	-.7	.6	.0	
	Critically Endangered	Count	0	0	0	1	1
		% within Endangerment_Status	0.0%	0.0%	0.0%	100.0%	100.0%
		% within Primary_Objective	0.0%	0.0%	0.0%	50.0%	4.5%
		Std. Residual	-.5	-.4	-.7	3.0	
Total		Count	5	4	11	2	22
		% within Endangerment_Status	22.7%	18.2%	50.0%	9.1%	100.0%
		% within Primary_Objective	100.0%	100.0%	100.0%	100.0%	100.0%

Figure 12: Chi-Squared Tests analyzing how Endangerment Status impacts Primary Objectives

To further analyze why some research objectives were more prevalent than others we looked at possible causations impacting the primary objectives of research. Figures 11 and 12 look at the statistical correlation between the endangerment status of the studied species and the primary objective. We analyzed this to see if research objectives were likely to be impacted by how endangered the studied species was. The chi-squared analysis shows a significance value of .059 (Figure 11). This is nearing the statistical significance of less than .05, however we cannot reject the null hypothesis stating there is no correlation between the primary research objective and the endangerment status of a species.

Another possible impact on the primary objective is how much the studied disease affects conservation status of primate populations. Figures 13 and 14 are the results of the chi-squared analysis that tested this correlation. The significance value of this test was .182 indicating that the null hypothesis cannot be rejected (Figure 13). There is no statistical significance indicating any correlation between the impact of disease on conservation and the main objective of research.

The last primary objective impact we analyzed was the correlation between the disease code and research objective. Figures 15 and 16 show the chi-square test results. The significance value give by the chi-square test is .085 (Figure 16). This is not statistically significant enough to reject the null hypothesis stating that there is no correlation between the type of disease studied and the primary objective, however it is nearing statistical significance.

Figure 13: Chi-Squared Test on Disease Impact on Endangerment/ Primary Objective correlation

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	8.861[a]	6	.182
Likelihood Ratio	8.773	6	.187
N of Valid Cases	22		

a. 11 cells (91.7%) have expected count less than 5. The minimum expected count is .45.

Disease_Affect_on_Conservation * Primary_Objective Crosstabulation

			Primary_Objective				
			Cross-Species Transmission Patterns	Public Health/ Wild Reservoir	Population and Ecosystem Health	Conservation	Total
Disease_Affect_on_Conservation	Unknown/ Not Mentioned	Count	2	1	4	0	7
		% within Disease_Affect_on_Conservation	28.6%	14.3%	57.1%	0.0%	100.0%
		% within Primary_Objective	40.0%	25.0%	36.4%	0.0%	31.8%
		Std. Residual	.3	-.2	.3	-.8	
	Minimal	Count	2	3	5	0	10
		% within Disease_Affect_on_Conservation	20.0%	30.0%	50.0%	0.0%	100.0%
		% within Primary_Objective	40.0%	75.0%	45.5%	0.0%	45.5%
		Std. Residual	-.2	.9	.0	-1.0	
	Present	Count	1	0	2	2	5
		% within Disease_Affect_on_Conservation	20.0%	0.0%	40.0%	40.0%	100.0%
		% within Primary_Objective	20.0%	0.0%	18.2%	100.0%	22.7%
		Std. Residual	-.1	-1.0	-.3	2.3	
Total		Count	5	4	11	2	22
		% within Disease_Affect_on_Conservation	22.7%	18.2%	50.0%	9.1%	100.0%
		% within Primary_Objective	100.0%	100.0%	100.0%	100.0%	100.0%

Figure 14: Chi-Squared Tests analyzing Disease Impact on Endangerment/ Primary Objective correlation

Figure 15: Chi-Squared Test for how the Disease Code impacts Primary Objective

Disease_Code * Primary_Objective Crosstabulation

			Primary_Objective				
			Cross-Species Transmission Patterns	Public Health/ Wild Reservoir	Population and Ecosystem Health	Conservation	Total
Disease_Code	Protist	Count	1	2	0	0	3
		% within Disease_Code	33.3%	66.7%	0.0%	0.0%	100.0%
		% within Primary_Objective	20.0%	50.0%	0.0%	0.0%	13.6%
		Std. Residual	.4	2.0	-1.2	-.5	
	Bacteria	Count	0	0	0	1	1
		% within Disease_Code	0.0%	0.0%	0.0%	100.0%	100.0%
		% within Primary_Objective	0.0%	0.0%	0.0%	50.0%	4.5%
		Std. Residual	-.5	-.4	-.7	3.0	
	Virus	Count	2	1	2	0	5
		% within Disease_Code	40.0%	20.0%	40.0%	0.0%	100.0%
		% within Primary_Objective	40.0%	25.0%	18.2%	0.0%	22.7%
		Std. Residual	.8	.1	-.3	-.7	
	Animalia	Count	0	1	2	0	3
		% within Disease_Code	0.0%	33.3%	66.7%	0.0%	100.0%
		% within Primary_Objective	0.0%	25.0%	18.2%	0.0%	13.6%
		Std. Residual	-.8	.6	.4	-.5	
	Protist and Animalia	Count	2	0	5	0	7
		% within Disease_Code	28.6%	0.0%	71.4%	0.0%	100.0%
		% within Primary_Objective	40.0%	0.0%	45.5%	0.0%	31.8%

		Std. Residual	.3	-1.1	.8	-.8	
	Protist and Virus	Count	0	0	1	0	1
		% within Disease_Code	0.0%	0.0%	100.0%	0.0%	100.0%
		% within Primary_Objective	0.0%	0.0%	9.1%	0.0%	4.5%
		Std. Residual	-.5	-.4	.7	-.3	
	Unknown	Count	0	0	1	1	2
		% within Disease_Code	0.0%	0.0%	50.0%	50.0%	100.0%
		% within Primary_Objective	0.0%	0.0%	9.1%	50.0%	9.1%
		Std. Residual	-.7	-.6	.0	1.9	
Total		Count	5	4	11	2	22
		% within Disease_Code	22.7%	18.2%	50.0%	9.1%	100.0%
		% within Primary_Objective	100.0%	100.0%	100.0%	100.0%	100.0%

Figure 16: Chi-Squared Test for how the Disease Code impacts Primary Objective

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	26.677[a]	18	.085
Likelihood Ratio	23.959	18	.156
N of Valid Cases	22		

a. 28 cells (100.0%) have expected count less than 5. The minimum expected count is .09.

Conservation-

Not only did this meta-analysis want to look at the general trends and the driving forces behind the research within zoonotic disease, but we also wanted to analyze how prevalent conservation was within the field. The primary objective analysis showed that there was no significant correlation between endangerment status and the primary objective, however we furthered our analysis by looking at how much conservation was mentioned within the articles. Figure 17 shows that despite only 9% of primary objectives focusing on conservation, 73% of the research articles mention conservation and the impact that zoonotic disease has on conservation (Figure 10 and Figure 17). Because so many articles mention conservation but do not focus on it as a primary objective we tested to see if there was any correlation between the two categories. A chi-squared test was used to show if any primary objective mentioned conservation more than other primary objectives. The significance value of this test was .055 (Figure 18). This is approaching statistical significance, however it is not significant enough to say that there is a correlation showing that certain primary objectives mention conservation more than others.

Figure17: Articles Mentioning Conservation

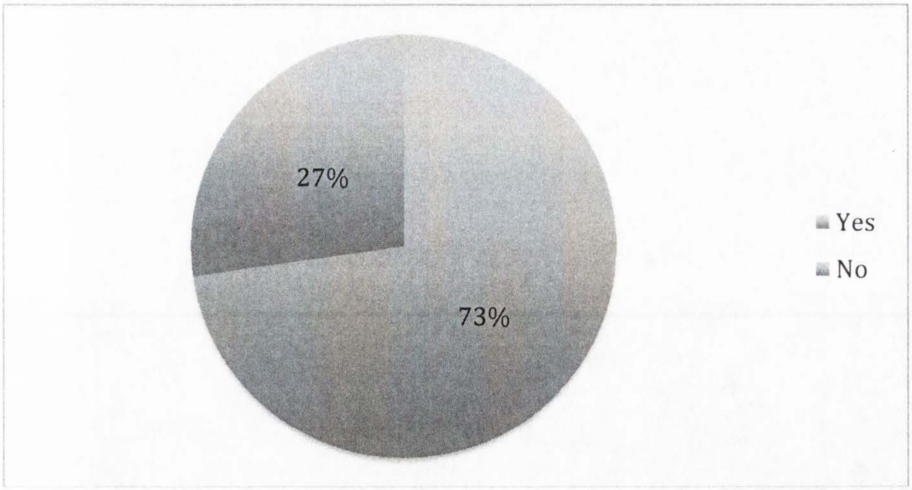


Figure 18: Chi-Squared Tests analyzing Mention of Conservation/Primary Objective correlation

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	7.585[a]	3	.055
Likelihood Ratio	7.851	3	.049
N of Valid Cases	22		

a. 7 cells (87.5%) have expected count less than 5. The minimum expected count is .55.

Figure 19: Chi-Squared Tests analyzing Mention of Conservation/Primary Objective correlation

Primary_Objective * Conservation_Mentioned Crosstabulation

			Conservation_Mentioned		
			Yes	No	Total
Primary_Objective	Cross-Species Transmission Patterns	Count	3	2	5
		% within Primary_Objective	60.0%	40.0%	100.0%
		% within Conservation_Mentioned	18.8%	33.3%	22.7%
		Std. Residual	-.3	.5	
	Public Health/ Wild Reservoir	Count	1	3	4
		% within Primary_Objective	25.0%	75.0%	100.0%
		% within Conservation_Mentioned	6.3%	50.0%	18.2%
		Std. Residual	-1.1	1.8	
	Population and Ecosystem Health	Count	10	1	11
		% within Primary_Objective	90.9%	9.1%	100.0%
		% within Conservation_Mentioned	62.5%	16.7%	50.0%
		Std. Residual	.7	-1.2	
	Conservation	Count	2	0	2
		% within Primary_Objective	100.0%	0.0%	100.0%
		% within Conservation_Mentioned	12.5%	0.0%	9.1%
		Std. Residual	.5	-.7	
Total		Count	16	6	22
		% within Primary_Objective	72.7%	27.3%	100.0%
		% within Conservation_Mentioned	100.0%	100.0%	100.0%

Another factor that we analyzed was if conservation was being mentioned based off of the endangerment status of the studied population. Over 50% of the studied primate populations had an IUCN status of Endangered if not more severe (Figure 20). However 41% of the populations were the status of Least Concerned (Figure 20). We analyzed any correlation between endangerment and the mention of conservation by using a chi-squared test. Figures 21 and 22 show the results of this test. The significance value was .102 meaning the null hypothesis couldn't be rejected (Figure 21). The mention of conservation cannot be significantly correlated to the various endangerment statuses of primate populations.

Figure 20: Endangerment Status of Primate Populations

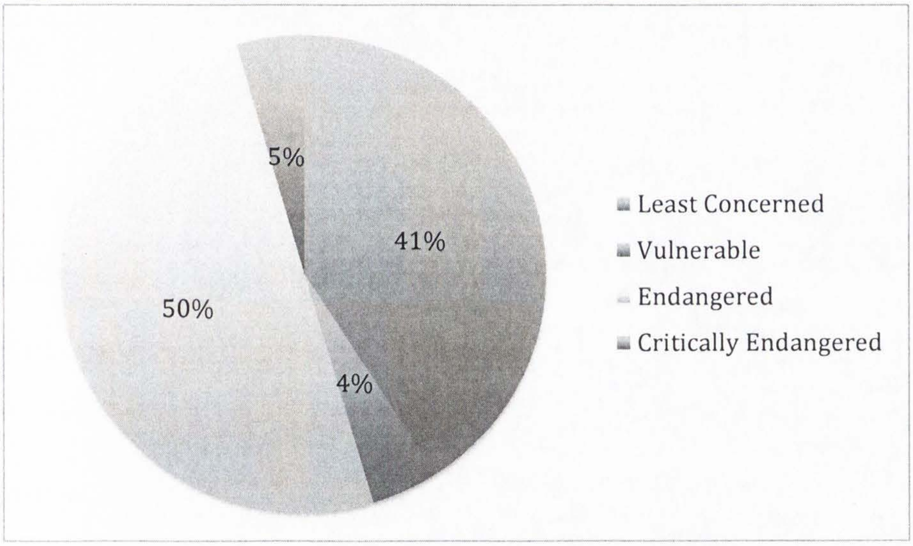


Figure 21: Chi-Square Test Endangerment Status correlation to Conservation Mention

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	6.213[a]	3	.102
Likelihood Ratio	6.715	3	.082
N of Valid Cases	22		

a. 6 cells (75.0%) have expected count less than 5. The minimum expected count is .27.

Figure 22: Chi-Square Test Endangerment Status correlation to Conservation Mention

Endangerment_Status * Conservation_Mentioned Crosstabulation

			Conservation_Mentioned		
			Yes	No	Total
Endangerment_Status	Least Concern	Count	5	4	9
		% within Endangerment_Status	55.6%	44.4%	100.0%
		% within Conservation_Mentioned	31.3%	66.7%	40.9%
		Std. Residual	-.6	1.0	
	Vulnerable	Count	0	1	1
		% within Endangerment_Status	0.0%	100.0%	100.0%
		% within Conservation_Mentioned	0.0%	16.7%	4.5%
		Std. Residual	-.9	1.4	
	Endangered	Count	10	1	11
		% within Endangerment_Status	90.9%	9.1%	100.0%
		% within Conservation_Mentioned	62.5%	16.7%	50.0%
		Std. Residual	.7	-1.2	
	Critically Endangered	Count	1	0	1
		% within Endangerment_Status	100.0%	0.0%	100.0%
		% within Conservation_Mentioned	6.3%	0.0%	4.5%
		Std. Residual	.3	-.5	
Total		Count	16	6	22
		% within Endangerment_Status	72.7%	27.3%	100.0%
		% within Conservation_Mentioned	100.0%	100.0%	100.0%

Discussion-

General Trends-

Our research found that wide arrays of primate species are being studied with regards to zoonotic disease. No superfamily makes up over 50% of researched primate populations implying that research within primatology is dispersed fairly evenly among superfamilies. However, zoonotic research is not being conducted within Lorisoidea and Tarsiiformes. The lack of research here could imply that zoonotic disease within these primate populations is not a concern or is not well known. Further trends show that the majority of primates studied are from wild populations. Since all of the articles come from primatology journals, it makes sense that 77% of the research conducts studies on wild primate populations versus medical laboratory or domestic populations (Figure 3). Our last general trend shows that the majority of primate populations studied have interaction with humans and over 50% of the populations have frequent interactions with humans. Within zoonotic disease research this would make sense to see high levels of interaction because more disease transmission can occur (Figure 4).

Disease Trends-

Before starting the meta-analysis the initial thought was that diseases classified as a bacteria or a virus would be more prevalent within research. Classic examples of zoonosis are often viral or bacterial diseases that affect larger portions of the population such as ebola, tuberculosis, or HIV (Wolfe et al., 2014). Because these diseases are often given as examples of zoonosis, we had originally thought that the data would suggest more research is being done with viral and bacterial zoonotic disease. After analyzing the data though, diseases within the kingdom of Protista and Animalia are more prevalent in the research. These kingdoms suggest parasitic zoonotic disease (Nunn and Altizer, 2006). Articles with this specific disease code suggested that increased transmission of parasites was a result due to anthropogenic encroachment on non-human primate habitat. This encroachment leads not only to increased interaction between humans and non-human primates, but increased interaction between primate populations and human livestock that are often considered disease reservoirs (Chapman et al., 2006; Howells et al., 2011; Koalewski et al., 2010; Rovirosa-Hernandez et al., 2013; Sá et al., 2013; Vitazkova et al., 2006; Weyher et al., 2006). Research outside of the meta-analysis articles suggested that parasitic zoonotic diseases can potentially play a big role in primate conservation. Many non-primate species have gone extinct due to parasitism within a species population (Nunn and Altizer, 2006).

The chi-squared analysis between the superfamily and the disease code showed that correlation between the two was approaching statistical significance (Figure 6). This analysis showed that zoonotic disease research does not focus on specific diseases solely within a particular superfamily. Rather research looks at all taxonomic kingdoms of diseases within all primate superfamilies. If the meta-analysis were to include medical journals, the statistical correlation could potentially become significant due to medical laboratories only studying specific primate populations that have a similar disease response to humans. Further studies expanding the meta-analysis to broader scientific journals could analyze this correlation to see if medical research targets specific primate species.

Another part of the disease trends portion of the analysis was looking at whether the impact of endangerment of a disease could be correlated back to a specific type of disease. Our study showed that there was no correlation between the two categories (Figures 8 and 9). With regards to conservation efforts, this means that there is no particular type of disease that zoonotic research should focus on more. All of the diseases studied do not impact the conservation status of primates more than any other taxonomic disease group.

Objective Trends-

This study shows that within zoonotic disease research most studies are focusing on Population and Ecosystem Health as a main objective (Figure 10). Before we can conclude that all zoonotic disease research focuses on primate populations more than human populations, the study would have to include broader scientific journals. Since the study only analyzed research articles from primatology journals, there is a bias towards only studying non-human primates because of the academic field. Further studies could expand the meta-analysis to the entire field of zoonotic disease research rather than only focusing on the research within primatology.

With 50% of the research focusing on Population and Ecosystem Health, it appears that primatology research is focused on understanding and bettering primate population health (Figure 10). Despite the interest in primate health only 9% of the research in primatology is focused on conservation efforts (Figure 10). The affect of zoonotic disease on conservation was mentioned by 73% of the articles yet conservation is not a primary objective (Figure 17). Our initial predictions explaining this included the research having to first establish a baseline for population health or the populations could have an increased IUCN endangerment status risk.

Many articles focusing on Population and Ecosystem Health as a primary objective mentioned that the standard level of health in many primate populations was unknown (Eckert et al., 2006; Howells et al., 2011; Kowalewski et al., 2010; Sá et al., 2013). Furthermore, research outside of the meta-analysis suggests that many disease models are based off of theoretical mathematical models rather than actual ecosystem models (Nunn and Altizer, 2006). Since there is a lack of research showing actual disease impact on ecosystems, there is a need for establishing baseline ecosystem health models. The research focused on Population and Ecosystem Health could essentially act as pilot studies that then go on to research zoonotic disease with conservation as a primary objective. Since there has not been any follow up to these research articles we cannot say if the research will continue on towards the objective of conservation.

We were able to analyze whether or not IUCN endangerment status impacted the primary objective of a study. Our results were heading towards statistical significance correlating the two, however the sample size of articles would most likely have to increase to see a full significant correlation (Figure 11 and Figure 12).

Since the impact of endangerment status on the primary objective was nearing statistical significance we also looked at other causes that could impact research primary objectives. This included looking at how the primary objective was impacted by how much the disease affected the conservation status of primate populations. We found that there was no statistical correlation to conclude that disease affect on conservation influences how research will be conducted with regards to the study's primary objective. The lack of correlation could be a result of not fully understanding how much the studied diseases impacted conservation. As mentioned before many articles were pilot studies analyzing the overall health of a population, so disease impact might not be fully known (Eckert et al., 2006; Howells et al., 2011; Kowalewski et al., 2010; Sá et al., 2013). However, this furthers that there is a lack of understanding on how much zoonotic diseases impact the conservation of primates.

To understand motives for primary objectives in research, we also analyzed whether or not the type of disease impacts research objectives. Our analyses showed that there was no statistical significance to suggest any correlation, however the significance value was nearing statistical significance. Disease Code and Endangerment Status have both been nearing statistical correlation to primary objectives within research, but no correlations within our study were proven statistically significant. These results however do not mean that research primary objectives are chosen at random. Primary objectives could be influenced by a number of different preexisting conditions within the study population. This would lead to multiple factors nearing statistical correlation, but not showing enough significance especially within a smaller sample size such as in this study.

Conservation Trends-

The analyses on conservation among zoonotic research showed that conservation is often mentioned as being impacted by zoonotic disease. A majority of articles mentioned conservation as a side affect of zoonotic disease, however this does not imply that the research is aiding towards conservation efforts (Figure 17). Our tests looked at the affects of endangerment status and the affects of primary objectives on the mention of conservation within research and they suggested that there was no correlation (Figure 18 and Figure 21). This means that the mention of conservation within research is at random. No primary research objective was more or less likely to mention conservation. Furthermore the status of endangered populations did not spark more talk of zoonotic disease affect on conservation. There is a lack of causal explanation as to why there is a high recognition of conservation in research. There are also no correlated explanations as to what prompts research to be concerned with conservation. This could suggest that within zoonotic research more emphasis is put onto understanding the disease instead of looking at the disease's future impacts.

Conservation within primatology is an important area to study due to over 60% of primates being threatened (Nunn and Altizer, 2006). If primatologists wish to continue studying wild primate populations then conservation efforts should be a main focus within research. Zoonotic disease is one of the many factors that contribute to primate endangerment (Nunn and Altizer, 2006; Woodford et al., 2002). This study shows that within primatology there is a lack of research on how zoonotic disease impacts conservation efforts. Research on zoonotic disease is still very limited due to the emerging interest in this field, however future research should focus more on the affects of zoonotic disease on conservation.

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REFLECTION

My honors undergraduate thesis stemmed from my interest in primatology. My career goals include furthering my education to a graduate level within the field of primatology and hopefully working with a primate conservation group. Because of my interest in primate conservation I wanted my undergraduate thesis to develop my knowledge of different areas impacting primate conservation. Zoonotic disease is an emerging area of interest within primate conservation. I was more interested in this topic versus other areas of primate conservation because it would allow me to combine my knowledge of anthropology and primates with my knowledge of biology and chemistry.

My honors undergraduate thesis emerged from an honors contract I completed in the spring of 2014 with Dr. Leslie Williams who was then teaching with the anthropology department at Utah State University. The honors contract was for the Anthropology of Disease class offered through the department and it was a meta-analysis on infectious disease within primates. Originally this project was not going to be my honors thesis due to Dr. Williams leaving for a different university. However, when primatologist Dr. Nanda Grow came to Utah State University in the fall of 2014 I decided to pursue this project as my thesis. When the project was solely and honors contract, Dr. Williams and I had discussed that if we wanted to further this project we would need the expert advice of a primatologist to add the primate component on top of Dr. Williams' knowledge of infectious diseases. Problems arose early on in the thesis planning due to Dr. Williams accepting a position at Beloit College. She was unable to continue collaboration on the project so I had to find another expert on diseases to add to Dr. Grow's knowledge of primates. Thankfully Amber in the honors office suggested that I talk with Dr. Kim Sullivan in the Biology Department and I was able to meet with an Utah State's epidemiologist, Dr. Scott Bernhardt. Dr. Bernhardt provided useful insights into epidemiology research and suggested certain patterns to look for within my meta-analysis.

Once I had my committee members finalized, I began the actual process of completing the meta-analysis. Besides doing a brief meta-analysis for the honors contract in the spring of 2014, I had never conducted this type of research. Since the research question was entirely my own original work I had to create various categories of what part of primate zoonotic disease I wanted to look at. This was a bit of a challenge for me because the research I had previously done in my undergraduate career had very specific goals in mind laid out by research professors' main area of interest within their field. In order to finalize what I actually wanted to accomplish within my meta-analysis I had to look at zoonotic literature to see what types of research has been and/or is being conducted. Many of the articles that I read mentioned the impact that zoonotic disease had on conservation, but failed to go into further detail. Many researchers recognized that zoonotic disease could potentially impact conservation, but failed to say how much of an impact it would have and how primate conservation should tackle this issue. The lack of information regarding conservation with regards to zoonotic disease prompted me to narrow my area of interest within my meta-analysis to address this problem.

A problem that I faced within the data collection portion of my thesis was having too small of a data set. I analyzed the three main primatology journals to gain a broad understanding of research within the field however the data amount was still too small for statistical analyses to produce any significant correlations between common research trends. Originally, I was hoping to have over one hundred different research articles, however this proved to be impossible. With the search term "zoonotic disease" that we entered into every journal database only 22 articles matched the criteria for our research analysis. We were still able to conduct statistical analyses, however I think our results would have been different and produced strong correlations if more articles would have been available. What this did show though was that research within primate zoonotic diseases is still an emerging field. Adding articles from other academic journals could have possibly resolved the problem of the data set being too small. Originally, I wanted to include research articles from multiple different academic disciplinary journals. Upon starting the data collection process though, I quickly realized that my area of interest needed to be narrowed down. I focused solely on research within primatology versus research in other academic disciplines so that I could have a baseline understanding of what zoonotic disease research looked like within my own field before analyze research in other fields. The meta-analysis could act as a pilot study for future analyses of research in other disciplines.

My advice to future honors students interested in completing a thesis research project is to find an area of interest that they love to study. I enjoyed the process of completing my honors thesis because I was actually interested in the content material. Furthermore my thesis work helped me realize what research I was interested in within primatology and it furthered my progression towards career goals. I would strongly encourage students to try and publish their honors thesis because even though the shiny gold honors medal is worth it as a reward for completion, I would assume that every honors undergraduate thesis represents the potential of a person and the potential of where their academic research field is headed.

AUTHOR BIOGRAPHY

Madalyn R. Page is an undergraduate within the Department of Sociology, Social Work, and Anthropology at Utah State University in Logan, Utah. She is graduating with a Bachelor's of Science in Anthropology in the Biological track and she has minors in Biology and Chemistry. She completed both University and Departmental Honors. During her four years at Utah State University, Madalyn was apart of several different undergraduate research projects across various academic disciplines. These projects included working with the Biology Department in a plant pathogen lab and working with the Anthropology Department in both a zooarchaeology lab and with Dr. Nanda Grow on this undergraduate honors thesis. As a result of her undergraduate research Madalyn presented her research at five different conferences, the most notable conference being the Great Basin Anthropology Conference in Fall 2014. Madalyn served as an undergraduate teaching fellow for the Biological Anthropology class and the Principles of Archaeology class at Utah State University. In the summer of 2013 she completed her first internship working with the Primate Department at Utah's Hogle Zoo. The following summer in 2014 she completed another internship this time working with the great apes at Saint Louis Zoo's Jungle of the Apes. During both internships she was able to complete various behavioral ethograms tracking aggression in gorillas and reproductive behaviors in orangutans. Her future career goals include furthering her education to a graduate level, continuing research with primates, and working with a primate conservation program.