

**FOREST RESOURCE OVERLAP IN HUMANS AND TONKIN SNUB-NOSED
MONKEYS OF HA GIANG PROVINCE, VIETNAM:
THEORETICAL AND CONSERVATION IMPLICATIONS**

By

AMY LOUISE HARRISON LEVINE

B.S., Michigan State University, 1992

M.A., Kent State University, 1998

A thesis submitted to the
Faculty of the Graduate School of the
University of Colorado in partial fulfillment
of the requirement for the degree of
Doctor of Philosophy
Department of Anthropology

2016

This thesis entitled:
Forest Resource Overlap in Humans and Tonkin Snub-Nosed Monkeys of Ha Giang
Province, Vietnam: Theoretical and Conservation Implications

written by Amy Louise Harrison Levine

has been approved for the Department of Anthropology

(Herbert Covert, Ph.D.)

(Michelle Sauther, Ph.D.)

(Darna Dufour, Ph.D.)

(Dennis Van Gerven, Ph.D.)

(Brett Bruyere, Ph.D.)

Date: _____

The final copy of this thesis has been examined by the signatories, and we find that both the content and the form meet acceptable presentation standards of scholarly work in the above mentioned discipline.

IRB protocol # 11 - 0123

Harrison Levine, Amy Louise (Ph.D., Anthropology)

Forest Resource Overlap of Humans and Tonkin Snub-Nosed Monkeys in Ha Giang
Province, Vietnam: Theoretical and Conservation Implications

Thesis directed by Professor Herbert H. Covert

ABSTRACT

Co-occurring primates differentiate habitats and resource use patterns across spatial and temporal scales. Such differential forest use can play a significant role in resource partitioning, especially in phylogenetically related taxa. When it comes to primate communities, however, it is all too often that human primates are excluded from such analyses. The research presented here is the first in-depth analysis of human-nonhuman primate forest use overlap in Vietnam. By applying a mixed methods toolkit, quantitative and qualitative data were gathered regarding people and monkeys sharing forest resources within the Tonkin Snub-Nosed Monkey Species and Habitat Conservation Area. Direct observations of the monkeys (48 observation hours) and the local people (67 events of human activity in the forest), as well as 75 household interviews, were conducted simultaneously between August 2011 and March 2013. Analysis indicated that several socio-economic (SES) variables, including a newly validated SES index, reliably predict human knowledge and expertise with specific forest plants. Timber harvesting activities, specifically for the purposes of construction and fuelwood, were identified as the most substantial threat to the monkeys. One tree species in particular, *Excentrodendron tonkinense*, was determined to be absolutely

essential to Tonkin snub-nosed monkey survival, but is also a highly valued resource for local people. Neither humans nor nonhuman primates appeared to shift forest plant species use seasonally, but monkeys narrowed their space use in the wet season and spent more time in less rugged areas compared to people. Additionally, timing of human forest access reflected a considerable degree of specificity – over 90% of observed events took place in the dry season and a significant percentage also occurred towards the end of each lunar month. The dry season not only encompassed the most important holiday of the year, it is also considered to be free time by the local residents. These findings have not only enhanced the current understanding of the human-nonhuman primate interface, they also inform future conservation action. Results were used to refine an Open Standards conceptual model, and to outline a series of recommended strategies and conservation interventions designed to preserve the critically endangered Tonkin snub-nosed monkey (*Rhinopithecus avunculus*).

DEDICATION

For Andy, Nicole and Owen

ACKNOWLEDGEMENTS

This body of work and the many years of effort behind it would have been impossible to complete without the devoted support and understanding of my loving family: my husband, Andy Levine; my daughter, Nicole Levine; my son, Owen Levine; and my parents, Greg and Judy Harrison. I credit my folks for my strong sense of adventure, thirst for knowledge, logical approach to life, and compassion for the natural world. With my husband I share a passion for each of these founding tenets and I can only hope we provide our children with the same appetite for learning and empathy, as well as a strong desire to explore and learn about the tremendous beauty this world has to offer. This brief paragraph does not do justice to my thankfulness for my family's love and support, so I pledge to spend the rest of my days ensuring they know how grateful and lucky I am.

In addition to my family, there are so many others that deserve my eternal gratitude. At the top of this list are my two most recent academic advisors; first, my dissertation advisor and committee chair, Dr. Bert Covert. Where do I begin? The journey to completing this manuscript was far from a short one, and it is difficult for me to express how much Bert's continued, positive support has meant to me throughout. He not only provided me the opportunity nearly eight years ago to join the team working to protect critically endangered Tonkin snub-nosed monkeys in Vietnam, he also gave freely of himself, offering time, inspiration, friendship, and superior guidance. Dr. Michelle Sauther acted as my advisor for the first four years of my doctoral program – through my coursework years. She increased my capacity to think critically, coached me through several excellent graduate seminars, and pushed me to start my research

endeavors not with thinking about *what* to do, but with thinking about *why* to do it.

Thanks also to Dr. Darna Dufour and Dr. Terry McCabe, for introducing me to the world of human ecology, to Dr. Brett Bruyere, for sharing his valuable insight into the human dimensions of conservation, and to Dr. Dennis Van Gerven who was willing to take time out of his busy summer to help me see this work through to the end. I would be remiss to not mention how all of these individuals and so many others during my time at the University of Colorado Boulder (especially Valerie McBride and Lesa Morris), have been beyond supportive despite my unique circumstances. I could not have completed this milestone without being championed by this incredible group of people.

There is no question this research would not have been possible without the help of many Vietnamese friends and colleagues. My trusted, patient, humorous, and intelligent Community Research Assistant, Mr. Luu Tuong Bach, helped me secure local government approvals, navigate over 100 household interviews, and manage everything in between. I truly have no idea how my Forest Research Assistant, Mr. Le Van Dung, was able to traverse that treacherous forest one or two weeks each month; I challenge any reader to find a more difficult terrain in which to work. I also thank Mr. Hoang Van Tue, Dr. Nguyen Anh Duc, Dr. Le Khac Quyet, Mr. Thach Mai Hoang, Mr. Dan Van Khoan, Mr. Nong Duc Gioi, Mr. Chung Van Thanh, and Mr. Dan Van Nhieu, as well as Community Patrol Group and governmental staff including Mr. Thuong, Mr. Sam, and Mr. Khoan in Tung Ba, Mr. Kanh, Mr. On, Mr. Kien, and Mr. Bien in Minh Son, and Mr. Tuyen and Ms. Hue in Yen Dinh. Several of these individuals also opened up their homes to me, Dung and Bach; I thank their families and especially their wives, who were gracious hosts, and who helped me feel safe, welcome and extremely well fed.

From a logistical and financial standpoint, this research would not have been possible without the support of a number of people and institutions. I thank the Ha Giang Forestry Protection Department and the Tonkin Snub-Nosed Monkey Species and Habitat Conservation Area Management Board, for their approvals, contacts, reports, and great ideas. I was incredibly humbled to receive a Margot Marsh Biodiversity Fund award in support of this research, and I could never thank Dr. Russ Mittermeier, Mr. Bill Konstant and the other program officers enough for their belief in my ideas. I am also grateful for several grants, fellowships, and tuition waivers from the University of Colorado Boulder – this assistance has always exceeded my expectations. My employer, Denver Zoo, provided substantial and enduring financial and temporal support for this project. I especially thank a few zoo colleagues who have played critical roles that helped ensure my journey was met with success - whether spending time with me in the field climbing that crazy limestone karst, enjoying a celebratory meal and toasting with our Vietnamese partners, talking me through the complexities of GIS data analysis, holding down the fort while I was away from work for weeks on end, or advocating for my logistical or financial needs: thanks to all – you know who you are.

The people and monkeys of Ha Giang Province, Vietnam, will always have a piece of my heart. I will never forget the end my first trip to Tung Ba commune – I cried because I was afraid I would never return. Return I did; and I will be forever grateful that nearly everyone I met thereafter welcomed me into their homes and into their lives. I am honored to have played even the smallest part in deepening our understanding of the human-nonhuman primate interface in Ha Giang and in using what we now know to help protect the incredibly rare and beautifully unique Tonkin snub-nosed monkey.

CONTENTS

CHAPTER

I. INTRODUCTION	1
1.1 Research Questions and Hypotheses.....	3
1.2 Dissertation Structure	7
II. THE HUMAN-NONHUMAN PRIMATE INTERFACE	9
2.1 Nature + Humans = Ethnoprimateology	9
2.2 Human Predation of Nonhuman Primates	11
2.2.1 Nonhuman Primate Responses to Being Hunted	12
2.2.2 Humans as Predators of Nonhuman Primates	13
2.3 Comparative Ecology of Humans and Nonhuman Primates	16
2.3.1 Crop Raiding	16
2.3.2 Human-Nonhuman Primate Forest Resource Overlap.....	17
III. PRIMATE ADAPTATION, PREDATOR-PREY RELATIONSHIPS, AND NICHE PARTITIONING	20
3.1 The Concept of Adaptation	20
3.2 Culture as Adaptation	23
3.3 Primates as Predators and Prey	24
3.4 Resource Partitioning.....	26
3.4.1 Niche Partitioning Theory	26
3.4.2 Resource Partitioning and the Human Primates	27
3.4.3 Evaluating Resource Overlap.....	29
IV. CONSERVATION AND NATURAL HISTORY OF PRIMATES IN SOUTHEAST ASIA	32
4.1 Conservation of Southeast Asian Primates.....	32

4.1.1 Anthropogenic Threats	33
4.1.2 Conservation Status of Vietnamese Primates	33
4.1.3 Conservation Status of the Genus <i>Rhinopithecus</i>	38
4.1.4 Conservation Status of <i>Rhinopithecus avunculus</i>	39
4.2 Natural History of Snub-Nosed Monkeys and Other Colobines	40
4.2.1 Asian Colobine Natural History	41
4.2.2 <i>Rhinopithecus</i> Natural History	43
4.2.3 <i>Rhinopithecus avunculus</i> Natural History	50
V. RESEARCH CONTEXT AND METHODS	55
5.1 Research Context	55
5.1.1 Study Site: Khau Ca Forest, Ha Giang Province, Vietnam... 56	
5.1.2 The People of Ha Giang Province	59
5.1.3 Anthropogenic Impacts to Khau Ca and its Inhabitants..... 60	
5.1.4 Socio-Cultural, Economic, and Political Context	63
5.1.5 The Antiquity of Coexistence in Northern Vietnam	70
5.1.6 Human Forest Resource Use in Northern Vietnam	71
5.1.7 Human – Nonhuman Primate Forest Overlap in Vietnam 72	
5.2 Research Methodology	73
5.2.1 Monkey Behavior and Ranging	74
5.2.2 Human Activity within the Forest	75
5.2.3 Household Interviews	76
5.2.4 Data Analysis	81
5.3 Conservation Planning and Evaluation	82
VI. UNDERSTANDING HOW SOCIO-ECONOMIC STATUS IMPACTS HUMAN FOREST RESOURCE KNOWLEDGE	86

Abstract.....	86
6.1 Introduction	87
6.1.1 Total Assets	88
6.1.2 Freelisting.....	90
6.1.3 Research Objectives	91
6.2 Methods and Materials.....	91
6.2.1 Study Site and Study Population.....	92
6.2.2 Data Collection.....	95
6.2.3 Data Analysis	98
6.3 Results.....	99
6.3.1 Interview Sample.....	99
6.3.2 Selection of Total Assets Variables.....	100
6.3.3 Socio-Economic Status	101
6.3.4 Resource Use Categories	103
6.3.5 Socio-Economic Parameters and Resource Knowledge	106
6.3.6 Ethnicity, Household Location, and Resource Knowledge .	107
6.4 Discussion	110
6.5 Conclusion	114
VII.HUMAN AND NON-HUMAN PRIMATE RESOURCE IMPORTANCE AND OVERLAP: CONSERVATION IMPLICATIONS.....	116
Abstract.....	116
7.1 Introduction	117
7.1.1 Assessing Human Forest Resource Importance	119
7.1.2 Assessing Nonhuman Primate Resource Importance	121
7.1.3 Human–Nonhuman Primate Resource Overlap	122

7.1.4 Northern Vietnam: An Ideal Study Site.....	123
7.1.5 Study Aims	125
7.2 Methods and Materials.....	126
7.2.1 Study Site.....	126
7.2.2 Study Subjects	128
7.2.3 Data Collection.....	131
7.2.4 Data Analysis	133
7.3 Results.....	134
7.3.1 Human Resource Use and Importance	134
7.3.2 Monkey Resource Use and Importance	139
7.3.3 Resource Use Overlap and Comparative Importance	141
7.4 Discussion	143
7.4.1 Monkey Resource Use.....	143
7.4.2 Human Resource Use.....	146
7.4.3 Comparison of Human and Nonhuman Resource Use	148
7.4.4 Conservation Implications and Recommendations	150
VIII.DIFFERENTIAL FOREST USE PATTERNS IN HUMANS AND TONKIN SNUB- NOSED MONKEYS.....	153
Abstract.....	153
8.1 Introduction.....	154
8.1.1 Seasonality.....	155
8.1.2 Ruggedness.....	157
8.1.3 Culture.....	159
8.1.4 Research Objectives	160
8.2 Materials and Methods.....	161

8.2.1 Study Site.....	161
8.2.2 Nonhuman Primate Study Subjects	163
8.2.3 Human Study Subjects.....	165
8.2.4 Data Collection and Analysis.....	168
8.3 Results.....	172
8.3.1 Seasonality.....	173
8.3.2 Ruggedness.....	180
8.3.3 Culture.....	182
8.4 Discussion	184
8.4.1 Spatial and Temporal Use of the Forest.....	185
8.4.2 Conservation Implications	193
IX. CONCLUSION AND FUTURE DIRECTIONS	196
9.1 Major Findings and Future Research.....	196
9.1.1 Socioeconomic Variables.....	197
9.1.2 Forest Resource Use Overlap.....	200
9.1.3 Spatio-Temporal Forest Use	203
9.2 Conservation Implications.....	207
9.3 Recommended Conservation Actions.....	214
BIBLIOGRAPHY	216
APPENDICES	241
A. Master Timber Species List.....	241
B. Master Non-Timber Forest Product List	244
C. Interview Script	248

TABLES

1.	Summary of the physical characteristics, geographic distribution, and habitat types of the five known species of snub-nosed monkeys	45
2.	List of plant taxa consumed by Tonkin snub-nosed monkeys of Khau Ca forest	53
3.	Fifteen household assets assessed in this study	98
4.	Interview sample distribution among communes, ethnicities and socio-economic status levels	100
5.	Knowledge of seven human resource use categories evaluated in this freelist study	104
6.	Spearman's rank correlation coefficients resulting from comparisons of resource use categories and socio-economic parameters	106
7.	Salience scores for timber forest products included in the top ten resources for each human use category	136
8.	Salience scores for non-timber forest products included in the top ten resources for each human use category	137
9.	Forest plants with the highest salience scores across all human resource use categories	139
10.	Proportional use frequencies and ranks of all identifiable monkey forest plant resources within each behavior category	141
11.	Forest plant species overlap between monkeys and local people	142
12.	Camera trap sampling effort summary	176

FIGURES

1.	Adult male Tonkin snub-nosed monkey, <i>Rhinopithecus avunculus</i>	45
2.	Tonkin snub-nosed monkey Species and Habitat Conservation Area map	57
3.	The limestone peaks of Khau Ca forest	58
4.	Tung Ba commune and the village-agricultural matrix surrounding Khau Ca forest	61
5.	<i>Excentrodendron tonkinense</i> , a linden tree known locally as <i>Nghien</i>	73
6.	Open Standards for the Practice of Conservation conceptual modeling process for a conservation program	84
7.	Study area map, showing locations of all three communes	92
8.	Histogram demonstrating respondent household socio-economic status index scores	102
9.	Significant and insignificant differences between mean total assets scores for Tay, Dao, and Hmong households	103
10.	Comparison of the three different local ethnic groups in terms of timber and non-timber forest product knowledge	108
11.	Comparison of timber and non-timber forest product knowledge in households from Tung Ba, Minh Son and Yen Dinh communes	110
12.	Photos of the rice wine distillation process and of a traditional Tay wooden stilt home	113
13.	Study area map, showing locations of the three communes surrounding Khau Ca forest	127
14.	Number of timber and non-timber forest product plants listed in each of seven human resource use categories	135
15.	Forest plants used by Tonkin snub-nosed monkeys during the current study for feeding, traveling, and resting	140
16.	Importance ranks of five of the most salient plants used by both humans and monkeys	144

17. Spearman's nonparametric rank correlation of human and monkey resource importance for all 10 overlap plant species	144
18. Study area map, showing locations of the three communes as well as transects and trails present within Khau Ca forest	162
19. Maps of camera trap and household interview locations, in relation to the Khau Ca forest boundary	170
20. Photos of household interviews in process	172
21. Comparison of mean monthly rainfall and availability of young leaves in Khau Ca forest	173
22. Comparison of mean monthly rainfall with fruit and flower availability in Khau Ca forest	174
23. Comparison of food items ingested by Tonkin snub-nosed monkeys during the wet and dry seasons	175
24. Seasonal pattern of direct observations of human traffic in Khau Ca forest	177
25. Seasonal pattern of type of human activity within Khau Ca forest	178
26. Human and Tonkin snub-nosed monkey core areas of forest use	179
27. Wet season habitat use for humans and Tonkin snub-nosed monkeys	179
28. Dry season habitat use for humans and Tonkin snub-nosed monkeys	180
29. Location of human and Tonkin snub-nosed monkey activity in relation to forest ruggedness class	181
30. Comparison of human and Tonkin snub-nosed monkey rugged class use in Khau Ca forest	182
31. Photos of non-timber forest product procurement and of a <i>Dong</i> leaf (<i>Phrynium</i> sp.)	184
32. Days of the month when forest timber was harvested from Khau Ca forest	190
33. Open Standards conceptual model for Tonkin snub-nosed monkey conservation	211
34. Modified Tonkin snub-nosed monkey conceptual model	212
35. Conservation conceptual model focused on timber harvesting	213

CHAPTER I

INTRODUCTION

“Holistic projects based on knowledge of the interaction between human and nonhuman primates, plans that include both the enhancement of the lives of local peoples and the needs of wildlife, are required if nonhuman primates are to survive.”
(Wolfe and Fuentes, 2007, p. 700)

This study aims to assess human-nonhuman primate interspecific relationships and to simultaneously evaluate behavior and ecology of Tonkin snub-nosed monkeys (*Rhinopithecus avunculus*) and humans within a shared forest environment in Ha Giang Province, Vietnam. By examining how both humans and Tonkin snub-nosed monkeys (TSNM) concurrently utilize forest resources within the TSNM Species and Habitat Conservation Area, the research presented here will answer questions regarding *R. avunculus* spatio-temporal responses to the presence of local people in the forest, and vice versa. Additionally, forest resource importance will be compared between the human and nonhuman primate study populations to determine the degree to which they rely upon the same forest resources, and as well, human demographic information will be considered to identify potential socio-economic drivers of protected area use. The results of this work will inform conservation interventions designed to minimize

anthropogenic threats to the Critically Endangered *R. avunculus* (Le Xuan Canh et al., 2008; Le Khac Quyet et al., 2016) at this study site in northern Vietnam.

Owing largely to the expansion of human populations worldwide, the interface between humans and wildlife more often than not results in the degradation, fragmentation, and destruction of habitats. Because scientists tend to consider humans as distinct or separate from nature, more research is needed focusing on humans as integral components of ecosystems and natural communities. Coexisting humans and animals have varying and complex interactions; a statement that is perhaps especially true when considering relationships between humans and their closely related nonhuman primate counterparts.

When humans and nonhuman primates share landscapes and resources, the interspecific interface can take one or more of a variety of forms. Humans may prey upon nonhuman primate species, or they may revere them – or both. When humans and other primates have inhabited the same region for hundreds or thousands of years, it would not be unexpected to observe behavioral repertoires that maximize this coexistence. For instance, nonhuman primates regularly predated upon by humans may exhibit evidence of spatially or temporally avoiding the presence of humans. Humans that revere their sympatric primate cousins could potentially show evidence of active protection of either the primates or their resources. And when nonhuman primates are not necessarily hunted or revered by humans, the two species may demonstrate other behavioral adjustments to coexistence, such as dietary divergence; the opposite of which – convergence of resource use – might alternatively be evidence

of the absence of behavioral adjustments typically observed in cases of long-lived sympatry.

By concurrently collecting quantitative and qualitative data on both human and nonhuman primate study subjects, a detailed picture of the human-nonhuman primate interface can be described. Not only will this holistic research methodology uncover patterns of overlap between human and nonhuman resource utilization, it may also point to underlying human social drivers of resource use. Clarifying these interspecific relationships and socio-cultural drivers will be essential for the development of an informed plan for preserving species, such as Tonkin snub-nosed monkeys, that are being pushed further and further towards the brink of extinction.

1.1 Research Questions and Hypotheses

The research pursued here was designed to determine if there is a measurable relationship between *R. avunculus* and human forest resource use within the TSNM Species and Habitat Protected Area. Data collected elucidated human and monkey patterns of forest use across temporal and spatial scales, and also examined comparative forest resource importance. To rule out niche separation as a driving force behind observed patterns of resource use, resulting relationships were tested against predictions expected in a case of resource partitioning. To determine if factors other than niche separation did a better job of clarifying resource use patterns, variables such as TSNM food availability, household socio-economic factors, seasonal and spatial forest use dynamics, and human cultural factors were also examined. While additional variables may also have an effect on resource use dynamics, they were outside the

scope of this project. Within this context, the following two groups of research questions were answered by testing the associated hypotheses (H):

- 1. Do Tonkin snub-nosed monkeys exhibit behaviors that may result from long-term coexistence with humans? Is there a measurable relationship between human and TSNM forest use patterns and resource importance at the study site? If so, is the relationship demonstrative of what would be expected in a case of resource partitioning? Is the relationship suggestive of active avoidance?**

Given that humans and Tonkin snub-nosed monkeys in northern Vietnam both rely upon forest resources for survival and knowing that humans and *Rhinopithecus* species have co-existed in this region for thousands of years, behavioral evidence of a long-term coexistence would not be unexpected. Alternatively, the degree of coexistence between humans and *R. avunculus* may be relatively new, due to recent human population expansion in Vietnam, or relatively minor, as a result of minimal human presence in the forest for the purpose of resource exploitation.

H1a: There is a negative relationship between human and TSNM seasonal forest use patterns. The competitive exclusion principle (Hardin, 1960) predicts that temporal variation in resource use is one way sympatric species can

minimize resource overlap; humans and nonhuman primates will not use the same forest resources at the same time of year.

H1b: There is an inverse relationship between human and TSNM spatial forest use patterns. Hardin's competitive exclusion principle (CEP) would also suggest that sympatric species can minimize overlap by using different parts of habitats; humans and TSNM will not use the same parts of the forest.

H1c: Human forest resource importance ranks are inversely related to TSNM importance ranks. According to the CEP, sympatric primates may demonstrate low overlap of important resources; resources that are most important to TSNM will not be most important to humans, and vice versa.

Note here, that support for *H1a* and *H1b* combined with the absence of support for *H1c* may be evidence of a predator-prey relationship, in that the TSNM may be acting to avoid spatio-temporal overlap with humans in the forest. Predation is considered to be a primary selective factor in shaping primate behavior, including ranging patterns (Eisenberg et al. 1972; Clutton-Brock and Harvey, 1977; van Schaik, 1983; Terborgh and Janson, 1986; Cheney and Wrangham, 1987; Miller, 2002).

2. Do other factors, such as human socio-economic status and/or human cultural factors explain observed patterns of human resource use and importance?

What socio-economic or cultural factors act as important drivers of human forest resource use patterns, and to what extent? Poor people may rely more heavily upon forest resources for survival; but on the other hand, those who frequently gather forest resources for sale in local or international markets may be wealthier. Because ethnicity contributes significantly to socio-economic status, it is also possible that specific ethnic groups may be more apt to utilize forest resources. While the majority of the population in this part of Vietnam identify themselves as farmers, those who maintain significant off-farm employment may be more or less likely to gather forest resources. Cultural traditions, celebrations, and beliefs may also influence patterns of human resource collection.

H2a: Human resource use patterns are related socio-economic status, education, employment, and ethnicity. Human groups in Vietnam are known to vary in resource utilization patterns as a result of differing socio-economic status (SES) factors (Gomiero et al., 2010; McElwee, 2010; Quang and Noriko, 2008); humans with comparatively high SES status will demonstrate less resource procurement expertise when compared to those with low SES status.

H2b: Human resource use patterns are predicted by the timing of human cultural factors. Cultural practices are known to be closely related to timing of forest resource exploitation in humans (Ghorbani et al., 2012; Woodward et al., 2012);

direct observations of human use of forest resources will temporally correlate with reported cultural events and traditional practices.

1.2 Dissertation Structure

Explained above, two broad research goals will be addressed in this dissertation. The first is to evaluate the patterns of resource overlap between humans and Tonkin snub-nosed monkeys in northern Vietnam, specifically with respect to uncovering evidence that may exist for behavioral adjustments to long-term coexistence. The second is to identify human socio-cultural factors that may act as drivers of forest resource use patterns, with an aim of using that knowledge to minimize anthropogenic threats to *R. avunculus* inhabiting the TSNM Species and Habitat Conservation Area in Ha Giang Province.

Following this introduction, Chapter 2 familiarizes the reader to the human-nonhuman primate interface and the body of work within the academic field of primatology known as ethnoprimateology, focusing specifically on predator-prey relationships and comparative ecology. Chapter 3 provides the theoretical basis of behavioral adaptation, predator-prey relationships, and resource partitioning. Chapter 4 focuses on Asian colobine (“leaf monkey”) feeding ecology, resource use, and conservation, with special attention to *Rhinopithecus* species and Tonkin snub-nosed monkeys. Chapter 5 brings the reader into the context of this specific investigation, providing historical and current details about the study site, human and nonhuman primate study populations, an overview of both quantitative and qualitative

methodologies employed in the research, and an introduction to a leading conservation planning and evaluation framework, called Open Standards for the Practice of Conservation.

Chapters 6 through 8 are the main data and results chapters, and as such, are structured differently; these chapters are written as independent journal articles prepared for submission to specific peer-reviewed publications. Chapter 6, planned for submission to the journal, *Environmental Management*, provides an evaluation of the cultural drivers of human resource use. It focuses on the development and application of an assets-based index to quantify socio-economic status of the human study subjects and compare this status to resource knowledge and use patterns. Chapter 7 describes human and Tonkin snub-nosed monkey forest resource importance and resource use overlap and evaluates evidence for niche separation between the two primate species. This chapter is designed for submission to the *International Journal of Primatology*. Chapter 8 examines the differential spatio-temporal use of the forest study site by humans and the monkeys and is written for submission to the journal, *Conservation Biology*.

Finally, in Chapter 9, a summary of research findings and conclusions, as well as future directions for research are discussed. In addition, results are incorporated into a conservation-focused conceptual model, and recommendations for applying the newfound knowledge to Tonkin snub-nosed monkey conservation action in Ha Giang Province, Vietnam are presented using the Open Standards for the Practice of Conservation framework.

CHAPTER II

THE HUMAN-NONHUMAN PRIMATE INTERFACE

“Primatologists studying nonhuman primates in the wild are required to deal extensively with the people of the tropics and subtropics, where most natural primate populations occur, and to deal with the complex issues of human-nonhuman primate interaction and competition for land and resources.” (Pavelka, 2002, p.41)

The ever-increasing rate of human population growth around the world is leading to intensifying encroachment upon wildlife habitats. At the same time, a large proportion of the most rapidly expanding human populations continue to rely upon native faunal resources for survival. As human demand for land increases, more areas are being settled in direct proximity to the edges of wildlife habitats, causing the geographical ranges of many species to shrink and fragment. As a consequence of continuing wildlife habitat degradation and destruction, human and non-human species are increasingly coming into direct contact (Kinnaird, 1992; Hockings and Sousa, 2013). Thus, Jacobson and Duff (1998), Manfredo and colleagues (1995), Riley (2006), Robinson (2006), and Hockings (2007), among many others, believe it is high time to re-examine various aspects of the human dimensions of wildlife conservation.

2.1 Nature + Humans = Ethnoprimateology

For far too long, scientists have treated their own species as being separate from nature – perhaps not in an evolutionary sense but certainly in an ecological one.

“Biological ecologists usually ignore humans as if they were unnatural and readily excluded from the natural environment for analytical purposes. Apparently the presence of humans in an ecosystem somehow contaminates pristine nature,” (Sponsel, 1997, p.143). Indeed, Cachelin et al. (2010, p.1) examined the discourse employed in ecological text books used in the United States and found that, “The language used to teach ecology perpetuates the idea that humans exist outside of its laws.” While this perspective is not a global one (West and Brockington, 2006) it speaks volumes about the shortcomings of common western science approaches to understanding socioecology. Most western socioecological models have placed humans outside of nature, almost certainly underplaying the role of anthropogenic influences on the environment, ecological processes, and yes, even natural selection and evolution. Examples of studies that exclude humans as integral components of community-level ecological assessments include classic investigations such as Gautier-Hion et al. (1980), Terborgh (1983) and Peres (1993), as well as more recent studies including Poulsen et al. (2002) and Sushma and Singh (2006).

Another pair of authors, Nobrega Alves and Silva Souto (2015), recently provided a thorough review of the history of a broad field of study known as ethnozoology, which has been in existence since the late 1800's. From the beginning, this discipline has aimed to clarify how humans perceive and interact with wildlife. However, this approach to understanding human-animal interrelationships currently focuses primarily on topics such as human cultural perceptions and bio-cultural aspects of fauna as resources, wildlife classification, the importance of animals in belief systems, animal collection and product extraction, domestication, and the management of animals as natural

resources. None of these research themes take on the daunting and complex task of evaluating humans as integral components of wildlife ecosystems.

Following Sponsel, Fuentes, and Hockings (2010) turned their attentions to the interrelationships between human and nonhuman primates more specifically. They asserted that it is incorrect to assume wild nonhuman primate populations have never been influenced by or forced to respond to human activities in their recent evolutionary histories. Many researchers have joined these authors in an effort to rebuff the mindset that humans are external to nature, and to instead consider the antiquity of human-nonhuman primate sympatry, exploring not only how humans use wildlife as resources or incorporate them into cultural practices, but also investigating the interspecific relationships and adaptations that likely result from such a long-standing co-existence.

While much is known about how humans, as ecosystem “invaders,” affect primate habitats by logging (Johns, 1985; Ganzhorn, 1995; Chapman et al., 2000; Songtao Guo et al., 2008), clearing land for agriculture (Johns and Skorupa, 1987; Yiming Li, 2004), and mining (Setiawan et al., 2009), for example, much less is understood about long-standing relationships between human and nonhuman primates as native residents reliant upon the same ecosystem. It is this intentional inclusion and integration of humans as integral components of ecosystems that forms the theoretical underpinning of the field known as ethnoprimateology (Sponsel, 1997; Fuentes, 2006; Riley, 2006; Fuentes and Hockings, 2010). Authors adhering to this tenet provide evidence through their research that, indeed, humans and wildlife – including, and perhaps especially, nonhuman primates – have co-existed for millennia, in a multitude

of different ways. There should therefore be no question that these interspecific relationships have the potential for adaptive and evolutionary consequences.

2.2 Human Predation of Nonhuman Primates

Certainly, throughout time humans have used primates as food. Fossil and archaeological records indicate that, “Human predation on non-human primates has an enormous antiquity extending back to the australopithecines in Africa and the pithecanthropines in Asia,” (Sponsel, 1997, p. 152). The immigration of humans to Madagascar 2,000 years ago was almost unquestionably a significant catalyst leading in large part to the extinction of several species of Malagasy lemurs (Richard and Dewar, 1991) and it is likely that the global distribution of primates today is at least in part due to thousands of years of human predation pressure (Struhsaker, 1999). Today, nonhuman primates are not only hunted as food items, but also for use as pets (Wolfheim, 1983; Shephard, 2002), body parts incorporated into traditional medicine practices (Nekaris et al., 2010), decoration or craft-making (Eudey, 1999; Parathion and Maldonado, 2010), trophies (Hoang Minh Duc, personal communication), trade into the biomedical research industry (Eudey, 2008), and for sale in the black market (Struhsaker, 1999; Rose, 2002; Nekaris et al., 2010). Cheney and Wrangham (1987) suggest that humans probably account for more primate deaths than any other predator species. That said, it is interesting that a recent literature review regarding predation on primates, written by Miller and Treves (2007), lists over 40 species of known primate predators around the world and a glaring absence in that list is the species, *Homo sapiens*.

2.2.1 Nonhuman Primate Responses to Being Hunted

Given that predation is considered to be a primary selective factor in shaping the physical and behavioral adaptations of primates (Eisenberg et al., 1972; Clutton-Brock and Harvey, 1977; van Schaik, 1983; Terborgh and Janson, 1986; Cheney and Wrangham, 1987; Peres and Dolman, 2000; Miller, 2002), it seems reasonable to hypothesize that nonhuman primates possess adaptive behaviors that aid them in avoiding human predators. The ephemeral nature of predation events, however, has limited the study of its effect on nonhuman primate behavior. Human and nonhuman predators of primates differ in many ways that we do not yet understand and these may be important for selective processes. For example, through the use of projectile weapons and traps, *H. sapiens* can hunt from a distance or completely out of range of prey sensory abilities. They not only target the ill, young, or elderly but also those individuals in the prime of their existence. In addition, human intelligence and cultural transmission of knowledge likely exact unique selective pressures on nonhuman primate prey species. These differences caused authors Miller and Treves (2007, p. 534) to argue that,

It is possible that primates have developed specialized morphologies and behaviors to avoid human predators, but we know of no studies exploring this phenomenon; it is probable that no such specialized adaptations exist. While humans have long represented a part of primate ecological communities, in more recent millennia they may have become a selective pressure superseding the prey species' capacity to adapt; thus, today's primate morphology and behavior are likely only weakly related to humans as predators.

Since this statement was published in 2007, however, at least one pair of researchers, Parathian and Maldonado (2010), has undertaken just such an endeavor. These authors employed qualitative and quantitative methods to determine the effect of

hunting practices on nonhuman primate population densities in southernmost Colombia. Historical data and primate census information indicated that, indeed, differential hunting pressure was likely the primary cause for the disparity in primate biomass between the two study sites. Given that population density can affect many behavioral aspects of primate societies, perhaps it is too soon to proclaim that, “It is probable that no such specialized adaptations exist,” (Miller and Treves, above). More evidence is needed.

2.2.2 Humans as Predators of Nonhuman Primates

So while there is not yet much substantiation for the claim that human hunting pressure has resulted in adaptive behavior within nonhuman primates, there is a body of literature that exists regarding the effect of nonhuman primate hunting practices on human ecology, behavior, beliefs, and culture. For instance, Kumpel et al. (2008), in agreement with Mittermeier and Cheney (1987) and Cowlshaw and Dunbar (2000), have hypothesized that large-bodied, diurnal, slow moving primates with slow life-histories are more at risk from human hunting than smaller, nocturnal, faster primates with quicker life-histories. Over a period of 15 months, Kumpel et al. (2008) set out to evaluate whether hunters in Equatorial Guinea were choosing specific nonhuman primate prey species and if so, why. The team collected data via hunter interviews, gun-hunter follows, carcass-counting, and primate transect surveys. Results of the investigation indicated that more *Colobus satanus*, or black colobus, were hunted than expected based on population densities. Neither price per kilogram nor ease of capture explained the bias for *C. satanus* as prey. Not unlike Parathion and Maldonado’s

findings above, Kumpel et al.'s black colobus populations were thought to be affected by gun-hunting in that the population densities of these primates were higher the farther they were from the village studied. In the end, hunter prey species choice appeared to be linked mainly to nonhuman primate body size.

Cormier (2002) took a different approach to explore human and non-human predator-prey relationships. She set out to evaluate the importance of primate meat in the diets of the Guaja Indians of Brazil. During daily rounds of human groups, spot checks indicated that howler monkey meat was ingested more frequently in the wet season than the other top three meat items (peccary, paca, and fish). However, the other three protein sources were each more important to the Guaja dry season diet than were howlers. While there was clear evidence that seasonal ecology influenced the presence of monkey meat in the diet, Cormier argued that the hunting-fishing pattern exhibited by the Guaja could not be attributed to ecology alone. Her research into human hunting preferences revealed that howler monkeys were the preferred game due to their physical and behavioral similarities to the Guaja and were ingested as a form of symbolic cannibalism.

It is not unusual for human hunters to proclaim a preference for monkey meat. The Bari of Venezuela, unlike the Brazilian Guaja, prefer spider monkeys to howler monkeys – though to them, even howler meat is better than the meat of other forest animals. Lizzaralde (2002) explained that the primary objective of most Bari hunting trips was to get monkeys. Primates were valued not only as food, but also as pets and for the retrieval of their teeth, important for the creation of traditional Bari necklaces. Similarly, the Matsigenka of Peru preferred spider monkeys and wooly monkeys to other

forest animals (Shephard, 2002). In both cases, preference for monkey meat appeared to be not only an ecological adaptation but also closely intertwined with the groups' cultural beliefs and practices. While neither Lizarralde nor Shephard systematically measured the effect of hunting on nonhuman primate populations, it was suspected by both that such hunting practices were locally sustainable.

2.3 Comparative Ecology of Humans and Nonhuman Primates

Comparative ecology aims to investigate similarities and differences between the ecology of different species as integral components of the faunal community of a particular ecosystem, regardless of whether or not these species directly interact with one another as predator/prey, as ecological competitors, or otherwise (Sponsel, 1997). Although considering such an intertwined ecology between human and nonhuman primates is an interesting and promising avenue of research, a thorough literature review revealed only a small handful of projects investigating overlapping forest resource use ecologies of human and other primate species as integral and sympatric components of forest communities.

2.3.1 Crop Raiding

Riley (2007) employed a mixed quantitative and qualitative toolkit to investigate zones of overlapping crop and forest resource use between sympatric humans and Tonkean macaques (*Macaca tonkeana*) in Indonesia. Palm and ficus plants were among the most important and most highly shared forest resources between the two species. While forest food abundance scores did not predict crop raiding frequency,

Riley concluded that cultural taboos against felling strangler figs had helped to sustain these forest trees that were important to both the local people and the monkeys.

Similar to Riley, Hockings and colleagues have focused their attentions on ape crop-raiding behavior and other conflicts over resources (Hockings et al., 2009; Hockings and Humle, 2009; Hockings and Sousa, 2013). Using interviews and observations, Hockings gained a preliminary understanding of crop and forest resource overlap between chimpanzees (*Pan troglodytes*) and humans living in Guinea-Bissau in Northwest Africa. The majority of respondents reported chimpanzees raided crops of 10 different varieties, especially maize and sugarcane. Cashew nuts were an important cash crop in the region but the level of human-chimp conflict over cashew appeared low, perhaps due to differential use of the plant by humans and chimpanzees. An anecdotal report of forest resource overlap indicated that chimpanzees and humans both utilize forest palms, as well as two other forest fruits, but the extent to which either species rely upon these forest resources has yet to be systematically evaluated.

2.3.2 Human-Nonhuman Primate Forest Resource Overlap

Although an assessment of forest resource use was included in the work conducted by Riley and Hockings, these researchers and other authors (e.g. Salafsky, 1993; Siex and Struhsaker, 1999; Campbell-Smith et al., 2010; Strum, 2010) have focused their comparative ecology research largely on the ecology of crop-raiding in particular. Evaluations of human-nonhuman primate resource overlap in other contexts are less common. However, the conservation significance of this type of study should not be underestimated. In addition, the importance of this type of study to successful

conservation interventions is likely reliant upon the significance of forest resources to nonhuman primate populations (Riley and Fuentes, 2011). To date, a thorough literature review revealed only three examples of empirical research focused solely on comparing human and nonhuman primate resource overlap within a natural habitat, such as a forest.

Wright and colleagues examined resource use overlap between humans and lemurs in Madagascar (Wright et al., 2005). The lemurs included in the study consumed parts of 24% of the 235 wild forest plant taxa used by local people. However, when people harvested those overlapping plant resources, the entire plant was felled or otherwise destroyed 60% of the time. This rate of anthropogenic resource destruction was likely not likely to be sustainable, especially since human use of these resources was suspected to be on the rise.

In 2002, Pruetz reported on preliminary data regarding the human and nonhuman primate usage patterns of a wild liana fruit, *Saba senegalensis*, in Senegal. Both humans and chimpanzees (*Pan troglodytes*) relied heavily on this fruit during the year-long study conducted in 2001. *S. senegalensis* seeds were found in 69% of examined chimpanzee feces, and the authors consider *S. senegalensis* to be a key food species for *P. troglodytes* at the site. Reliance of local human populations on the same fruit species was determined via counting the number of fruit collected for sale in local markets. During peak *S. senegalensis* phenological abundance, humans extracted approximately 75,000 fruits per month, most likely reflecting a non-sustainable usage pattern that will ultimately impact both humans and chimpanzees, alike.

Ten years prior to this study, another author (Kinnaird, 1992) presented evidence that humans and sympatric Tana River mangabeys (*Cercocebus galeritus*) in Kenya both relied heavily on the *Phoenix reclinata* palm, especially when it was seasonally in fruit. This 1.5 year, 1987-89 study gathered data via interviews, direct observation and forest transect surveys focused on the harvesting level of known *P. reclinata* plants. The palm was used for a wide variety of purposes by humans and several parts of the plant (mostly seeds but also thorns, flowers, pith, fruit, and seedlings) together made up 42-62% of the *C. galeritus* diet. This palm plant was incredibly important to both humans and the Tana River mangabeys, and it appeared that the continuation of human exploitation levels of *P. reclinata* would likely result in the local extirpation of this once abundant wild palm.

Unlike the projects described above, the current research will focus not only on dietary overlap, but will also include resources used for other purposes, by both humans and nonhuman primates. And in addition to evaluating overlapping plant taxa, this study will also include a quantitative and qualitative analysis of spatial and temporal elements of forest use overlap, thereby taking a more holistic approach to understanding how humans and nonhuman primates share forests as equally important members of forest communities. While the aforementioned studies certainly help to clarify the human-nonhuman primate interface within forest ecosystems, with so few published papers on the topic of human and nonhuman primate forest resource overlap (Riley and Fuentes, 2011), there is much to be gained from investigations such as the one proposed here.

CHAPTER III

PRIMATE ADAPTATION, PREDATOR-PREY RELATIONSHIPS, AND RESOURCE PARTITIONING

“An adaptation is a characteristic that allows an organism to live and reproduce in an environment where it probably could not otherwise exist.” (Vermeij, 1978, p.3)

Animals dwelling within the same community often demonstrate adaptations to their coexistence with other species. Whether sympatric species are predators, prey, or competitors, given enough time in coexistence with one another (which need not be millennia), change in morphology, physiology, and/or behavior is likely. Indeed, the existence of adaptive traits in any animal including human and nonhuman primates reflects an interaction with the evolutionary history of other organisms in the same ecosystem (Fleagle, 2013).

3.1 The Concept of Adaptation

In contemporary biology, adaptation refers to both a state and a process; organisms are believed to be adapted to the conditions in which they live (Vermeij, 1978), but adaptation can also refer to the process by which organisms obtain particular traits (Fleagle, 2013). Morphology, physiology, behavior, and life history intertwine with a species' biogeographical and phylogenetic history allowing a species or population to

adapt to its specific environmental context (Vermeij, 1978; Waser, 1984). Ultimately, adaptation is a genetic process, in that characteristics – whether morphological, behavioral, or otherwise – are possible only within genetic constraints (Lee, 1991). And because natural selection is the primary mechanism of adaptation, it is the heritable anatomical or behavioral features that either enhance or diminish reproductive fitness (Futuyma and Moreno, 1988; Fleagle, 2013). It is important to note, however, that any characteristic that allows for reproductive success is adaptive, regardless of whether it is optimal (Gould and Lewontin, 1979). As a noun, then, an adaptation refers to a phylogenetically constrained feature that improves reproductive fitness relative to alternative features (Kawecki and Ebert, 2004), whereas adaptation – the verb – is, “...usually defined as the ability to survive, function, and reproduce” (Mazess, 1975).

Also significant is the fact that closely related species may demonstrate similar characteristics more as a result of phylogeny than adaptation. Fleagle (2013, p. 198) argues this is, “a potentially very serious complication for identifying adaptations, and it is essential that comparative studies make some effort to take phylogeny into account.” But adaptation and phylogeny are not mutually exclusive. Since both phenomena contribute to evolutionary processes, both must be considered in comparative studies (Harvey and Purvis, 1991). All organisms, including human and nonhuman primates, display a mixture of adaptive features which have been selected for at various times, for a variety of different purposes during their evolutionary history. Some traits may also become fixed within a population (Kawecki and Ebert, 2004), even if the trait is no longer contributing to reproductive success. Therefore, in addition to genetics, an

existing suite of phenotypic traits displayed by an organism may also constrain the form or value other traits can take (Clutton-Brock and Harvey, 1991).

Investigators use the term adaptation to refer to many points on a continuum, from the broad sense of survival and reproduction to a much more narrow view of minor adjustments made quickly in response to specific, local contexts (Mazess, 1975). Although traditionally believed to occur over immense, almost unimaginable time scales inducing small changes incrementally, adaptive change is today known to also occur both rapidly and in major evolutionary leaps (Grant and Grant, 2002). Such rapid changes are often alternatively referred to as acclimatization, accommodation, or habituation (Mazess, 1975); however, these latter terms more accurately refer to changes that are reversible. Flexibility and plasticity are labels also used to explain this type of quick and reversible adaptation – often behavioral or physiological modifications – in the presence of new selective pressures (Chapman, 1987; Phillips, 1995; Wen Xiao et al., 2003). It is hypothesized that among large-brained primates especially, selection for plasticity itself may be advantageous, but even this type of adaptation would be constrained both by the genetic limits for of the expression of plasticity and by the speed with which the local environment changes (van Schaik, 2013). Ultimately, an organism's behavior defines many of the selective pressures to which it is exposed, but it can also initiate a niche shift leading to directional selection on other traits (Futuyma and Moreno, 1988).

Clearly, use of one of the adaptation concepts can be a source of confusion if authors do not explicitly define what they mean. Here, the term *adaptive behavior* (behavior that fosters effective or successful individual interaction with the environment)

will be employed to refer to behavioral adjustments occurring within the context of coexisting human and nonhuman primate populations. These adaptive behaviors have evolutionary significance in the sense that they may lead to reproductive fitness. Because direct assessment of the effect of this type of behavioral adjustment on reproductive fitness is rarely possible (Clutton-Brock and Harvey, 1979), adaptive behavior (such as avoidance of potential human predators in space and time) will be measured in this research by providing evidence (or lack thereof) that a given behavior is a likely solution to a local environmental problem.

3.2 Culture as Adaptation

Few would disagree that human culture plays a significant role in shaping behaviors that allow people to adapt to their local environmental contexts. This type of cultural adaptation has been well-studied with regards to humans solving problems associated with living in cold or hot climates, with disease prevention, and with the avoidance of nutrition shortages (Kormondy and Brown, 1998). For humans, decisions surrounding the basic need of food procurement are often deeply intertwined with culture and are therefore reliant upon factors beyond what might be optimal foraging from a caloric perspective. The same holds true for other resource use decisions – which may in part be made based on optimal solutions to environmental problems, but may also be influenced heavily by belief systems, traditions, myths, taboos, and other cultural values. In addition, the development of agriculture and a sedentary lifestyle, as well as the use of tools, augment human resource acquisition to a great extent. These types of cultural adaptations allow the human primate to access resources that might

otherwise be unattainable and thus have significant ramifications for humans as potential competitors or predators within natural ecosystems.

3.3 Primates as Predators and Prey

The predator-prey interface has exerted important influences on the adaptation and evolution of many aspects of primate ecology and behavior (Miller, 2002; Fleagle, 2013). Behavioral adaptations in primates such as group size, activity budgets, social organization, choice of sleeping sites, differential habitat use, and ranging patterns are thought to be shaped – at least in part – by inter-relationships between predators and prey (Janson, 1992; van Schaik, 1983; Isbell, 1994; Miller and Treves, 2011). Because predation is considered to be an important selective pressure for both the hunters and the hunted, it seems logical to expect that both human and nonhuman primates would possess behavioral adaptations that aid them in being successful hunters and/or avoiding death at the hands (or teeth – or for that matter, tools) of a predator.

Forest-dwelling nonhuman primates succumb to predators from a number of different taxonomic groups. Fleagle (2013) notes that large felids, birds, and snakes are frequent primate predators. There are a handful of publications prior to Sponsel's seminal 1997 paper that focused on the idea of humans as nonhuman primate predators began receiving significant attention as an important evolutionary selective pressure (Mittermeier, 1987). Extant human groups have been demonstrated to be important hunters of nonhuman primates in Africa and South America (Mittermeier and Cheney, 1987; Jorgenson and Redford, 1993). Recall the second section of chapter two within this dissertation discussing humans as predators of nonhuman primates

where, more recently, researchers such as Parathion and Maldonado (2010), Kumpel et al. (2008) and Cormier (2002) were highlighted as those who have examined this predator-prey interface in Africa and South America. Compared to the Neotropics, however, hominins (the primate group that includes modern humans) and other primates have coexisted far longer in Africa and Asia – a coexistence dating back to the time of *Australopithecus* in Africa (1.8-6.0 mya) and *Homo erectus* in Africa and Asia (0.2-1.7 mya) [Isbell, 1994; Sponsel, 1997; Fleagle, 2013].

Authors agree that today the primary threat to Asia's primates in particular, is human hunting (Oates and Davies, 1994; Nadler et al., 2007; Workman, 2010; Blair et al., 2011). Whether small or large, nocturnal or diurnal, all nonhuman primates are fall victim to hunting in Asia. Smaller nocturnal primates like lorises and tarsiers are collected as pets, talismans, or snack foods, or are used in traditional medicine (Nadler et al., 2007; Mittermeier et al., 2009). Diurnal medium-sized monkeys like macaques and leaf-eating monkeys are hunted as pets, for food, for use in the biomedical industry, or for body parts (bones, bile, organs, and tissues) used in traditional medicine such as monkey balm; each of which may be used locally or traded. Oates and Davies (1994) explain that monkeys have long been hunted as part of human diets in Southeast Asia. Depending upon their reliance on human crops, monkeys and some ape species, as well, may also be hunted as persecution for being crop-raiding pests. Gibbons are also at risk of hunting pressure, being commonly hunted for food, medicine, and for sale in the pet trade. With the exception of hunting for international trade, the biomedical industry, and perhaps as crop-raiding retribution, most of these forms of hunting are

traditional in nature and have likely been in practice for hundreds or thousands of years – plenty of time for behavioral adaptations to take shape.

3.4 Resource Partitioning

Like predator-prey relationships, the acquisition of resources including food, water, shelter, and mates, is recognized as an important agent in the process of natural selection. Both human and nonhuman primates demonstrate a variety of behavioral adaptations for obtaining resources (Fleagle, 2013). One of the primary selective factors driving resource acquisition adaptation is resource competition. According to Fleagle (2013, p. 38), “Birds, bats, various carnivores, and numerous rodents eat many of the same fruits as the primates and are often found in the same trees at the same time. There has certainly been competition among these different animals for access to the various food items in the forest.” If this is true, the same must also be said for humans as competitors with nonhuman primates, and as integral components of primate communities.

3.4.1 Niche Partitioning Theory

Niche theory predicts that the coexistence of species within a community should be associated with a mechanism of resource partitioning (Arletazz et al., 1997). Species within a community tend to demonstrate measures of niche separation (Hardin, 1960; Colwell and Futuyma, 1971; Sponsel, 1997). This is arguably one of the most important components of the competitive exclusion principle, which argues that, “complete competitors cannot coexist,” (Hardin, 1960). Sympatric primates appear to

be no exception. For example, some herbivorous primates that share landscapes show differences in the plant species eaten, plant part ingested, food item size, hardness, and color, or the importance of each species to overall dietary intake (Terborgh, 1983; Chapman, 1988). Others show differences in fallback foods relied upon in times of food scarcity (Buzzard, 2006). Species that share a habitat may also differ in the timing of resource utilization; for example, by ingesting unripe fruit (Kinzey, 1997) or young leaves – which may be related to the ingestion of parts with differing chemical composition (Glander, 1981; Kay and Davies, 1994) – or through seasonal shifts in diet, or ranging patterns (Peres, 1993). In Peru, diets of sympatric primates (Terborgh, 1983) were shown to differ in terms of the size, hardness, and color of fruit ingested. Spatial niche separation among primates is also observed via forest strata and habitat differentiation (Peres, 1993). Many of these forms of food resource partitioning have also been demonstrated amongst sympatric mammals in general (Gautier-Hion et al., 1980; Ganzhorn, 1988; Koehler and Hornocker, 1991; Arletazz, 1999; Sushma and Singh, 2006) and between more phylogenetically distant taxa, such as birds and arboreal primates (Poulsen et al., 2002).

3.4.2 Resource Partitioning and the Human Primate

Although humans are the most terrestrial of all primates (Fleagle, 2013) this does not mean members of the genus *Homo* do not or did not rely upon tree-borne foods for sustenance. There is little dispute that early hominins were bipedal. However, what is less clear is the extent to which they were also engaging in arboreal activities (DeSilva, 2009). It has long been argued that hominins maintain a number of trunk and forelimb

features that allow for climbing. Although Sayers and Lovejoy (2008) claim that derived bipedal adaptations preclude successful frequent climbing in hominins, most researchers disagree with this assessment (Fleagle, 2013). Despite the absence of specialized anatomical adaptations for tree-climbing that were present in human ancestors including australopithecines, many contend that hominin bipedal adaptations have, in fact, *not* significantly constrained regular access to trees (DeSilva, 2009). On the contrary, Tocheri et al. (2008) and Fleagle (2013) agree that *Australopithecus* hand bone features, such as phalangeal curvature, indicate intermediate levels of arboreality.

Even today, some humans regularly climb trees in search of resources, without the assistance of climbing tools. Venkataraman and colleagues (2013) recently observed extant African hunter-gatherers and determined that ankle joint flexibility was key to their climbing success. They then analyzed ankles of modern humans who were known to routinely climb trees, but found no skeletal correlate for regular climbing behavior. This research challenges the dichotomous arboreal versus terrestrial way of thinking about human locomotion and suggests that, “Derived aspects of the hominin ankle associated with bipedalism remain compatible with vertical climbing and arboreal resource acquisition,” (p. 1237). Thus, it would not be surprising if some level of arboreal resource partitioning was present between human and nonhuman primate taxa that have coexisted and relied on similar plant resources for centuries, if not thousands of years, or more.

While some might argue that the common exclusion of humans from primate community-level studies is a result of phylogenetic differences between humans and nonhuman primates, it is important to keep in mind that humans and monkeys are more

closely related than strepsirrhines and haplorrhines (wet-nosed and dry-nosed primates, respectively). But investigators do not typically exclude strepsirrhines (such as lorises) from primate community-level research, calling into question the phylogenetic rationale for excluding humans.

In addition, there is evidence that among some sympatric primate species, those with similar diets demonstrate the greatest differences in locomotor style (Fleagle and Mittermeier, 1980; Walker, 1996), allowing for differential access to shared forest resources. Such locomotor differentiation certainly exists for humans (whose predominant locomotor pattern is terrestrial bipedalism) and Asian leaf monkeys (whose predominant locomotor pattern is arboreal quadrupedalism).

3.4.3 Evaluating Resource Overlap

Regardless of phylogenetic proximity between species, several methods have been employed by the authors mentioned above and others to demonstrate the degree of niche overlap of sympatric animals and test the competitive exclusion principle. Niche overlap was defined by Colwell and Futuyma (1971, p. 567) as, “The joint use of a resource, or resources, by two or more species.” While commonly used (Chapman, 1987; Buzzard, 2006), it is argued that evaluating dietary overlap via summing the number of shared resources is not sufficient and can lead to inflated estimates of overlap (Poulsen et al., 2002). Therefore, methods that incorporate the proportional use of resources are expected to be more robust.

In an investigation of the degree to which two closely related tamarin monkeys experienced dietary overlap, Peres (1996) utilized a simple proportional-based niche

overlap index developed by Schoener (1968): $O_{ab} = 1 - 0.5 \sum (P_{ah} - P_{bh})$, where O_{ab} is the overlap of animal species a and b and P is the proportion of feeding records for each animal species, allocated to resource category h . Peres' results indicated that the average proportion of plant resource overlap between the two tamarin species was high (84%), which was not unexpected as the species commonly formed interspecific associations.

Two different proportional measures were employed by Sushma and Singh (2006) in studying the resource partitioning of less closely related arboreal mammals of India. These authors aimed to determine not only the degree of overlap between the mammals in question but also to compare the degree of dietary specialization of each species. They applied two measures; Levins' standardized measure of niche breadth and Morisita's measure of niche overlap. The standardized niche breadth index, also recommended by Colwell and Futuyma (1971), is designed to emphasize the most frequently used resources and is calculated as follows, $B_A = (B-1)/n-1$, where B_A is the standardized niche breadth of species A , B is Levins' measure of niche breadth, and n is the number of resources. Levins' measure of breadth is: $\sum p_i^2$, where p_i is the proportion of resource category i in the diet of the animal species. Like Schoener's niche overlap index above, niche breadth scores range in value from 0 to 1, where a score of 1 represents a very broad niche breadth. Morisita's measure of niche overlap, which minimizes bias regardless of sample size but requires knowledge of sample population size, is $C = 2 \sum_i^n p_{ij} p_{ik} / [\sum_i^n p_{ij} [(n_{ij} - 1)/(N_j - 1)] + \sum_i^n p_{ik} [(n_{ik} - 1)/(N_k - 1)]$ where C is the overlap index between species j and k , p_{ij} and p_{ik} are the proportion of resource i in the total resources used by species j and k , respectively, n_{ij} and n_{ik} are the

number of individuals of species j and k , respectively, that use resource category i , and N_j and N_k are the total number of individuals of each species in the sample. In applying these two equations to their data set, Sushma and Singh (2006) demonstrated higher overlap between more closely related species.

While aspects of the comparative ecology projects focused on primate crop-raiding behavior may not benefit tremendously from the application of such quantitative resource overlap measures, those focused on the overlap of forest resources likely would. This is a promising avenue for future studies regarding human- nonhuman primate sympatry and results can be applied to conservation interventions aimed at preserving important resources, both for humans and their nonhuman primate counterparts. Similar quantitative resource overlap measures will be applied here to evaluate niche differentiation between humans and Tonkin snub-nosed monkeys.

CHAPTER IV

CONSERVATION AND NATURAL HISTORY OF PRIMATES IN SOUTHEAST ASIA

“Nowhere are the mutual benefits of the cross-species and cross-cultural approaches of anthropology more complementary and more applied than in the area of ethnoprimateology and primate conservation.” (Pavelka, 2002, p.41)

Today, nonhuman primate communities of Southeast Asia include prosimians, such as tarsiers and lorises; monkeys, like macaques and leaf-monkeys; and apes, including gibbons, siamangs, and orangutans. Each of these primate groups possess distinctive physical and behavioral adaptations that allow them to thrive in their native forest communities. Generally speaking, however, Southeast Asian prosimians tend to be small nocturnal insectivores, gummivores, or frugivores while their monkey and ape counterparts exhibit a diurnal activity pattern, are larger in body size and typically ingest more fruits and leaves than insects or gums (Fleagle, 2013). A striking number of these Asian nonhuman primates are endangered.

4.1 Conservation of Southeast Asian Primates

For many reasons, the future role of nonhuman primates in Southeast Asia's ecosystems is in question. High rates of endemism combined with intensive hunting of primates and fast-paced habitat loss have led to precipitous population declines in recent decades. In 2016, the biennial report entitled, “Primates in Peril,” (Schwitzer et

al.) indicated that ten (40%) of the world's top twenty five most endangered primate species were found on the Asian continent. Two countries that stood out as global hot spots were Madagascar, with five species on the list of the 25 most endangered primates, and Vietnam with three species on the list. Only four primates have remained on the top 25 list since its inception in the year 2000 (all eight iterations) and three of those four are Vietnamese primates (Cat Ba langur, Delacour's langur, and TSNM); a frightening statistic, indeed.

4.1.1 Anthropogenic Threats

In addition to hunting (described in detail in chapters two and three), many Southeast Asian primates are at risk as a result of other anthropogenic activities which only compound the effects of human predation. Such exacerbating threats include fuelwood collection, logging, dam construction, human population density, forest loss and fragmentation, and agricultural expansion (Nadler et al., 2007; Mittermeier et al., 2009; Harrison-Levine et al., *in review*). These variables are not only deeply intertwined with one another, they can also lead right back to threat number one: hunting pressure. Because as humans encroach upon the forest habitats of nonhuman primates during activities such as dam construction and agricultural expansion, the mere proximity of people to nonhuman primates increases the likelihood that hunting will take place.

4.1.2 Conservation Status of Vietnamese Primates

In turning to the current population status of primate species of Vietnam in particular, current taxonomy suggests that there are at least twenty five primate taxa

residing in Vietnam (Roos et al., 2013). Two are lorises, seventeen are monkeys (including 12 colobines) and six are gibbons, or lesser apes. All of these primates are protected by the Vietnamese wildlife protection law (Nadler et al., 2007), and at least three of Vietnam's primate species are endemic: Delacour's langur (*Trachypithecus delacouri*), the grey-shanked douc langur (*Pygathrix cinerea*) and the Tonkin snub-nosed monkey. Each of these endemic species is listed as Critically Endangered (CR) on IUCN's Red List (2015). In total, seven Vietnamese primate species, endemic or not, are listed as Critically Endangered and ten are Endangered (EN). An additional four species are listed as Vulnerable (VU). In other words, 21 of the 25 primate taxa living in Vietnam – an astounding 84% – are Vulnerable, Endangered or Critically Endangered; they are at high, very high or extremely high risk of becoming extinct within our lifetime. These are alarming figures especially given the small size of the country, at only 329,566 km², or about the size of the state of New Mexico.

Lorises. Two species of the lorisiform primate group inhabit Vietnam, the pygmy loris (*Nycticebus pygmaeus*) and the Bengal slow loris (*N. bengalensis*). Both loris species are listed as Vulnerable (VU) by the IUCN (2015) and both are hunted in Vietnam as pets or as food, but both species are even more often exploited for the medicinal trade (Nadler et al., 2007; Nekaris et al., 2010). Rather than live lorises, it is their body parts that are most commonly found in the illegal wildlife trade. These two Vietnamese lorises have both been observed in the TSNM Species and Habitat Conservation Area in Ha Giang Province.

Gibbons. The country of Vietnam is also home to several species of lesser ape. While the exact number has and will likely continue to be debated, Thinh et al. (2010), Rawson et al. (2011), and Roos et al. (2013) list six Vietnamese species (all within the genus *Nomascus*) based on morphological, genetic, and vocal acoustic data. All Vietnamese species are listed as Endangered or Critically Endangered, with the exception of *N. annamensis*, which has yet to be evaluated (Roos et al., 2013). Gibbons appear to currently be just as threatened by destructive use of their forest habitats as they are by human predation (Bartlett, 2007; Schwitzer et al., 2016). Vietnamese gibbons are hunted for food, medicine, or trade as pets (Rawson et al., 2011). Additional factors such as commercial logging, fuelwood, timber and non-timber forest resource extraction, agricultural expansion, and free-grazing of livestock are cited as having severe impacts on the persistence of gibbon populations, especially when combined with significant hunting pressure (Nadler et al., 2007; Rawson et al., 2011).

Macaques. Members of Cercopithecinae, along with baboons and many other African species, macaques are found mainly in Asia. Macaques tend to be semi-terrestrial primates that live in a wide array of habitats, thus allowing for their expansive distribution – second in the primate world only to the genus, *Homo* (humans). Five species of macaque can be found living within the country of Vietnam. All macaque species are hunted by humans for use as food, in traditional medicine, as pets, or as restitution for crop-raiding behaviors. Both rhesus (*Macaca mulatta*, listed as a species of Least Concern [LC]) and long-tailed macaques (*M. fascicularis*, LC) are hunted not only for the above end purposes, but are also captured for use in breeding programs

and biomedical laboratory research (Eudey, 2008). Of these monkeys, only the stump-tailed macaque (*M. arctoides*, VU) and the Assamese macaque (*M. assamensis*, listed as Near Threatened) are known to range in limestone karst forests such as the Tonkin Snub-Nosed Monkey Species and Habitat Conservation Area, also known as the Khau Ca forest of Ha Giang province, Vietnam.

Leaf Monkeys. Asian colobines, like their African leaf monkey counterparts, differ from cercopithecines in a range of anatomical and behavioral attributes. They lack cheek pouches, tend to be more arboreal, exhibit distinctive gut specializations, and arguably have less omnivorous and more folivorous dietary patterns. Although the latter adaptation gives the group the name, “leaf monkeys,” it has long been recognized that the diets of colobine monkeys are highly variable. The colobines that inhabit Vietnam are allocated to three genera, *Trachypithecus*, *Pygathrix*, and *Rhinopithecus*.

The Francois’ langur (*Trachypithecus francoisi*, EN) was historically widespread across northern Vietnam but hunting has led to fragmented populations with a total current estimated population size of 300 individuals. These 300 monkeys are spread over 10 locales, including recent records of the species living in Ha Giang province (Nadler et al., 2007). Not surprisingly, hunting is a primary threat to the future of the species but limestone quarrying also presents tremendous risk, as the species is known to inhabit limestone karst habitat.

Delacour’s langur (*T. delacouri*, CR), a species that is endemic to Vietnam, is estimated to have a current population of no more than 250 individuals. Also a limestone karst species, hunting, limestone quarrying, and tourism threats have helped

to place this colobine on the top 25 world's most endangered primate list (Mittermeier et al., 2009).

The Hatinh langur (*T. hatinensis*, EN) is yet another endangered Vietnamese limestone monkey. A recent survey of the primary *T. hatinensis* population stronghold at a National Park in central Vietnam suggested the size and density of the Hatin langur population at this location are much higher than previously thought. Whereas estimates from the mid-1990's indicated only 520-750 individuals were present, Haus et al. (2009) calculated a population size of around 2,000 monkeys in the park.

One of the most critically endangered primates on the planet is the Cat Ba langur (*T. poliocephalus*, CR). The Cat Ba langur is a limestone colobine that is currently restricted to about 100 square kilometers of habitat on Cat Ba Island in Ha Long Bay. In 2002, research suggested that only 50-60 individual langurs remained in several isolated populations and only a few of the fragmented populations consisted of adult members of both sexes (Nadler et al., 2002). In 2014, Lees et al. reported a slight growth in the population – a total of 63 individuals, with a promising adult to sub-adult ratio of 1:1.75. Perhaps the most endangered primate taxa in the world today, the Cat Ba langur joins *T. delacouri* on the top 25 list of endangered primates.

Little is known about Vietnam's grey and silvered langurs (*T. crepusculus*, *T. germaini*, and *T. margarita*). Each is listed as EN (Roos et al., 2013) and while not restricted to such habitats, both *T. crepusculus* and *T. germaini* have been observed dwelling in limestone karst habitats in addition to other types of tropical forests (Nadler et al., 2007). In addition, whereas *T. germaini* is typically found west of the Mekong

river in southern Vietnam, *T. margarita* occurs east of the river (Blair et al., 2011), but this east/west division is not yet entirely confirmed (Roos et al., 2013).

All three *Pygathrix* species are found in Vietnam: the red-shanked douc (*P. nemaeus*, EN), grey-shanked douc (*P. cinerea*, CR) and black-shanked douc (*P. nigripes*, EN). They are distributed along a north-south gradient, with zones of hybridization (Groves, 2007; Nadler et al., 2007). These species are widely hunted for food, medicine, and the pet trade. Historically, habitat destruction has been an important cause of *Pygathrix* population decline – especially as it relates to the post-war human population explosion in Vietnam – and resulting massive human settlement relocations, extensive logging, and widespread habitat conversion for rubber, coffee, and cashew plantations (Nadler et al., 2007). Red and grey-shanked doucs have been successfully bred in captivity, making prospects of reintroduction brighter. In addition, grey and black-shanked species are both known for their ability to persist in highly disturbed or degraded habitats. Of the three, it is the grey-shanked douc that faces the greatest risk of extinction.

4.1.3 Conservation Status of the Genus Rhinopithecus

In addition to the Vietnamese *R. avunculus*, there are four other snub-nosed monkeys in the *Rhinopithecus* genus, three of which are found exclusively in China and one is found in China and Myanmar. Whereas the three Chinese-endemic species are classified as Endangered by the IUCN (2015), the other two snub-nosed monkeys are Critically Endangered. Hunting and various levels of habitat use and destruction have been the primary drivers of extremely low snub-nosed monkey population sizes in both

China and Vietnam (Kirkpatrick and Grueter, 2010). While gun-confiscation programs have had positive effects on the reduction of *Rhinopithecus* hunting events in these countries in recent years, snub-nosed monkeys are still at risk from both pressures. According to Yiming Li (2002), illegal timber extraction is one of the biggest threats to golden snub-nosed monkey (*R. roxellana*) populations, and Bleisch and Jia Hua Xie (1998) note the potential for human – nonhuman primate resource overlap given that gray snub-nosed monkeys (*R. brelichi*) seem to, “...compete for Magnolia buds with humans, who collect buds for preparation of a marketable medicinal oil,” (p. 222). This type of human – nonhuman primate competition for resources is just one of many threats to the future of the *Rhinopithecus* genus.

4.1.4 Conservation Status of Rhinopithecus avunculus

Endemic to Vietnam, the Tonkin snub-nosed monkey, *Rhinopithecus avunculus* (Dollman, 1912), joins the world’s top 25 most endangered primate species list (Schwitzer et al., 2016). In fact, it is one of only four species that have remained in the top 25 since the list’s inception in the year 2000 – all eight iterations. In 2012, *R. avunculus* was also named one of the world’s most threatened species (Baillie and Butcher). Though the historical distribution of TSNM is thought to be unusually limited to a narrow spread east of the Red River in northern Vietnam, massive deforestation and intensive hunting in recent decades has led to steep population declines (Covert et al., 2008). Even in the last ten years, populations that once appeared robust have all but disappeared. This once thought extinct species (Mittermeier and Cheney, 1987) was believed to be maintaining a population of approximately 300 individuals living in

three isolated habitats as recently as 2005 (Mittermeier et al., 2006). Ten years later, the most recent TSNM population estimate has been reduced (Le Khac Quyet et al., 2016).

Currently *R. avunculus* are scattered among five subpopulations in two provinces, Tuyen Quang and Ha Giang, and the total population is estimated at less than 250 individuals (Le Khac Quyet et al., 2016). The outlook is not good in Tuyen Quang where recent field surveys suggest that 18-26 individuals remain at Na Hang (Thach Mai Hoang, 2011), a Nature Reserve that was home to well over 100 individuals as recently as 1998 (Boonratana and Le Xuan Canh, 1998b). Also in Tuyen Quang, Cham Chu Nature Reserve housed about 70 individuals in 2001 but this population is today estimated at between 8-12 individuals (Le Khac Quyet et al., 2016). The Tuyen Quang population declines are thought to be closely related to the construction of the Na Hang hydroelectric dam within the last 15 years (Harrison-Levine et al., *in review*). Fortunately, two new populations have also been discovered in the past fifteen years, both within Vietnam's northernmost province, Ha Giang. An estimated 20 TSNM were discovered in a forest along the Chinese border (Le Khac Quyet and Covert, 2010), and the population inhabiting the TSNM Species and Habitat Conservation Area appears to be the single remaining viable population of TSNM (Covert et al., 2011; Le Khac Quyet et al., 2016). This latter population was discovered in 2002 and has grown from 60 to more than 125 individuals in just over ten years (Le Khac Quyet et al., 2006).

4.2 Natural History of Colobines and Snub-Nosed Monkeys

Successful conservation of Vietnam's primates depends in large part upon a thorough understanding of primate natural history. What follows is an overview of the natural history of Asian colobines, the *Rhinopithecus* genus and *R. avunculus*.

4.2.1 Asian Colobine Natural History

Asian colobines, along with their African relatives, demonstrate remarkable physical and physiological adaptations that may be designed for leaf-centered diets. These adaptations are reminiscent of ruminant mammals such as artiodactyls, sloths and kangaroos (Chivers, 1994) and include, a) specialized dentition that for colobines consists of narrow incisors, large canines, and molars with tall cusps and long shear crests, b) enlarged salivary glands which appear to help nullify the ill-effects of plant defensive compounds, and c) multi-chambered stomachs that are the site of foregut fermentation and that act as host for specialized microbes which assist in both the detoxification of plant secondary compounds and in the digestion of leaves by producing readily accessible volatile fatty acids (Fleagle, 2013).

However, it has been recognized for more than two decades that many colobines complement the leaves in their diets with fruit, seeds, and flowers (Kay and Davies, 1994; Lucas and Teaford, 1994; Kirkpatrick, 2011). Lucas and Teaford (1994), for example, argue that colobines likely are not solely folivorous, and perhaps were not even evolutionarily adapted for folivory, but rather exhibit anatomical and physiological adaptations for a broader dietary niche that includes leaves and seeds. Their analysis of dental wear patterns indicated that colobine teeth – the molars especially – are used for processing a diet of both leaves (shearing) and seeds (wedging). This is not to

suggest that many Asian colobines do not rely heavily on the ingestion of young and mature leaves, as this statement would be wholly false. In fact, a recent review of Asian colobine diets (Kirkpatrick, 2011) indicates that for species that have undergone dietary analysis in the wild, all but one (*Rhinopithecus bieti*) rely on young and/or mature leaves for 29-78% of dietary intake. However, the same dietary review shows a broad diversity of Asian colobine diets that can include between 11-58% fruits and seeds, as well as flowers, buds, bark, insects, lichens, and fungus. While colobine digestive systems allow processing of nutrients most primates cannot easily access, such as those from leaves, referring to this group of monkeys as leaf monkeys does not adequately represent the dietary flexibility of this family of primates.

Colobines have not only been shown to be more plastic with respect to dietary breadth than originally thought, but also appear to be flexible with regard to their social organization. Almost unanimously, scientists agree that the fundamental structure of Asian colobine social groups is the one-male unit, or OMU, typically comprised of a single male with several females and their offspring (Newton and Dunbar, 1994; Kirkpatrick, 2011). If male and female offspring are produced at roughly equivalent rates, this suggests a surplus of males who often times will band together to form so-called bachelor groups. However, since subadult females sometimes join these bachelor groups, this term may be as much of a misnomer as the term leaf monkeys. Asian colobine OMU's tend to travel together, display low rates of agonistic behavior, and also show low frequency of overt social interaction among adults and subadults. When affiliative social interactions do occur, they are most common between females of the same OMU (Newton and Dunbar, 1994). Asian colobine females are also known for

strong patterns of infant allocare and males are often thought to participate in evolutionarily adaptive infanticide (Newton and Dunbar, 1994) [wherein males, after taking over a group of females from another male, are hypothetically pre-disposed to kill dependent infants that do not carry their genetic material, potentially causing females to quickly re-enter estrus and become receptive to breeding with the new male].

While colobine intergroup relations tend to be comparatively rare, non-aggressive, and consist primarily of avoidance behaviors, in some species colobine OMU's regularly coalesce into large super-troops. In *Nasalis* (proboscis monkeys), for example, these associations frequently occur at riverbanks (Boonratana, 2000; Kirkpatrick, 2011), which is hypothesized to reduce the threat of predation during risky river-crossing activities (Yeager, 1991). It is the *Rhinopithecus* species, however, that are best known for their multi-level societies, where large numbers of OMU bands consistently coalesce. Wada and colleagues (2015) suggest that inter-group affiliation between females and infants may act as a bridge connecting OMU's in *Rhinopithecus* species. These *Rhinopithecus* bands can range up to 340 individuals (*R. roxellana*: Kirkpatrick, 2011).

4.2.2 *Rhinopithecus* Natural History

Roos et al. (2013) currently recognizes five snub-nosed monkey species, each of which are found only in either 1) China; *R. bieti* (Yunnan snub-nosed monkey or black and white snub-nosed monkey) *R. brelichi* (Guizhou snub-nosed monkey or gray snub-nosed monkey), and *R. roxellana* (Sichuan snub-nosed monkey or golden snub-nosed monkey), 2) China and Myanmar; *R. strykeri* (Myanmar snub-nosed monkey) or 3)

Vietnam; *R. avunculus* (TSNM). While research indicates that all *Rhinopithecus* species retain the basic colobine OMU social structure, the genus is somewhat distinct in that several OMU's often band together to form large groups (*R. roxellana* – up to 340 individuals, *R. bieti* – up to 400 individuals, *R. brelichi* – up to 225 individuals, *R. avunculus* – up to 125 individuals; Le Khac Quyet et al., 2016). Recent data from Myanmar indicates that *R. strykeri* also maintains the typical OMU-based multilevel society, but studies are too preliminary to estimate band size (Yixin Chen et al., 2015). And important to note, is that estimates of *R. avunculus* band size are most likely limited due to the small size of existing populations and habitats. Le Khac Quyet (2014) suggests that the entire population at Khau Ca forest in Vietnam likely bands together at certain times of year, such as in April 2015 when at least 125 individuals were observed together (Le Khac Quyet et al., 2016).

Rhinopithecus monkeys in these multilevel societies are large in body size and also highly sexually dimorphic, with males weighing in at about 15 kg and females at just over half that number – around 8.5 kg [Table 1]. Individuals of this genus also share striking facial features not limited to their oddly delicate and upward-turned noses, but also including prominent lips and hairless, blue or pink-tinted skin around their eyes [Figure 1]. Populations of these large and unusual monkeys are often found dwelling as high as 2,000-4,000 m above sea level and in temperate regions where four months of heavy snow cover is common. Flexibility on both social and dietary fronts is likely requisite for survival in such climactic extremes.

Most observations of *Rhinopithecus* species indicate mixed diets that include items typically not present in primate feeding regimes, such as lichen and bark

Table 1. Summary of the physical characteristics, geographic distribution, and habitat types of the five known species of snub-nosed monkeys.

Common and Scientific Names	General Description	Weight		Current Distribution	Elevation (m.a.s.l.)	Forest Types Inhabited
		Male	Female			
Tonkin snub-nosed monkey ¹ <i>Rhinopithecus avunculus</i>	Back and outer limbs black; inner limbs, thighs, and head creamy white	14.5	8.3	104°55' to 106°05' E, 21°45' to 22°30' N 1,200 km ² in northern Vietnam	200-1,300	Subtropical forest: Evergreen broadleaf
Gray or Guizhou snub-nosed monkey ¹ <i>Rhinopithecus brelichi</i>	Back brown and grades of gray; distal limbs and head black; chest golden	14.5	7.8	108°45' E, 27°55' N (center) 275 km ² in southwest China	800-2,300	Subtropical forest: Deciduous broadleaf Evergreen broadleaf
Golden or Sichuan snub-nosed monkey ¹ <i>Rhinopithecus roxellana</i>	Back and outer limbs reddish brown to golden; inner limbs and thighs creamy white	16.4	9.4	102° to 111° E and 30° to 35° N 14,000 km ² in central China	1,000-4,100	Subtropical and temperate forest: Conifer broadleaf, evergreen broadleaf, deciduous broadleaf
Black and white or Yunnan snub-nosed monkey ¹ <i>Rhinopithecus bieti</i>	Back, distal limbs, and head black; flanks, chest, and front of neck white	15.3	9.1	98°35' to 98°40' E, 26°15' to 29°20' N 4,200 km ² in southwest China	2,600-4,600	Subtropical and temperate forest: Conifer broadleaf, evergreen broadleaf deciduous broadleaf
Myanmar or Burmese snub-nosed monkey ^{2,3} <i>Rhinopithecus strykeri</i>	Mostly black; shades of brown on throat, inner limbs and ventrum	?	?	26.31° to 26.51° N and 98.34° to 98.81° E 270 km ² in northeast Myanmar	1,800-3,600	Subtropical and temperate forest: Conifer (silver fur), mixed temperate, cool temperate rainforest

¹Kirkpatrick and Grueter, 2010; ²Geissman et al., 2010; ³Ma Chi et al., 2015

(Kirkpatrick, 2011). Indeed, members of this genus were found to have a more robust mandible than other Asian monkeys, supporting the idea that they are better adapted for the regular ingestion of tougher foods such as bark (Wright et al., 2008; Ruliang Pan et al., 2008). The ingestion of food items like bark and lichen becomes less surprising when considering the altitudinal and latitudinal extremes of some *Rhinopithecus* species' ranges [Table 1].

Figure 1. Adult male Tonkin snub-nosed monkey, *Rhinopithecus avunculus*, photographed by Le Van Dung.



One lichen-eating snub-nosed monkey, *Rhinopithecus roxellana*, ranges in south central China within temperate montane forests. These golden monkeys were the first *Rhinopithecus* species to be named. Interestingly, their namesake – the wife

(*Roxellana*) of Suleiman the Magnificent, a sultan of the Ottoman Empire in the 16th century – was well-known for her up-turned nose (Kirkpatrick and Grueter, 2010). This snub-nosed species can be found at altitudes between 1,600 m (Bauguo Li and Dapeng Zhao, 2007) and more than 3,000 m (Kirkpatrick, 1999; Yiming Li, 2002). Winter temperatures frequently dip below freezing and their forested habitats are often blanketed in snow for up to four months per year (Yiming Li, 2002). Thus it is not surprising that infants are typically born after the spring thaw, from March through May (Bauguo Li and Dapeng Zhao, 2007). They are often highly arboreal in the wild. Yiming Li (2007), for example, found that individuals spent an average of 97% of their time in the trees. Most *R. roxellana* observations come from the Qinling Mountains where the groups have been provisioned. One group was followed by Songtao et al. (2007) revealing a diet heavy in fruit/seeds (29%), lichen (29%), leaves (24%), and bark (11%). Yiming Li (2001), who conducted 75 days of group follows at a different location, found a similar dietary make-up but also noted that insects that live under bark were frequently ingested and a potentially important source of nutrients. Studies of other populations indicated similar dietary composition (Yiming Li, 2002; Tan et al., 2007). Songtao and colleagues also noted that the species appeared to exhibit a passive foraging strategy in dealing with periods of low food availability: in the winter, they do not seem to move as much. This notion is supported by information collected by Tan et al. (2007) on a different and un-provisioned population of the same species. These data indicated increased re-use of study habitat quadrants, or more sedentary behavior, in winter months. Tan and colleagues (p. 585) also reported that *R. roxellana*, “increase consumption of leaves from spring to summer and switch to fruit/seeds in autumn and

winter when leaves are no longer available. Lichens become the fallback food item.” Information from Kirkpatrick (1999), Grueter et al. (2012), and Xuecong Liu (2012) supports the idea that lichens are a staple fallback food item, making up nearly 40% of annual diet and approximately 90% of winter diet. *R. roxellana* are one of only three primate species known to consume lichen (along with *R. bieti* and *Macaca sylvanus*), which – at least in the case of *Rhinopithecus* species – is hypothesized to be an adaptation to high altitude environments (Kirkpatrick, 2011). The same author also commented that in addition to lichen, *R. roxellana* also ingest bark when leaves are unavailable and that feeding upon bark within the order Primates is more common (*R. brelichi* and *M. fuscata* are among those known to eat bark) than lichen-feeding.

Less is known about the other two *Rhinopithecus* species that inhabit south central China. Authors report that while *R. brelichi*, the can be found at about the same altitude as *R. roxellana*; between 1,500 m and 2,200 m (Mouyu Yang et al., 2009), it is *R. bieti* that is considered to be an alpine species. These latter monkeys typically range between 2,500 m and 4,000 m in altitude (Ze Hua Liu and Qi Kun Zhao, 2004; and up to 4,600 m, Grueter et al., 2009) among the peaks of the eastern Himalayas. Both *R. brelichi*, the gray snub-nosed monkey, and *R. bieti*, the black and white snub-nosed monkey, are considered to be more terrestrial than *R. roxellana*. Whereas *R. bieti* were referred to as semi-terrestrial by Ze-Hua Liu and Qi-Kun Zhao (2004), *R. brelichi* are known to frequently cross open areas on the ground but are still considered to be an arboreal primate (Bleisch et al., 1993). In 2009, Grueter et al. reported on a 20-month study regarding dietary intake of *R. bieti*. This investigation indicated that their habitat tended to be a mixed coniferous and deciduous broadleaf forest. While snow and

below freezing temperatures were common, snow cover tended to last only a few days at a time. Much like *R. roxellana*, *R. bieti* ingested young and mature leaves, lichen, bark, and fruit. Also similar to *R. roxellana*, *R. bieti* spent a significant amount of time foraging on lichen (Kirkpatrick and Grueter, 2010) and likely rely on this food item during harsh winter months when other foods are not readily available. In addition, several fungus species were eaten and there were also signs of insect foraging. Differences between the findings of Grueter et al. and previous studies (Xiang et al., 2007; Kirkpatrick, 1995) which suggested a specialized lichen diet, may be the result of plant species richness and food availability variations and/or observer methodologies between study sites (Kirkpatrick and Grueter, 2010).

In 1998, Bleisch and Jia Hua Xie reported that *R. brelichi* relied heavily on leaves and leaf buds with fruits, seeds, and flowers added in varying proportions throughout the year. Authors of this study also make an interesting note about the potential for human – nonhuman primate resource overlap given that *R. brelichi* apparently compete for *Magnolia* buds. This type of human – nonhuman primate competition for resources is the first documented reference of such a relationship between humans and monkeys of the genus *Rhinopithecus*.

Towards the end of October, 2010, a new species of snub-nosed monkey, *R. strykeri*, was named based on observations in the mountains of northeastern Myanmar (Geissman et al., 2010). This first report indicated that the species most likely ranges between the altitudes of about 2,600 and 3,200 m, their habitat is snow-covered from November through April, and the forest types that typify their inferred range occur on an altitudinal cline and include cool temperate rain forest at the lowest elevations, mixed

temperate forest, and silver fur conifer forest at the highest elevations. Externally, *R. strykeri* most closely resembles its most geographically proximate congener, *R. bieti*, but more information is required before phylogenetic relationships can be established. Group size of the new Myanmar snub-nosed monkey reportedly varies from about 30 to 150 individuals and the current total population size in Myanmar is estimated at between 260 and 330 individuals. Even more recent data from China adds to the global population estimate, with between 490 and 620 animals believed to dwell in southern China proximate to the Myanmar border (Ma Chi et al., 2014). Geissman and colleagues (2010) believe hunting, especially as may be exacerbated by future plans for road and dam construction, is the primary threat to *R. strykeri* in Myanmar, and the same may be true for Chinese populations, as well.

4.2.3 *Rhinopithecus avunculus* Natural History

One of five snub-nosed monkey species, the current knowledge base of *R. avunculus* is small but growing, owing largely to the intensification of fieldwork in Vietnam over the last 15-20 years (Blair et al., 2011). The relative lack of knowledge regarding the natural history of this species is very likely due to two primary factors. First, it was thought to be extinct until a population was re-discovered by a team of Vietnamese and Polish scientists in 1989 (Mittermeier et al., 2006) and second, the limestone karst habitat where these monkeys are currently found in northern Vietnam are incredibly challenging to traverse, making traditional full-day group follows virtually impossible (Pat Wright and Russ Mittermeier, 2015, personal communication). This seems to be true regardless of sub-population, as Boonratana and Le Xuan Canh

(1998b) report that a five-month field study at Na Hang, Vietnam, returned a mere 122 contact hours, only 47 of which were observation hours when visual contact was maintained. However, in recent years scientists and field assistants have been slowly building a knowledge base regarding TSNM social behavior and travel patterns (Boonratana and Le Xuan Canh, 1998b), positional behavior and substrate use (Covert et al., 2006; Le Khac Quyet, 2014), and diet (Le Khac Quyet et al., 2007; Le Khac Quyet, 2014). These studies indicate that the TSNM in northern Vietnam tend to follow typical *Rhinopithecus* patterns of social organization, forming single-male units that coalesce into large multi-male, multi-female super-troops (Kirkpatrick, 2007; Grueter et al., 2009; Kirkpatrick and Grueter, 2010; Le Khac Quyet et al., 2016). However, this monkey has surprised researchers studying locomotion and positional behavior by exhibiting a higher than expected frequency of suspensory behaviors, such as arm-swinging locomotion (Covert et al., 2006). This type of locomotor behavior has also been observed in *Rhinopithecus brelichi* (Bleisch et al., 1993), as well as in other odd-nosed colobines (*Pygathrix*: Byron and Covert, 2004; *Nasalis*: Verhaegen et al., 2011), but is not often seen in other colobine monkeys.

R. avunculus are the only snub-nosed monkey species found in sub-tropical montane forest; most *Rhinopithecus* species live in temperate zones where snow cover is common (Kirkpatrick and Grueter, 2010; Geissman et al., 2010). Unsurprisingly, these habitat differences impact *R. avunculus* diet. TSNM appear to have a diet similar to other colobine monkeys yet different from their *Rhinopithecus* congeners, eating a higher proportion of foods such as ripe and unripe fruit, seeds, young leaves, and leaf

petioles (Boonratana and Le Xuan Canh, 1998b; Baopeng Ren et al., 1998; Le Khac Quyet et al., 2007; Le Khac Quyet, 2014) [Table 2].

Data presented by Le Khac Quyet et al. (2007) were based on dietary information collected at Khau Ca between December 2004 and May 2006. Four kilometer-long, 2-meter wide phenology transects were established to compare food availability with dietary intake. Diameter at breast height, bole height, tree height, canopy shape, canopy diameter, % leaf flush, % fruit, and associated lianas and epiphytes were measured for each tree that was captured within the transects. Results of this study identified 31 TSNM food species belonging to 21 families. Unripe fruits (25%), ripe fruits (22.2%), and leaf petioles (22.2%) were the most common part of the TSNM diet, followed by young leaves (11.11%), inflorescences and flowers (8.33%), seeds (5.56%), and piths (2.78%). The plant species most frequently consumed by TSNM in Khau Ca during the study period were, *Lodes siguini* (leaf stems and ripe fruit), *Garcinia fagraeoides* (leaf stems), *Acer tonkinensis* (leaf stems), *Excentrodendron tonkinense* (flowers), and *Brassaiopsis stellata* (ripe fruits). Of 93 identified tree genera in the forest, 12 (13%) were eaten by the TSNM and this indicates some degree of dietary selectivity.

The information provided by this preliminary study conducted by Le Khac Quyet et al. (2007), elucidates some important differences compared to earlier data. Research carried out during a 1998 TSNM feeding study (Boonratana and Le Xuan Canh, 1998b) suggested that the three most important dietary components of the TSNM living in Na Hang (Tuyen Quang province) were fruits, seeds, and leaves rather than unripe fruit, ripe fruit, and leaf petioles. Differences in available foods at each site, seasonal

Table 2. List of plant taxa consumed by Tonkin snub-nosed monkeys at Khau Ca forest.

No.	Latin Name (English Common Name) ^{1,2}	Vietnamese Common Name ²	Plant Type (Mean DBH ¹ , cm)	Part(s) Eaten by TSNM ^{1,11}	Used by Local People?	Human Use Categories
	Aceraceae (Maple)	Họ Thích				
1	<i>Acer tonkinensis</i>	Thích	Tree (28.2)	ST	Yes	Fuel, construction, trade
	Apocynaceae (Dogbane)	Họ Trúc đào				
2	<i>Melodinus toumeri</i>	Giôm Toumer	Liana/Shrub ²	FR		
3	<i>Apocynaceae</i> sp.	Trúc đào (?)		ST		
	Araliaceae (Papaya)	Họ Ngũ gia bì				
4	<i>Brassaiopsis stellata</i>	Đu đủ rừng	Shrub ²	FR		
5	<i>Brassaiopsis</i> sp.	Đu đủ	Tree	FR	Yes	Fuel, construction, fodder
6	<i>Schefflera velutosa</i>	Chân chim mây	NTFP	PI		
7	<i>Schefflera palmiformis</i>	Chân chim lá nhỏ	NTFP	ST		
	Asclepiadaceae (Milkweed)	Họ Thiên lý				
8	<i>Goniostemma punctatum</i>	Thiên lý (?)	Small tree ²	ST		
	Bignoniaceae (Bigonia)	Họ Núc nác				
9	<i>Rhademachera</i> sp.	Đa đét	Tree	FL, YL*		
	Cannabaceae (Hackberry)	Họ Du				
10	<i>Celtis</i> sp.	Sếu	Tree	YL*		
	Clusiaceae (Mangosteen)	Họ Bứa				
11	<i>Garcinia bracteata</i>	Trái bứa	Tree (17.5)	ST, FR	Yes	Fuel, construction, food, trade
12	<i>Garcinia fragransoides</i>	Trái thừng	Tree (21.7)	FR	Yes	Fuel, construction, food, trade
	Ebenaceae (Persimmon)	Họ Thị				
13	<i>Diospyros</i> sp.	Mãng cầu	Tree (58.65)	FL, FR*, YL*		
	Euphorbiaceae (Milk Tree)	Họ Thầu dầu				
14	<i>Antidesma</i> sp.	Chối mội	Tree (21.65)	FL		
15	<i>Bridelia retusa</i>	Đóm lòn	Tree	FR		
16	<i>Inadica rotundifolia</i>	Đặc mã	Tree	SD, FR*, FL*		
	Fabaceae (Rosewood)	Họ Đậu				
17	<i>Dalbergia tonkinensis</i>	Sưa	Tree	FR		
	Lauraceae (Laurel)	Họ Long não				
18	<i>Litsea baviensis</i>	Bời lợt Ba vi	Tree (19.55)	FR		
19	<i>Litsea</i> sp.	Bời lợt	Tree	FR		
20	<i>Lauraceae</i> sp.	Kháo đá	Tree	FR, YL*	Yes	Fuel, construction, trade
	Isocarpaceae (Aster)	Họ Thụ đào				
21	<i>Iodes sequini</i>	Tứ quả Senqui	Liana (?) ²	ST, FR		
	Mimosaceae (Pea)	Họ Trinh nữ				
22	<i>Archidendron</i> sp.	Cứt ngựa	Tree (40.6)	SD		
	Moraceae (Fig)	Họ Dâu tằm				
23	<i>Ficus</i> sp.	Sung	Tree (39.1)	FL	Yes	Fuel, constr., fodder, medicine, trade
	Oleaceae (Olive)	Họ Nhài				
24	<i>Olea</i> sp.	Nhài (?)	Tree (19.45)	FR		
	Orchidaceae (Orchid)	Họ Lan				
25	<i>Bulbophyllum affine</i>	Cầu diệp gân	Orchid ²	YL		
26	<i>Orchidaceae</i> sp.	Phong lan**	Orchid	FL*	Yes	Trade
	Sabiaceae (Magnolia)	Họ Mát xa				
27	<i>Meliosma fordii</i>	Mát xa Ford	Tree (19.1)	ST		
	Sapindaceae (Lychee)	Họ Bồ hòn				
28	<i>Pometia pinnata</i>	Săng	Tree (92.9)	FR	Yes	Fuel, construction, trade
	Sapotaceae (Bully Tree)	Họ Hồng xiêm				
29	<i>Sinosideroxylon wrightianum</i>	Sến đất	Tree (24.7)	ST, YL*	Yes	Fuel, construction, trade
	Tiliaceae (Linden)	Họ Đay				
30	<i>Excentrodendron tonkinense</i>	Nhài	Tree (78)	FR, ST*, FL	Yes	Fuel, construction, trade
	Vitaceae (Grape)	Họ Nhọ				
31	<i>Tetragium oliviforme</i>	Tứ thụ dạng ô liu	Liana ²	FR		
32	<i>Tetragium</i> sp.	Khau tén	Liana ²	FR		
	Urticaceae (Nettle)	Họ Gai				
33	<i>Debregeasia squamata</i>	Chà pan	Shrub ²	FL		

ST = leaf stems, YL = young leaves, FR = fruit, FL = flowers, SD = seeds, PI = pith; NTFP = Non-timber forest product. *No record of item as TSNM food prior to the

current study; **Often grows on *E. tonkinense* trees; †DBH = diameter at breast height; ††Identified as TSNM food item by Le Khac Quyet¹. ¹Le Khac Quyet et al. (2007), ²Ha Giang FPD et al. (2008), ³Flora of China, www.dFloras.org, accessed Feb. 21, 2012.

differences, cultural differences of the two TSNM societies, small sample size of the 1998 sample (34 feeding bouts), or observers neglecting to differentiate between ripe and unripe fruits and leaves versus leaf stems (petioles) may account for these variations. Baoping Ren et al. (1998) also suggested that young leaves were important dietary components for TSNM in spring and that fruit composed the majority of dietary intake in autumn. Regardless, it is clear that fruits (unripe or ripe) and seeds, as well as leaves and leaf stems are among the most important components of TSNM dietary intake. There is also evidence that the diet of *R. avunculus* may, overall, be composed of tougher food items than the diets of their congeners (Ruliang Pan et al., 2008). Still, Le Khac Quyet, et al. (2007) share that much is left to be uncovered regarding TSNM diet. For example, full dietary breadth remains unclear and more information is needed to determine how the apparent selectivity of TSNM in Khau Ca may impact the minimum home range size required by this species. In the meantime, human activities – part of the human-nonhuman primate interface – continue to encroach on the remaining TSNM habitat.

CHAPTER V

RESEARCH CONTEXT AND METHODOLOGY

“Traditionally, conservation monitoring has meant looking at quantitative indicators of biological health. Although conserving biodiversity is the ultimate goal, most organizations now recognize the importance of looking beyond biological indicators when assessing ecosystem health. Evaluation activities for both status assessment and effectiveness measurement now frequently include the monitoring of social, economic, political and cultural threats and opportunities that influence conservation.” (Stem et al., 2005, p. 305)

5.1 Research Context

Vietnam is rich not only in biodiversity, but also in long-standing human cultural traditions. Located in one of Conservation International’s Biodiversity Hot Spots (Meyers et al., 2000), and containing six of the World Wildlife Fund’s Global Ecoregions (Olson et al., 2001), this Southeast Asian country demonstrates high rates of wildlife endemism combined with equally high anthropogenic pressures. A variety of primatological research has been undertaken in Vietnam in recent years, including significant work conducted by Nadler (2007), Dong Thanh Hai (2008), Workman (2010), Rawson (2011), Blair (2011), and Le Khac Quyet (2014). Each of these investigations have contributed in critical ways to current knowledge of Vietnamese primate conservation status, natural history, ecology, and taxonomic diversity but to date, very little is understood about the human-nonhuman primate interface from a synecological perspective.

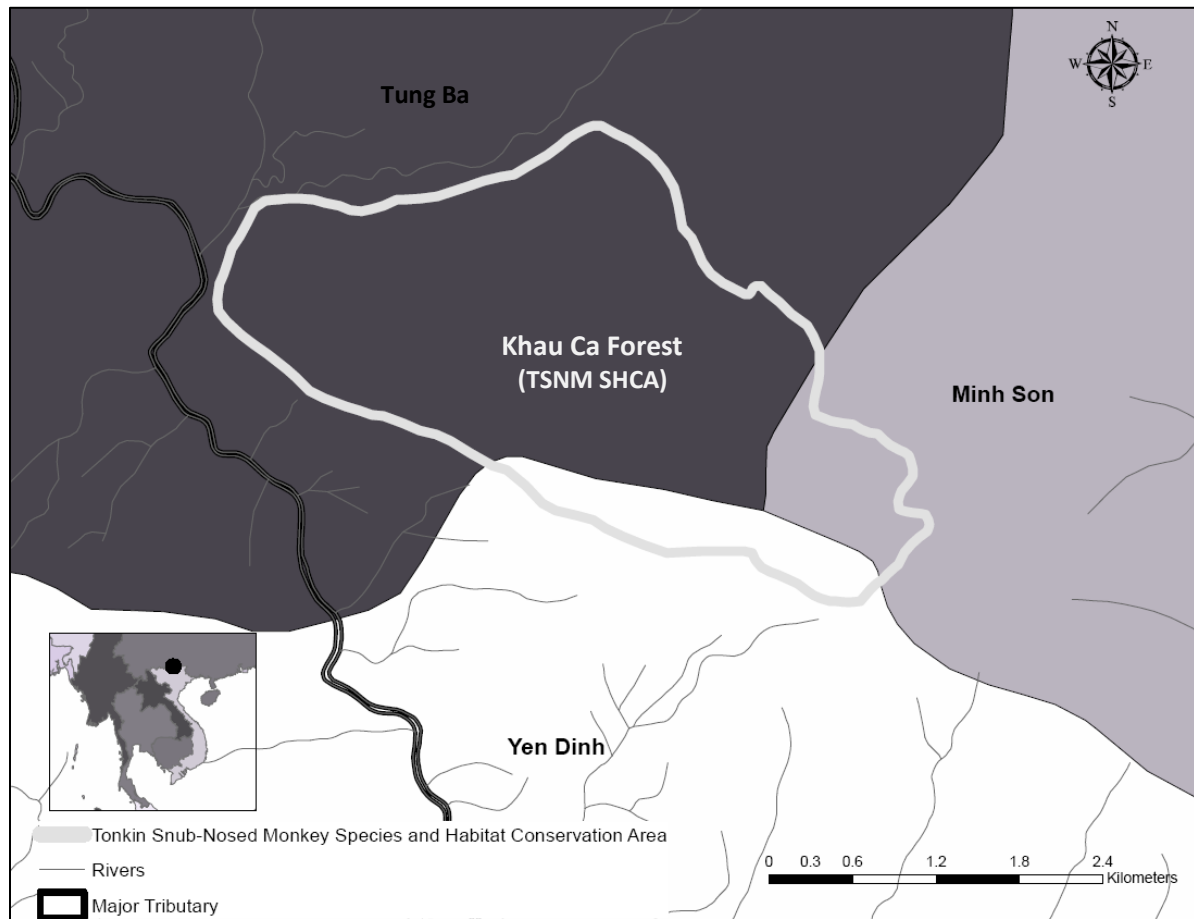
5.1.1 Study Site

This study takes place in Ha Giang, Vietnam's northern-most province [Figure 2]. Located within the Lo River watershed of northern Vietnam, the Tonkin snub-nosed monkey Species and Habitat Conservation Area (SHCA) [22° 50' N, 105° 07'E] rests atop a block of steep, irregular limestone karst, ranging in altitude from 600 to 1,400 m above sea level [Figure 3]. With an annual rainfall of about 2,300 mm, a mean temperature of 23.3°C, and average monthly humidity ranging from 35.5% to more than 87%, the sub-tropical region exhibits pronounced warm, wet (April – September) and cool, dry (October – March) seasons (Covert et al., 2008). This approximately 1,000 hectare TSNM SHCA forest, known locally as Khau Ca, is dominated by lower montane evergreen limestone forest and it is one of the least degraded, most intact examples of this rare forest type left in Vietnam (Ha Giang FPD et al., 2008).

Floral and faunal surveys of Khau Ca indicate the TSNM SHCA is an important center for biodiversity conservation. Recent studies of the floral community have identified 471 plant species (268 genera) belonging to 113 families and 4 phyla (Ha Giang FPD et al., 2008). While secondary forest, savannah scrub, and grassland also occur, higher elevations are dominated by primary and secondary evergreen forest. Researchers have reported the presence of 29 plant species and 16 animal species recognized as nationally or globally rare and threatened (Ha Giang FPD et al., 2008).

Though animal biodiversity of the TSNM SHCA is not particularly well-studied, 33 mammal, 153 bird, 12 reptile, and 2 amphibian species have been recorded within Khau Ca and many more are suspected to live there (Ha Giang FPD et al., 2008). While large cats such as leopards and tigers are presumed to have been extirpated from the

Figure 2. Tonkin snub-nosed monkey Species and Habitat Conservation Area map.



region, some venomous snakes (especially pit vipers) and large birds of prey are potential nonhuman primate predators. Khau Ca is also home to several birds and mammals that may compete with primates for floral resources, including avian taxa such as barbets, bulbuls, hornbills, and orioles, and mammalian animals like civets, bats, squirrels, and four nonhuman primate species. In addition to TSNM, two loris species (*Nycticebus pygmaeus* and *N. bengalensis*), as well as two macaques, the stump-tailed macaque (*M. arctoides*) and the Assamese macaque (*M. assamensis*), can be found at this site. Lorises and macaques have not been the focus of scientific research at this particular site, but from what is known more generally about the ecology

of these primate taxa (Nekaris and Bearder, 2011), lorises are probably not major dietary competitors (they primarily ingest exudates and animal matter). Sympatric macaques are more likely significant TSNM competitors, and given that a) stump-tailed macaques tend to be mostly terrestrial, and b) Assamese macaques are highly frugivorous (Thierry, 2011), it may well be the Assamese species that have the most substantial dietary overlap with TSNM at this study site.

In addition to these potential nonhuman primate competitors that dwell within Khau Ca, this particular study focuses in on another primate that is expected to act either as a resource competitor, or as a predator of TSNM, or both: humans (*Homo sapiens*). The rationale for an emphasis on the human primate falls into two categories, 1) the human-nonhuman primate interface has yet to receive empirical attention in Vietnam, and 2) the significance of anthropogenic pressure as a threat to future protection of critically endangered Tonkin snub-nosed monkeys.

Figure 3. The limestone peaks of Khau Ca forest, viewed from a homestead in Tung Ba commune (left) and from a ranger station located within Yen Dinh commune (right).



5.1.2 The People of Ha Giang Province

The people of the region encompassing the Tonkin snub-nosed monkeys' forest habitat reside within three communes in Ha Giang Province: Minh Son, Tung Ba and Yen Dinh. Living at a density of about 38 people/km² (Vu An Tai, 2013), the dominant ethnic group is the Tay people, who comprised approximately 75% of the population in 2008 (Ha Giang FPD et al.). People of Dao (about 13.5% of the population in 2008) and Hmong (6.5% of the population in 2008) ethnicities complete the local population of perhaps as many as 13,000 people today (Vu An Tai, 2013; CIA, 2016).

The three ethnic groups represented in the region are dissimilar in a number of respects. The predominant ethnic groups vary in their time of arrival to northern Vietnam. Evidence suggests that while the Hmong people migrated from China in the late 1700's and early 1800's, the Tay people – the most populous in the region – have occupied northern Vietnam since before written records (Tran Duc Vien, 2003). In addition, each ethnic group is associated with different ecological and agricultural settings (Tran Duc Vien, 2003). Hmong people, the poorest and most marginalized ethnic group in the region, live mainly at higher elevations and typically practice a combination of slope-side agriculture with forest product procurement. For thousands of years, other culture groups (especially in China) referred to the Hmong as a people who refuse civilization, are aggressively warlike, and who are inferior barbarians (Lee, 1998). This derogatory perception continues today. The Dao commonly practice agroforestry in the mid-level altitudes of the region (Tran Duc Vien, 2003). They are known for their breadth of knowledge of medicinal plants (ICEM and PADP, 2003) and hunting contributes to their group identity (Novellino, 2000). Lower elevations and flat fertile

valleys are dominated by Tay people. The Tay most commonly practice fairly sustainable composite rice paddy and swidden agriculture subsistence and tend to have more favorable socio-economic conditions than the other two ethnic groups (Tran Duc Vien, 2003).

5.1.3 Anthropogenic Impacts to Khau Ca and its Inhabitants

Despite its rugged, cavernous terrain, Khau Ca is not immune to human impacts. The forest is a virtual island amidst a village-agricultural landscape [Figure 4] and resource extraction, forest clearing, livestock grazing, fire, and hunting are all potential threats. While becoming less frequent in recent years, timber and non-timber forest product procurement remains a significant threat to the persistence of the evergreen forest of the TSNM SHCA, especially as smaller nearby forests are depleted. Forest resources are used for construction, consumption, traditional medicine, ornamentation, special holiday use, fodder, making alcohol yeast, and fuel purposes, as well as for market sale (Ha Giang FPD et al., 2008).

A preliminary analysis of habitat structure within Khau Ca identified a few areas of anthropogenic habitat disturbance. The edges and lower, flat valley sections of the forest (600-700 m) were considered highly disturbed habitat (Ha Giang FPD et al., 2008). Rather than the primary and secondary evergreen forest that typifies higher elevations within the protected area, authors noted that these lower and edge areas were dominated by secondary scrub growth and vegetable crops, respectively. Thus, human activity such as agricultural practices and forest resource harvesting has had an important and disturbance effect on the Khau Ca forest.

Agricultural expansion and shifting cultivation also threaten the future of the Species and Habitat Conservation Area and the TSNM population (Ha Giang FPD et al., 2008). The soils that sit upon the limestone mountains of the region are nutrient poor and remain viable for only a few years before being left fallow. The practice of free-grazing livestock inhibits regeneration of fallow land as well as degraded areas within Khau Ca, as pigs, goats, and buffalo are commonly observed in the forest and buffer zone (Harrison Levine, unpublished data). Shifting cultivation not only threatens to

Figure 4. Tung Ba commune and the village-agricultural matrix surrounding Khau Ca forest (viewed from a path leading up to Khau Ca).



reduce the size of the TSNM habitat, it also increases the risk of forest fire. In addition, by replacing forest cover with crops and fallow land, traditional slope-side agriculture may ultimately cause erosion, changes in water potability, flooding, and even landslides (Tran Van Phung and Troung Thanh Nam, 2008).

Another traditional practice – wildlife hunting – continues to be the primary liability to TSNM population persistence in most areas where this rare primate can still be found (Boonratana and Le Xuan Canh, 1998a) but is less concerning at Khau Ca. Ingestion of wildlife, particularly at restaurants and during holidays or celebrations, is an important Vietnamese tradition (Boonratana and Le Xuan Canh, 1998a; Nguyen Van Song, 2008). Religious beliefs and taboos, however, are not reported to limit primate hunting in Vietnam (Workman, 2004). Hunting is not currently a major concern within the TSNM SHCA, as a 2005 gun confiscation program, the constant presence of researchers and community patrol group members, and recent conservation education and awareness programs have limited hunting activities in Khau Ca.

The 2009 gazettelement of the TSNM Species and Habitat Conservation Area, along with collaborative work with governmental officials and the presence of forest patrol and research teams since 2004, has afforded some protection for *R. avunculus* and their habitat at this site. Hunting and timber extraction are becoming less common and it is now technically illegal to enter the TSNM SHCA without permission. However, enforcement is still lacking. No law enforcement officials are assigned to the protected area. A team of local Community Patrol Group (CPG) members has been hired to patrol the forest and local communities but they do not have authority to take action in cases of illegal activity. In April 2010, eight months after the establishment of the TSNM

SHCA, local CPG members reported encountering unauthorized people within the forest approximately seven out of every ten days spent patrolling Khau Ca (Harrison Levine, unpublished data).

5.1.4 Socio-Economic and Political Context

To better understand why and how the above factors have become threats to the Khau Ca TSNM population, it is important to view the situation in the broader ethnoprimateological context. Vietnam's history, politics, laws, economics, demography, and traditions undoubtedly play interconnected roles in the underlying causes of many of the identified threats to the species.

History. Vietnam has a deep history of foreign invasion and colonization and as a result also exhibits a proud spirit of independence. According to Corfield (2008), at least 1,000 years of Chinese rule (200 BC – 938 AD) was followed by several millennia of Vietnamese independence until the French colonization of Vietnam in the 1800's. Rebellions in the mid-1800's triggered French military action, ultimately resulting in French control of the country in 1859 and Vietnam officially becoming part of French Indochina in 1887. Resistance to colonial power continued throughout French rule until the Franco-Viet Minh War, which began in 1946 and ended with Vietnamese sovereignty in 1954. Vietnam, however, was at the same time officially divided into two zones, North and South. While leaders in the north had embraced communism, a movement initiated by Ho Chi Minh in the 1930's led many in the south to hold strong anti-communist sentiments. This division is what led to the Vietnam War, or the

American War as it is known in Vietnam, which began in the 1960's when the North Vietnamese Army began taking over regions in the south. The United States provided strong support for the anti-communist efforts of the south, acting in effect as yet another invader in the north. U.S. involvement in the war lasted until the south surrendered in 1975, and Vietnam began steps towards reunification under northern communist rule.

Governance. In 1976, Vietnam was renamed the Socialist Republic of Vietnam and its constitution outlines the leading role of the communist party in Vietnam and guarantees all citizens fundamental rights (Ingle and Halimi, 2007). Vietnamese citizens are represented by a voter-elected National Congress of the Communist Party (which is also responsible for electing the country's President) and locally elected People's Committees. All land is owned collectively by the people and managed by the state (ICEM and PADP, 2003). A Ministry of Natural Resources and Environment (MoNRE) was established in 2002, and this governmental body is taking steps towards developing policies and procedures for environmental protection (Ingle and Halimi, 2007). Other Ministries are involved in natural resource management, too. For example, the Ministry of Agricultural and Rural Development (MARD) is responsible for identifying and classifying Vietnam's remaining forest cover (approximately 7% of the country, or 2 million hectares) into one of three categories, production, protection, and special use. Laws regarding use of the latter two of these forest types are managed by provincial Forestry Protection Departments (which fall under the direction of the MARD), but management effectiveness remains problematic and funding is insufficient. Laws against illegal wildlife trade are also in place, and enforcement of these laws has

improved; however, in 2008 it was estimated that 3-4,000 tons of wildlife were still being traded out of the country each year (Nguyen Van Song).

Vietnam is a country just slightly larger than the state of New Mexico (310,000 sq km) that consists of 58 provinces (CIA, 2016). It is the northernmost of these – Ha Giang Province – where the current investigation takes place. Ha Giang is, in turn, divided into ten districts, including Bac Me and Vi Xuyen. The three communes surrounding Khau Ca forest are located within these two districts; Minh Son and Yen Dinh fall under the governance of Bac Me district, and Tung Ba is situated within Vi Xuyen. Finally, within each commune – a municipality most akin to what we often refer to as a city or township in the U.S. – a number of hamlets, or villages, are further distinguished, and each is also distinct in terms of its socio-economic status.

Economics. The National Congress of the Communist Party of Vietnam meets every five years to determine the ‘politically guided’ direction of the country and outline policies for the future (Ingle and Halimi, 2007). In 1986, for example, the party initiated *Doi moi*, a policy of capitalist-style economic reform. The policy included decentralization and private enterprise initiatives which have led to rapid economic growth (currently 6% per year). The policy also helped reduce Vietnam’s poverty rate from 70% in 1986 (ICEM and PADP, 2003) to 11.3% in 2012 (CIA, 2016) and household income has been on the rise since 1986 (Thanh Binh Nguyen, 2011). Per capita annual household income was estimated to be \$200 in 1986, \$400 in 2003, and as of 2008, it was approaching \$600 (ICEM and PADP, 2003; Thanh Binh Nguyen, 2011). Although income is increasing on average and poverty is decreasing, Vietnam’s

ethnic minorities, who represent about 14% of the population (CIA, 2016), are often those found living in poverty. In Vietnam's Northern provinces, 24% of ethnic minorities were living below the poverty line in 2009 (Thanh Binh Nguyen, 2011). Their relatively low income is likely related to the fact that ethnic minorities tend to live in remote, rural areas and proximate to protected areas where access to modern infrastructure, markets, and arable land is limited. Authors of a 2003 (ICEM and PADP, p. 14) report note, however, that living near protected areas can,

Provide a number of important benefits that help mitigate the impacts of poverty. In many remote locations, for example, protected areas provide medicinal plants, which are often the only form of medicine available for local use. They serve as "food banks" in times of food shortages. They provide clean water to surrounding communities and can help control flooding. Protected areas provide areas for scientific research and educational programmes during school outings. Some protected areas also help conserve ethnic minority culture by protecting religiously important "spirit" or "sacred" forests.

The inhabitants of the region surrounding Khau Ca forest are undoubtedly just this type of protected area benefactors. While there have been no reports to date that indicate Khau Ca as being a sacred forest, community patrols indicate high rates of entry into the forest for the purpose of forest resource extraction (primarily for household use but also for local and international sale) and the limestone hills certainly act as water catchment areas for cultivar irrigation and are also important in protecting watersheds and mitigating flood damage (ICEM and PADP, 2003). In fact, some researchers (Ha Giang FPD et al., 2008, p. 26) believe that, "The watershed protection value of the proposed nature reserve [Khau Ca] is immense as water availability is probably the single largest constraining factor on agricultural productivity."

Preliminary data reported in 2008 (Ha Giang FPD et al.) suggest that about 35% of the households in Tung Ba commune live below the poverty line – a percentage that would likely be higher in Minh Son and Yen Dinh. In Tung Ba, livestock sales and services, combined with crop or forest product sales, generate nearly 100% of annual income. Wealthier families also run small stores or sell distilled alcohol and cash crop products including ground nuts, fruit, and cinnamon. These families also apparently have access to more agricultural land with which they can better nourish their revenue-generating livestock and this feeds into a self-reinforcing feedback loop contributing to household wealth. Broadening the scope beyond the wealthiest of families of Tung Ba to a commune-wide perspective, livestock generates about 40% of income and aids with 60% of cultivation activities. Indeed, all respondents participating in preliminary work carried out in 2009 (Harrison Levine, unpublished data) considered themselves to be farmers, even if they were engaged in significant off-farm employment.

Approximately 48% of Vietnam's citizens currently earn a living via agriculture (CIA, 2016), with rice being the primary food crop augmented by cultivars such as maize and taro, as well as other vegetables and fruit. The country's cash crops include rice, coffee, rubber, tea, pepper, soybeans, cashews, sugar cane, peanuts, and bananas. Often, governmentally-driven economic policies that promote agricultural production of crops have had major impacts on protected forests by encouraging farmers to expand their agricultural land into comparatively fertile soils of protected areas. In the Khau Ca region, interviewees indicate having recently taken advantage of government-funded programs to plant tea and acacia as cash crops (Harrison Levine, unpublished data), though crops were still too young to produce revenues.

Demographics. More than 94.3 million people are reported to live within Vietnam's borders (CIA, 2016). At approximately 287 people per km² and with a population growth rate of almost 1% each year, Vietnam is one of the world's most densely populated countries. About two thirds of Vietnam's citizens live in rural areas and while some of these regions can be extremely populous, Ha Giang Province had a relatively low population density of about 90 individuals per km² as recently as the year 2000 (Novellino). Likely due to the mountainous terrain, human population density in the three communes encompassing Khau Ca forest is even lower than in Ha Giang in general, falling between 50 and 60 individuals per km² (Ha Giang FPD et al., 2008).

Education. Whether inhabiting densely populated regions or not, the people of Vietnam are relatively well-educated. The literacy rate within the country is estimated at 94.5% at present (CIA, 2016). Nearly all children complete a primary school level of education and at least half go on to secondary school. Preliminary data from recent research indicate a similar trend is true within the three communes that surround Khau Ca forest. All children are expected to attend primary school and provisions are made to ensure school attendance. For example, dormitory and family-stay programs are in place, small satellite campuses in the most remote regions are usually staffed by at least one teacher, and education staff are expected to seek out students who do not show up when school is in session (Harrison Levine, unpublished data).

Traditions. Not only do Vietnam's people typically have strong academic backgrounds, they also have a wealth of knowledge and experience with regards to the

utilization of natural forest resources. Hunting, for example, of all primate species in Vietnam is historically a traditional practice that – with few exceptions – does not seem to be affected by religious beliefs or cultural taboos (Workman, 2004). Ingestion of wildlife, particularly during special holidays such as the annual *Tet* or Lunar New Year, is an important part of celebratory feasts (Boonratana and Le Xuan Cahn, 1998a; Nguyen Van Song, 2008). Focusing in on TSNM, however, it is interesting to note that local people of the Na Hang TSNM habitat region (in Tuyen Quang Province) said the meat of this species is, “bad tasting,” but they were nevertheless killed when encountered (Boonratana and Le Xuan Cahn, 1998a). Hunters from the Khau Ca region, interviewed in April 2010 (Harrison Levine, unpublished data), do not report the same ill-taste of TSNM meat, although they do admit to having hunted tens or hundreds of these monkeys in their lifetime.

While primates were historically hunted to put food on the table; today, wildlife trade is more frequently the driving factor (Lippold and Vu Ngoc Thanh, 1998; Nguyen Van Song, 2008). More often than not, the industry Vietnamese primates are traded into is one related to traditional medicinal use. Whether ingested directly, as monkey balm, or mixed with soup, rice wine, whisky, or brandy, different primate parts are believed by many Vietnamese to affect a person’s intelligence, vigor, or level of fatigue, and are sometimes thought to cure forms of madness (Lippold and Vu Ngoc Thanh, 2002; Workman, 2004; Thach Mai Hoang, 2009). Boonratana and Le Xuan Cahn (1998a) attested that TSNM are either directly consumed or are made into a medicinal stock as a cure for fatigue and Thach Mai Hoang (2009) reported a similar TSNM soup, as well as talismans used as a cure for rickets.

Primates, or parts of them, are also traditionally traded as pets, decorations, souvenirs, and food. Nguyen Van Song (2008) suggests that about half of all illegally hunted wildlife are consumed domestically (80% consumed in restaurants) and the other half traded internationally. Most wildlife that is moved internationally out of Vietnam crosses the Vietnam-China border. This factor, in particular, hits close to home when one considers that the single remaining viable population of TSNM live in Vietnam's northern-most province which shares an expansive border with China. Indeed, Boonratana and Le Xuan Cahn (1998a) report that TSNM from Na Hang (further south than Khau Ca) are frequently traded into China. Current wildlife trade frequency estimates do not appear to have slowed even though forests have for years been considered by many local hunters to be relatively empty (Workman, 2004). In fact, trade into and out of Vietnam was recently estimated at between 3,500-4,000 tons per year, yielding projected revenue of over 65 million US dollars per year (Nguyen Van Song, 2008). Laws exist to help prevent this trade but high demand coupled with lax enforcement, bureaucracy, lack of resources and cooperation, corruption, traditional values, and absence of alternative income options are all working against trade prevention.

5.1.5 The Antiquity of Coexistence in Northern Vietnam

In switching from present-day to a pre-historical view, the fossil record indicates that the presence of nonhuman primates in Southeast Asia date back as far as the Eocene, 55-34 mya. Even more clear is that fossil hominoid species (apes), such as *Sivapithecus*, radiated to Southeast Asia by about 15 mya (Hartwig, 2007). Specimens tentatively considered to be fossil colobines appeared in China during the late Miocene

(8-5 mya), but it is not until the Pleistocene (2.5 mya – 11,700 years ago) that good evidence exists with regards to extant colobine genera (*Presbytis*, *Trachypithecus* and *Rhinopithecus*) inhabiting the region proximate to what is currently Northern Vietnam (Delson, 1994; Takai, et al., 2014). Takai and colleagues recently examined nearly 3,600 teeth from cave sites in southern China and found both *Rhinopithecus* and *Homo* teeth in the same caves throughout the Pleistocene (Sanhe: Early Pleistocene; and Shuangtan, Zhiren, and Baxian: Late Pleistocene) [Takai et al., 2014]. Given that humans (*H. sapiens*) were most likely present in the northern limestone region of Vietnam 30,000 years ago and there is undisputed evidence that human hunter-gatherer groups lived in limestone rock shelters and caves between 9,000 and 18,000 years ago (Sterling et al., 2006), this human-nonhuman primate sympatry has continued from the Pleistocene through the Holocene epoch (11,700 to the present). This is clear evidence that hominins and non-hominin primates – including *Rhinopithecus* monkeys – have coexisted in Southeast Asia for more than a million years and in Vietnam for at least 30,000 years.

5.1.6 Human Forest Resource Use in Northern Vietnam

Current patterns of human forest resource use are likely very similar to historical and pre-historical resource use dynamics spanning centuries (Rambo and Jameison, 2003). Sterling et al. (2006) notes that northern Vietnam is one of the oldest continuously (anthropogenically) modified environments in the world. Prior to the appearance of rice cultivation in the archaeological record 2-3,000 years ago, evidence supports a hunting and gathering lifestyle wherein humans hunted large mammals such

as rhinoceros, elephants, and primates. Today, local people in northern Vietnam are primarily subsistence-based, still relying on water buffalo and manpower – as opposed to modern machinery – for crop production and harvest. Rice and maize are the primary cultivars, supplemented by other crops such as cassava, taro, garden vegetables, and fruit. In addition, forest exploitation remains a common practice both for subsistence and for income supplementation (Ha Giang FPD et al., 2008).

5.1.7 Human – Nonhuman Primate Forest Overlap in Vietnam

It is also clear that there may be some degree of forest resource overlap between the Tonkin snub-nosed monkeys and humans living near and within TSNM SHCA. For example, a pilot study conducted in Ha Giang in 2011 indicated that *Excentrodendron tonkinense* trees [Figure 5] are likely an important TSNM resource (Harrison Levine, unpublished data) and these forest trees are also reportedly used by local people for fuelwood and other purposes (Insua-Cao, 2006; Le Khac Quyet et al., 2007 and Ha Giang FPD et al., 2008). In Tuyen Quang Province, *R. avunculus* and humans demonstrate similar overlap with respect to species the monkeys relied upon for food, especially bamboo and fruit species (Boonratana and Le Xuan Canh, 1998b). In the TSNM SHCA region, bamboo is commonly used by local people to build fencing, large tree boles (including those of *E. tonkinense*) are felled for home construction, orchids are taken as decorations, *Phrynium* leaves are harvested for consumption during the *Tet* (Lunar New Year) holiday, leaves and flowers of numerous plants are gathered for the distillation and flavoring of alcohol, and wild fruits and vegetables are collected as dietary supplements (Ha Giang FPD et al., 2008). A more specific understanding of

forest plant use overlap between humans and TSNM of Ha Giang will provide valuable information for future conservation interventions.

Figure 5. *Excentrodendron tonkinense*, a linden tree known locally as *Nghien*, is a giant tree species. Harrison Levine stands with Le Khac Quyet in front of a giant *Nghien* tree in Khau Ca in the picture on the left (photo taken by Herbert Covert); on the right, is a recently felled *Nghien* tree, photo taken from within Khau Ca by Le Van Dung.



5.2 Research Methodology

As with a number of previous ethnoprimateological studies, a mixed-methods toolkit was employed in this study, capturing both quantitative and qualitative data concurrently. This type of research methodology is recommended, and commonly employed, by researchers seeking to integrate evidence from the primarily quantitative biophysical realm with information from a primarily qualitative sociocultural dimension (Driscoll et al., 2007). The strength of this mixed-method approach lies primarily in the researcher's ability to statistically validate qualitative findings, while at the same time using qualitative information to explain trends and anomalies in the quantitative data set. The methods below were designed to examine why, when, where, and how forest

resources are used by both a) local human populations and b) the critically endangered Tonkin snub-nosed monkeys of Khau Ca forest.

5.2.1. Monkey Behavior and Ranging

Answers to the research questions posed in the first chapter require information regarding both Tonkin snub-nosed monkey and human resource use. To gather data on monkey behavior and eliminate inter-observer reliability concerns, one researcher (Le Van Dung) aimed to spend at least seven days per month in the forest conducting TSNM group follows. Upon making contact with a group, and every 5 minutes thereafter, instantaneous scan samples (Altman, 1974; Martin and Bateson, 1993) were conducted. This type of sampling, which involves recording data snapshots at standardized intervals, are often implemented for describing group, as opposed to individual, behavior (Campbell et al., 2011). The incredibly difficult limestone karst terrain of Khau Ca typically does not allow for all-day group follows; thus, sampling commenced upon group encounters and continued as long as possible. During each scan, the estimated central point of group location was recorded using GPS and rangefinder, and the behavior of the first three individuals in sight recorded (moving left to right and using four broad categories of behavior: feed, rest, travel, other). Whenever known, plant species being used was noted, and the plant part ingested (fruit, seeds, young leaves, flowers) was also recorded for all feeding samples.

While commonly employed (Chapman, 1987; Buzzard, 2006), it is argued that calculating dietary overlap via summing the number of shared resources is not sufficient and can lead to inflated estimates of overlap (Poulsen et al., 2002). Methods that

incorporate the proportional use of resources are typically more robust. Therefore, the proportion of feeding, traveling, and resting bouts was calculated for each forest plant resource species and used in statistical analyses.

5.2.2 Human Activity within the Forest

Data regarding the local human population were sampled via a) direct observation of evidence of human presence in the forest and b) semi-structured household interviews (Bernard, 2006). Direct observations were obtained from relatively novel camera trapping (Griffiths and van Schaik, 1993) and trail survey (Olupot et al., 2009; Vaidyanathan, 2010; Wiafe, 2010) evidence. Because there are several points of entry into the forest and since a 2011 pilot study indicated a low rate of human presence in the forest, we anticipated remote methods of direct observation would be more efficient than in-person direct observation for this study. At the onset of the study, a total of 20 camera traps were secured and hidden along human footpaths; distributed throughout the trailed section of the forest, as well as along known points of entry into Khau Ca. Humans, like other animals (Sequin, et al., 2003), may make efforts to evade cameras; however, given the dangers of venturing off trail in Khau Ca (e.g. sinkholes and cliffs), a reasonable assumption could be made that most people who entered the forest stayed on or near footpaths. Camera trap data were filtered to exclude images of the same individual on the same day (Tobler et al., 2008).

During trail surveys, evidence of human presence (new tree-cuttings, garbage, fire pits, traps, and encounters with people, for example) was recorded on an all-occurrence basis and the GPS location of each event was noted. All forest trails were

surveyed each season (late dry: January-March, early wet: April-June, late wet: July-September, early dry: October-December) and because we anticipated small sample sizes, the number of new evidence items was combined into wet and dry season data.

5.2.3 Household Interviews

We aimed to carry out 75 semi-structured household interviews, conducted in Vietnamese, balanced between location (commune of residence), estimated socio-economic status levels (low, medium, and high), and ethnicity (Tay, Dao, and Hmong). Interviews were designed to elicit qualitative and quantitative information about household demographics, resource importance and seasonal resource use and were approved by the University of Colorado Boulder's Human Subjects Institutional Review Board (Protocol # 11-0123: Evaluating human and nonhuman primate forest resource use in Ha Giang Province, Vietnam). Both the lead interviewer (Luu Tuong Bach) and the lead researcher (Amy Harrison Levine) passed a Human Subjects Research training module prior to pilot testing interviews.

The interview script was tested prior to meeting with official household respondents. Before piloting the interview tools, researchers assumed it would be possible to isolate one interviewee within the household, but this was not the case. Unless an interviewee was alone in the home, a number of adults (of one or both sexes) would gather around and participate in the interview. The interview team therefore opted to redesign the tool accordingly and conduct household interviews, which did not limit the number of household respondents (although the number and gender of all participating household respondents were recorded for each interview).

The pilot interviews also led to a modification of household size estimation. In this part of Vietnam, many children under the age of 18 must live at a boarding school a significant distance from home. Not only were pilot respondents inconsistent with respect to either including or excluding these children in reported household counts, but the frequency with which these children would return home (weekly, monthly, etc.) was highly variable. Due to the complexity of their inclusion, the best course of action was to consistently exclude children under the age of 18 in household size estimations. Because most households in this area included two or more generations and since most students permanently returned to the area by the age of 18, we concluded that the number of adults (18 and older) within the home was a good proxy for estimated household size, especially since adults were more likely to gather forest resources. The interview pilot test additionally helped hone the interview techniques described below.

The process of selecting household respondents was a collaborative effort. In each commune, local governmental officials assigned one or more local informants to support the interview process. The majority of respondent households were selected by those local informants following guidance from the principal investigator with respect to balancing participants among various locations, SES levels, and ethnicity. A typical interview day would start with a discussion of priority household types. The local informant would accompany the interview team to the first location and once that interview was complete, the principal investigator would commonly ask if a specific neighboring household could be interviewed. Two of these more randomly selected potential household participants declined to be interviewed, but the resulting sample included about 75% of households selected by informants and 25% selected by the

interview team. This method of participant selection is akin to a convenience sampling regime.

Demographics. After acquiring consent and engaging in pleasantries such as sharing a pot of tea, and with a goal of easing interviewees into the discussion, household respondents were first asked a series of easy-to-answer demographic questions. Gender (male/female), age (or year of birth), ethnicity (Tay, Dao, Hmong or other), off-farm employment activity (to the nearest 25% of time), and education level (ranked 0-4, where 0=none, 1=primary education complete, 2=middle school education complete, 3=high school education complete, 4=college or trade school education pursued) were recorded for all adults.

Freelisting. To minimize cultural context concerns (Teufel, 1997), a freelisting technique was employed next (Bernard, 2006; Riley, 2007; Opalinski, 2010). This methodology is designed to analyze data regarding cultural domains, or how people interpret the content of cognitive realms (plants, animals, colors, etc.). Respondents are asked to list all of the things they can think of that belong in a specific category and this is used to calculate a salience score for each category – a measure of the importance of shared knowledge. At least two assumptions are implicit in this methodology. First, researchers must assume items listed first are most important (or at least most familiar) to the respondent. Second is the presumption that most respondents will list the most important things within a particular cultural domain.

For this part of the interview, respondents were asked to name all of the wild forest plants and tree species known to them in each of eight resource-use domains (fuelwood, construction, distillation, fodder, food, medicine, trade, and gardening). Household interviewees were then asked to describe the purpose or function of each. Sometimes problematic, recall methods are more robust when paired with direct observations, as was done here. In addition, probing may increase accuracy of free listed recall by as much as 40% (Bernard, 2006), and was accomplished in this study via redundant questioning and nonspecific prompting. Such probing cues included but were not limited to asking follow-up questions such as, “What other kinds of wild plants or trees are there that you or someone you know has used for X purpose?”

To quantify the freelisted data, the number of resources listed for each category, the number of different uses for each plant species, and the total number of resources listed were used in subsequent analysis. A species accumulation curve was applied to estimate the sufficiency of sample size for each use category – in this case, by plotting the cumulative number of plant species listed as a function of the number of household interviews conducted. The curves were expected to plateau by the time the 75th household interview data was added, indicating only the least commonly used (and thus least important) plants species had yet to be included in the sample. In addition, ANTHROPAC software was employed to analyze salience scores for resources listed within each use-category. This software combines response frequency (the number of times an item appears on the list) and percentage (% of respondents who listed the item) to generate a rank score for each response. The rank score is then divided by the

total number of different items in the list to create a salience score. These scores range from 0.0 (least salient) to 1.0 (most salient, or most important).

Calendaring. The next interview activity was designed to elicit information about when respondents typically utilized previously freelisted resources. A blank twelve-month, traditional lunar calendar was presented to household respondents, who indicated the months and/or weeks during which each listed forest resource was commonly harvested or used. Small stickers corresponding to each previously listed plant species were placed in the appropriate position on the calendar, and notes were taken regarding the described rationale for preferred resource use timing. For quantitative and qualitative analysis, weeks and months were grouped into two seasons: wet and dry.

Scoring. A scoring exercise then prompted respondents to rank the importance of each forest plant species, relative to all other species they listed (after Sheil et al., 2006). Respondents were provided with 100 seeds and were asked to place the seeds within circles corresponding to each free listed resource, such that circles (or resources) with a high number of seeds were viewed as more important than those with fewer or no seeds. The number of seeds piled within each resource circle was recorded and those numbers were converted to a proportional resource importance score. Mean scoring importance scores were then calculated for each free-listed species.

Qualitative Probing. Bernard (2006) outlined a number of probing questions that can be used to uncover reasons behind resource use decisions and these (or similar) questions were employed during the free listing, calendaring, and scoring activities described above. Responses to these probes were analyzed qualitatively and were also coded and quantified to determine how frequently each explanation was given.

Socio-Economic Status. To conclude the interview, respondents were asked to lead a household tour, during which information was recorded about durable assets (fan, TV, radio, motorbike, rice cooker, buffalo, pig), access to infrastructure (phone, electricity, water source), and housing condition (wall, floor and roof condition, and toilet and bathing facilities). Binary data regarding these household assets were used to generate a proxy socio-economic status (SES) score after Lan Vu et al. (2011). This SES index was then validated via correlations with other measures previously demonstrated to mirror socio-economic status, namely education level, amount of off-farm employment, and ethnicity (Bernard, 2006; Lan Vu et al., 2011).

5.2.4. Data Analysis.

Quantitative variables described above were evaluated via a variety of non-parametric statistical tests executed using SPSS statistical software, unless otherwise noted. Because statistical results were bolstered by analyzing trends and anomalies in the qualitative data, and given that research outcomes were applied to the local conservation context and not interpreted as relevant at other study sites, results were considered significant when $p \leq 0.1$.

5.3 Conservation Planning and Evaluation

Once the quantitative and qualitative data were evaluated, the results presented here were incorporated into a TSNM conservation action plan. Perhaps the most widely used method for developing such a plan – the Open Standards for the Practice of Conservation (OS) – was created by the Conservation Measures Partnership (CMP), a consortium of world renowned conservation organizations (CMP, 2007). Based on the principles of adaptive management, OS advocates the use of consistent terminology and backwards design when developing, implementing, evaluating effectiveness of, and adjusting conservation action plans (Salafsky et al., 2002; Salafsky et al., 2008; Margoluis et al., 2009).

Several key terms and definitions arose from this global collaboration. For example, a *goal* details the anticipated impact of a project such as the desired future status of a conservation target. An *objective*, on the other hand, is a statement detailing the desired outcome of a project, focused specifically on threat reduction. Goals and objectives should both be measurable, time limited, and specific. *Threats* are human activities that directly or indirectly degrade one or more conservation targets, which could be species, habitats, and/or ecological processes. A *conservation strategy* is designed to achieve specific goals and objectives and is defined as a group of actions with a common focus that work together to reduce threats, capitalize on opportunities, or restore natural systems. An *indicator* is a precise, measurable entity related to a specific information need such as the status of a target, a change in threat, or progress made toward an objective. OS defines the term *method* as a specific technique used to collect accurate, reliable data to measure an indicator. *Interventions* are activities

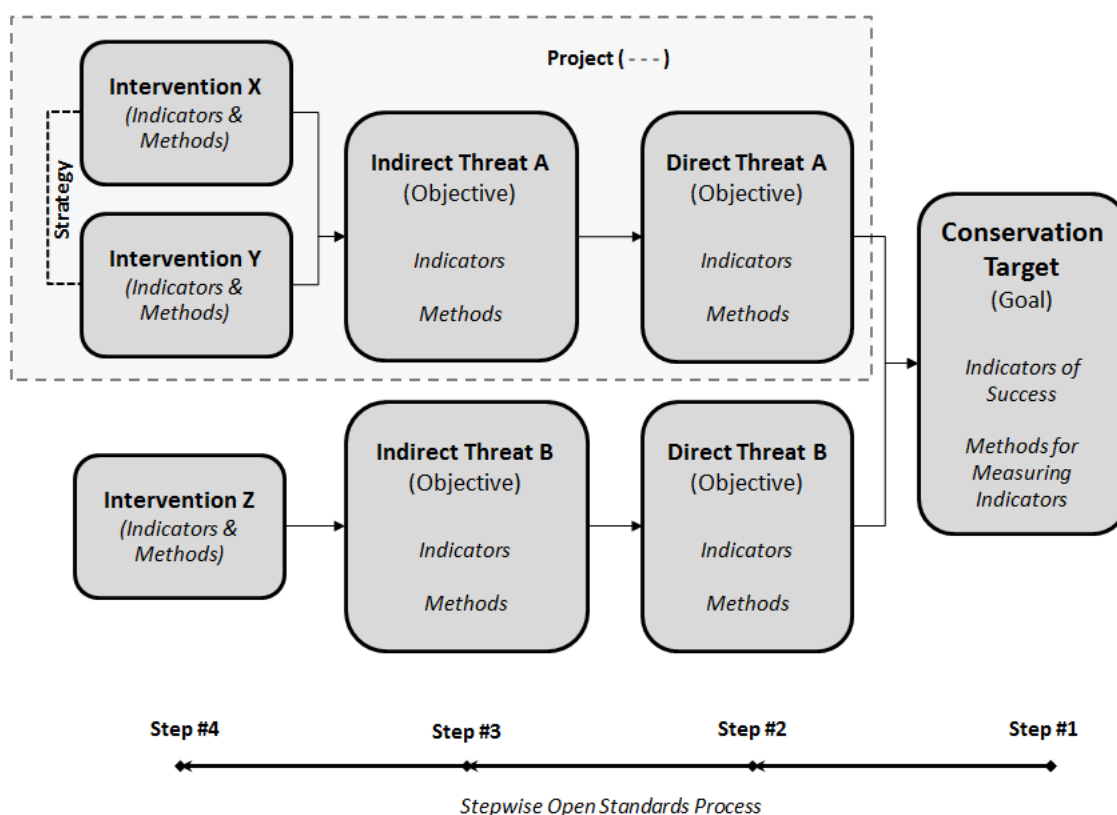
undertaken by project staff to reach one or more objectives. A *project* is a set of interventions undertaken by stakeholders to reach one or more objectives, and a *program* is a group of projects that together aim to achieve a common goal.

The stepwise backwards design process of OS begins by identifying goals for one or more conservation targets and defining success indicators. Next, conservation teams list threats that act as barriers to achieving outlined goals; at the same time clarifying specific, measurable objectives for mitigating those threats. This is followed by a) the identification of potential threat reduction strategies, or sets of interventions and activities designed to reduce anthropogenic threats, as well as b) the selection of indicators and methods that will be used to evaluate the status of threats and conservation targets. What results from this process is a conceptual model outlining a theory of change for a particular conservation strategy [Figure 6]. Such conceptual models can be powerful planning and evaluation tools, and Margoluis et al. (2009, p. 93) argue that,

Most conservationists erroneously believe that by measuring only the dependent variable (e.g., species and ecosystems), one can tell if conservation interventions have been successful. In fact, to reach this conclusion one must measure incremental change at various points along a theory of change, from the intervention to intermediate outcomes to ultimate impacts (Foundations of Success, 2007). What interventions led to knowledge change? What knowledge change led to attitude change? What attitude change led to behavior change? What behavior change led to a mitigation of threats? Which threat mitigation led to species or ecosystem improvement? These “incremental evaluations” help evaluators break down complexity, understand system components, and reconstruct an understanding of the conditions within which interventions operate. They also foster incremental learning and help develop a body of evidence – a plausible case for association, causality, and ultimately conservation impact.

Thus, by clearly connecting and measuring changes in human behavior resulting from conservation interventions, as well as assessing threat status and progress towards reaching a conservation target, it is possible to more clearly demonstrate whether the chosen conservation interventions truly result in achieving well-defined conservation goals (Margoluis et al., 2009; Jenks et al., 2010; Heimlich, 2010).

Figure 6. Open Standards for the Practice of Conservation conceptual modeling process for developing, implementing and evaluating a conservation program.



The research described here is focused on evaluating threats to Tonkin snub-nosed monkey survival within the TSNM SHCA. More specifically, this investigation will

assess the level and types of within-forest, anthropogenic threats. Once these threats are more clearly identified, it will be possible to suggest a suite of specific interventions – a strategy for threat reduction – that will ultimately lead to *R. avunculus* conservation success.

CHAPTER VI

UNDERSTANDING HOW SOCIO-ECONOMIC STATUS IMPACTS HUMAN FOREST RESOURCE KNOWLEDGE

Abstract

Many people living in rural areas within developing countries are dependent upon natural resources for survival. Human use of natural resources can have a significant impact on biodiversity and conservation. This is especially true in countries such as Vietnam, where human population density is very high. Although few debate the idea that socio-economic status (SES) factors are related to patterns and frequency of forest product procurement in the developing world, it seems SES has variable, context-specific impacts on resource use dynamics. Measuring SES can be time-intensive, and in communities that do not rely primarily on a cash-based economy, estimating SES is not as simple as determining income rates or monetary net worth. Modeled after methodology employed by Lan Vu et al. at a site in northern Vietnam (2011), this study aimed to a) evaluate the total assets (durable goods, access to infrastructure, and household condition) for household respondents, b) validate the resulting total assets index as an indicator of SES at the study site, and c) use the index to identify site-specific trends in resource procurement expertise for people of differing SES levels.

Knowledge of how forest use dynamics correlate with SES will be used to develop biodiversity conservation interventions designed for specific target audiences.

6.1 Introduction

Socioeconomic status is a multi-dimensional variable that often interacts with human forest resource usage patterns, sometimes significantly impacting conservation interventions (Borgerhoff Mulder and Copollilo, 2005). Such interaction between socioeconomic status (SES) and forest resource use has been demonstrated to occur in Vietnam (Quang and Noriko, 2008; Gomiero et al., 2010; McElwee, 2010). Traditionally, SES has been defined on the basis of education, occupation, or income – or on a combination thereof (Bernard, 2006). These SES variables are also independently related to patterns of human forest resource use (i.e., education: Godoy and Contreras, 2001; occupation: Uberhaga et al., 2012; income: Quinlan, 2005; McElwee, 2010), as is another social factor: ethnicity (Baral and Heinen, 2007). In a study based in Nepal, Adhikari et al. (2004), found that all of these factors were related to forest resource use in one way or another. The type of influence socio-economic factors have on forest product procurement is debatable, however. Some studies suggest low SES leads to frequent use of forest resources (Godoy et al., 1995; Quang and Noriko, 2008; Phyal et al., 2006; Appiah et al., 2009; Robbins et al., 2009; Davidar et al., 2010) while others demonstrate the opposite to be true (Adhikari et al., 2004; Uberhuaga et al., 2012). Therefore, a clear understanding of the unique relationship between SES variables and forest product expertise at specific study sites will serve to

improve forest conservation activities such as education and awareness interventions that tailor programs to specific audiences.

Socioeconomic status is difficult to measure, particularly in heavily subsistence-based societies, where cash income does not contribute as much to SES as it does in the developed world. In more industrialized locations, SES can be efficiently assessed by combining measures of income, education, and occupation (Bernard, 2006). The same measures are not always as effective in developing countries, where income often comes from multiple sources, can fluctuate greatly from season to season or year to year, and where SES is not necessarily dependent mainly upon cash income (Lan Vu et al., 2011). In addition, methods used to clarify the multitude of factors impacting SES in predominantly subsistence-based societies are often resource and time intensive (e.g., McElwee, 2010; Uberhuaga et al., 2012).

6.1.1 Total Assets

Measurement of total assets is becoming a common method for rapidly and accurately assessing SES in rural areas and developing nations. Total assets methodology focuses on collecting three types of information: a) ownership of durable goods, b) access to infrastructure, and c) household condition. Together, these three asset categories have been shown to closely correlate with more intensive rural SES assessment methods (Lan Vu et al., 2011). However, there are at least two challenges with utilizing this methodology. First is the complexity of defining which assets, infrastructure, and housing characteristics truly reflect regional SES. Second is the challenge of determining how to aggregate variables to achieve a derived SES index

resulting in a range of critical values that accurately represent real-world socioeconomic status.

In 2011, Lan Vu and colleagues validated the use of a total assets index as a proxy for SES in rural Hai Duong Province, in northern Vietnam. A total of 28 items belonging to the three assets categories (durable goods, access to infrastructure, and household condition) were ranked on various scales and the results were loaded into a principal components analysis. The analysis indicated that 15 of the original 28 variables would be useful in deriving a robust SES index. Not only were these 15 assets determined to be internally consistent, they were also validated via demonstrating a clear linear relationship with a more traditional SES proxy: education level.

Another method for determining how well an index represents a real-world, accurate scale is known as the Guttman scaling technique. Most researchers use indices that are not cumulative in nature; it does not matter which items representing the index are assigned, correct, or present/absent. In the case of an assets index, for instance, people either own a radio, a stove, a sewing machine, a wardrobe, and/or a television or they do not (DeWalt, 1979). A household can present with an assets score of three whether they own the former three items (radio, stove, and sewing machine) or the latter three (sewing machine, wardrobe, and television). Since either scenario results in the same score, an assets index of three may not have significant meaning within the population being studied. To create a more precise, uni-dimensional index – one in which the ownership of one asset would *predict* ownership of another – Bernard (2006) recommends employing the Guttman scaling technique.

The Guttman coefficient of reproducibility (*CR*) is designed to test how closely a given data set reproduces a perfect scale (Bernard, 2006). By sampling the presence (+) or absence (-) of items and then arranging them in the best possible order, such that the presence of one item predicts the presence of another, researchers can calculate Guttman's *CR* as follows: $1 - (\text{number of errors} / \text{number of entries})$. Items in a cumulative Guttman index that scale with a *CR* of 0.9 or higher are typically considered uni-dimensional for the sample tested. In other words, the items used in a robust Guttman index can be assumed to represent a hierarchical measure of one single fundamental concept, such as socio-economic status.

6.1.2 Freelisting

The freelisting technique is a standard anthropological method used to examine cultural domains (Smith, 1993; Bernard, 2006; Riley, 2007; Schrauf and Sanchez, 2008). Ethnobotanists often employ this methodology to better understand human use of forest plant resources (Quinlan, 2005; Castaneda and Stepp, 2007; Ghorbani et al., 2012). A quick, efficient, and simple method, freelisting can indicate areas of consensus and variation within a community. By taking into account both frequency and rank, salience of items listed represents group consensus. Differences in freelist content and length, however, can be indicative of domain variability. For example, freelist length can act as a surrogate for depth of knowledge of a particular category of information, such that experts' lists are longer than novices' (Quinlan, 2005; Ghorbani et al., 2012).

A weakness of the freelisting methodology has to do with the exhaustiveness of the information provided. Other, more time-consuming methods, such as completing forest walks with expert informants or conducting several long interviews with key respondents can increase list exhaustiveness. On the other hand, informants may provide a short freelist with a goal of ending the interview quickly. Or, they may decide to intentionally not share items they know, as a way of protecting their traditional ecological knowledge. In addition, respondents are expected to be able to recognize more items than they can name. Probing however, such as with redundant questioning (Bernard, 2006), can help maximize freelist recall output (Quinlan, 2005).

6.1.3 Research Objectives

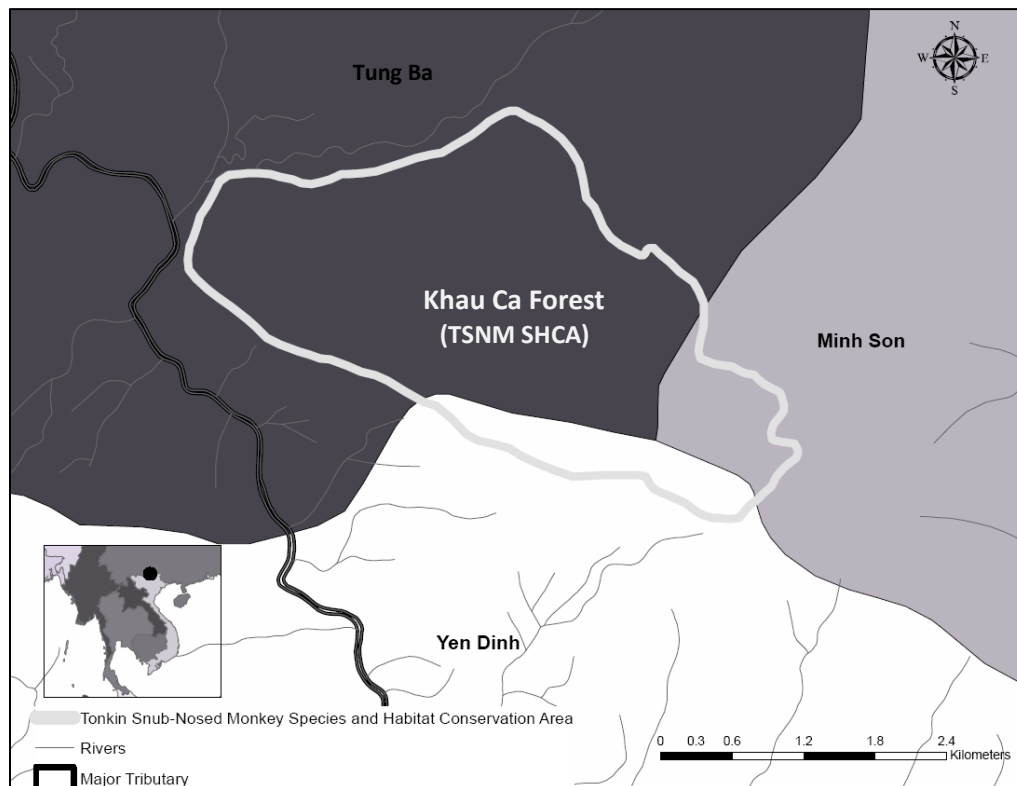
The research presented here evaluates interactions between a derived, validated total assets SES index and forest resource expertise in Vietnam's northernmost province, Ha Giang. Previous research in rural Vietnam indicates that households with high socio-economic status tend to be less well versed in forest resources than households with lower SES (McElwee, 2010; Quang and Noriko, 2008). We predict the same will hold true for households of the three Ha Giang communes that surround Khau Ca forest. Understanding the relationship between human knowledge of forest plants and SES variables is important at this site, as it will help customize conservation interventions aimed at protecting the critically endangered Tonkin snub-nosed monkey (*Rhinopithecus avunculus*) population that inhabits an adjacent protected area.

6.2 Methods and Materials

6.2.1 Study Site and Study Population

Located along the Chinese border, Ha Giang is Vietnam's northernmost province. There are three subsistence-based communes within Ha Giang that surround the Khau Ca forest (22° 50' N, 105° 07' E), also known as the Tonkin Snub-Nosed Monkey Species and Habitat Conservation Area [Figure 7]. Tung Ba is a wide and sprawling commune mainly comprised of large rice-paddy covered valleys, dotted with jagged limestone mountains of varying sizes. Southeast of Tung Ba, Yen Dinh is a long and narrow commune where the rice-paddy valleys are sandwiched between two long, tall mountain chains. The third commune, Minh Son, is also wide and sprawling, but with fewer valleys and more mountainous terrain than either Tung Ba or Yen Dinh.

Figure 7. Study area map, showing locations of all three communes (Tung Ba, Yen Dinh and Minh Son).



Wealth and Income. A protected area feasibility study conducted in 2008 by the Ha Giang Forestry Protection Department reported that wealthy households in Tung Ba, Yen Dinh and Minh Son typically earned the equivalent of just over \$700 per year, mid-range households earned an average of about \$400 each year, and those with an annual income of less than \$150 (about 35% of households surveyed) were considered to be living in poverty. Livestock, crop, and forest product sales accounted for nearly 100% of annual income for most households. In addition, people from all three communes considered themselves to be farmers, even if they were engaged in significant off-farm employment (Harrison Levine, unpublished data).

Education. Whether living in urban or rural areas, Vietnamese people are comparatively well-educated. The literacy rate within the country is currently estimated at 94.5% (CIA, 2016). Nearly all children complete a primary school level of education and at least half go on to secondary school. Data from recent research indicate a similar trend is true within the three communes surrounding Khau Ca forest. All children are expected to begin preschool at the age of 18 months, and to attend primary school. In addition, provisions are made to ensure school attendance. Most students in these communes attend middle school in their home communes; however, the high school is located relatively far away in the capital city of Ha Giang. Thus, attendance rates drop at this level of education due to travel and financial barriers (Harrison Levine, unpublished data).

Ethnicity. People of Tung Ba, Yen Dinh, and Minh Son most commonly hail from three of Vietnam's 53 ethnic minorities. The dominant ethnic group in this part of Ha Giang Province is the Tay people, with over 7,500 individuals as of 2008 (Ha Giang FPD et al.). Tay inhabitants have lived in the region since before written records, and they are the second most populous ethnic group in all of Vietnam (but note that they only account for 1.9% of the national population). This ethnic group, most often dwelling at lower elevations in the flat fertile valleys, practices fairly sustainable composite rice paddy and swidden agriculture subsistence, and tends to have more favorable socio-economic conditions than the two other groups (Tran Duc Vien, 2003). In 2008, people of Dao (over 1,450 individuals) and Hmong (nearly 650 individuals) ethnicities completed the local population of nearly 10,000 (Ha Giang FPD et al.). The Dao commonly practice agroforestry in the mid-level altitudes of the region (Tran Duc Vien, 2003). They are known for their breadth of knowledge of wild medicinal plants (ICEM and PADP, 2003) and hunting contributes to their group identity (Novellino, 2000). Hmong people, the poorest and most marginalized ethnic group, are also the most recent immigrants to the area, having arrived 100-300 years ago from China (Lee and Pfeifer, 2006). The Hmong are often considered backwards, environmentally destructive, or are even believed to be savages by other ethnic groups (Blankston, 2007). In Ha Giang, they live mainly at higher elevations and practice a combination of shifting, slope-side agriculture and forest product procurement (Tran Duc Vien, 2003).

Forest Product Resource Use. The vast majority of human inhabitants of this region practice a largely subsistence-based lifestyle. They grow and make the majority

of the things they need to survive. Traditional wooden homes, whether resting on stilts or on the ground, are made by the families that dwell in them. Most house walls and floors are made of wood slats or woven bamboo, and roofing material is typically thatched palm. The same materials are also used to construct outbuildings, fencing, and household implements. Fuelwood, most commonly burned within a traditional open hearth inside the home, is used to cook food for people and livestock, to sanitize water, and to heat the home in colder months. Local people distill their own rice wine and other spirits and forest plants are indispensable in the process. Although most area residents have vegetable and tree gardens, timber and non-timber forest products are also regularly collected for livestock fodder, human consumption, traditional medicine, and for trade or sale in local markets. In other words, harvesting of forest plants plays a significant role in the daily lives of most people living in these three communes of Ha Giang Province.

6.2.2 Data collection

A total of 75 household interviews were conducted in Ha Giang between April 2012 and March 2013. Within each of the three communes, a convenience sample of respondent households was chosen either upon the recommendation of local informants, or by one of the two lead interviewers whenever possible. More rigorous sampling methods were not possible in this region, due to local customs and stipulations from local governmental officials who insisted that our informants should make final decisions about respondent households to include in the sample. Interviews were conducted in Vietnamese by the second author, both authors were successfully

trained in human subjects research, and the research and interview script were approved by the lead author's Institutional Review Board. In addition, at least one member of each household provided verbal and written consent prior to participating in the study.

Data collected during interviews included household location (GPS), total number of adult household members (18 years or older), and age, gender, ethnicity (self-ascribed), level of education (ranked 0 to 4, based on grade level completed), percentage of off-farm employment (0, 25, 50, 75 or 100% of time spent in off-farm, income-generating work), and birth place of all adult household members. Note that we chose not to include minor children in the total number of household members, given the large proportion of children who live either in school boarding facilities or with host families near their schools and the difficulties of determining whether each child was truly a household member most of the year.

In order to apply a Guttman scale technique to derive an SES index that would accurately reflect SES in this part of the world, we gathered information regarding the presence or absence each household's total assets. We employed several asset variables validated by Lan Vu et al. (2011), including durable goods such as electric fan, motor bike, television, cupboard (which we renamed "wardrobe"), and access to water as infrastructure. And in terms of household condition, we assessed condition of a household's floor, roof, and restroom facilities. Based on our knowledge of people's assets in these three communes, we also chose to evaluate items that were eliminated from Lan Vu's derived index, including pig, buffalo, mobile phone (there are no land lines in the region), and wall condition. As gas cookers were virtually absent from the

communes, we looked for rice cookers instead, and we also added two assets not considered by Lan Vu et al.: electricity (as access to infrastructure) and home size (as part of housing condition). The resulting set of 15 assets (7 durable goods, 3 infrastructure access, and 5 housing condition) were judged to be present (+) or absent (-), or in good (+) or poor (-) condition, for each household [Table 3].

To gain a clear picture of forest resource knowledge and expertise, we asked household respondents to freelist all the wild forest plants that people can use for each of the following categories: firewood, construction, human food, livestock fodder, rice wine distillation, traditional medicine, and trade/market. The use of these particular categories was based on those employed by others undertaking similar research (i.e. Riley, 2007), on specific mention of these types of uses for forest products from Khau Ca specifically (Ha Giang FPD et al., 2008), and from personal observations of domain differentiation gleaned through a set of about 15 pilot interviews. The freelist exercise was explained to the respondent/s and then the first resource use category was provided. Respondents were given time to consider the category, name as many resources that fit into that category as they could, and after about 5-10 seconds of silence, we commenced redundant questioning and nonspecific prompting (Bernard, 2006) to probe for additional resources. Once a cue was provided and followed by an additional 5-10 seconds of silence, respondents were asked if they were done with that list and if so, the interview team moved on to the next use category. If respondents could not think of a single item within a particular resource use category, the interviewer moved on to the next category.

Table 3. Fifteen household assets assessed in this study.

Asset Category	Asset Name	P-A or G-P*	Assessment Rubric
Durable Goods	Electric fan [‡]	P-A	Own one or more functioning electric fans
	Television [‡]	P-A	Own one or more functioning television sets
	Rice cooker**	P-A	Own one or more functioning rice cookers
	Motorbike^{‡,**}	P-A	Own one or more functioning motorbikes
	Wardrobe [‡]	P-A	Own one or more large wardrobes, in addition to cupboard used for kitchen wares
	Buffalo**	P-A	Own one or more adult water buffalos
	Pig**	P-A	Own one or more adult pigs
Access to Infrastructure	Mobile phone**	P-A	Own one or more functioning mobile phones and have access to cellular service at home
	Electricity**	P-A	Regular, uninterrupted access to government-supplied electricity considered present; less-reliable generator-produced electricity considered absent
	Water^{‡,**}	P-A	Regular, on-property access to clean water such as a well, stream or irrigated water considered present; access to polluted water and/or having to walk off property to water source and carry water back to household considered absent
Household Condition	Walls**	G-P	Walls made of solid timber or concrete considered good; walls made of bamboo, rotting wood, plastic tarps, or in disrepair considered poor
	Floor [‡]	G-P	Floors made of solid timber, concrete or tiles considered good; floors made of bamboo, rotting wood, crumbling concrete, dirt, or in disrepair considered poor
	Roof^{‡,**}	G-P	Roof made of corrugated concrete or palm thatch considered good; roofs that were rotting, covered in plastic tarps, or otherwise in disrepair considered poor
	Size**	G-P	Home is considered good sized if there were at least two bedrooms and there was ample space to comfortably entertain several guests
	Bathroom^{‡,**}	G-P	Bathroom condition considered good if there was a flushing toilet, shower plumbing, or was made of concrete and/or tiles; absence of both toilet and shower facilities considered poor

*P-A = Presence/Absence; durable goods and access to infrastructure were scored as being either present (+) or absent (-). G-P = Good/Poor; we scored household condition as either good (+) or poor (-). Whenever necessary, authors discussed examples in the Assessment Rubric column before assigning a score of (+) or (-).

[‡]Indicates assets also used in Lan Vu's (2011) derived SES index.

**Indicates the ten asset variables included in the final, derived SES index for the present study, but note that Buffalo and Pig were combined into a single durable goods asset: Livestock.

6.2.3 Data Analysis

To evaluate the interaction between SES and forest resource knowledge, list lengths (Quinlan, 2005) for each resource use category were compared with the household SES total assets indices derived via the Guttman scaling technique (Bernard, 2006). We also compared list length with other social variables including education, employment, ethnicity, and commune of residence of respondents. Freelists were analyzed using ANTHROPAC software (Smith, 1993; Smith and Borgatti, 1998) and non-parametric Spearman's rank correlations or Mann-Whitney *U* tests were employed for these comparisons.

Before the statistical tests were run, the derived SES index was validated by comparing the index to traditional SES measures including mean ranked household education level, mean percent of off-farm employment, and dominant household ethnicity. In doing so, we tested the assumption that if the derived SES index was an accurate proxy for household wealth or living standard, it would be significantly related to at least one other socio-economic factor. Spearman's rank correlations were used to compare the SES index with education level and employment, and a series of three, one-tailed, Mann-Whitney *U* non-parametric tests were applied for the SES-ethnicity comparison. All statistical results were conducted using SPSS statistical software unless otherwise noted and were considered significant when $p \leq 0.1$.

6.3 Results

6.3.1 Interview Sample

Interviews were distributed evenly among the three communes (Tung Ba: 26, Yen Dinh: 25, Minh Son: 24) and we worked with local informants to attempt to balance

the number of household respondents suspected to be wealthy, mid-range, and poor. Additionally, we gathered interview data from all three ethnic minorities such that 56% of respondent households were Tay, 26% were Dao and 16% were Hmong (one household declined to provide information regarding ethnicity). The resulting sample distribution is outlined in Table 4. This matrix clearly shows that while interview sample sizes were considerable and consistent across the three communes and were reflective of the size of ethnic group populations in the region, when these two factors were also combined with a third layer – namely SES – the number of households interviewed within each cell in the table is quite small, ranging from 0-11.

Table 4. Interview sample distribution among communes, ethnicities, and socio-economic status levels.

Ethnicity & SES	Number of Households Interviewed			TOTAL
	<i>Tung Ba</i>	<i>Yen Dinh</i>	<i>Minh Son</i>	
Tay				42
High SES	7	4	4	15
Med SES	4	11	2	17
Low SES	6	4	0	10
Dao				20
High SES	1	1	1	3
Med SES	3	3	5	11
Low SES	3	1	2	6
Hmong				12
High SES	0	0	2	2
Med SES	0	1	5	6
Low SES	2	0	2	4
TOTAL	26	25	23	74

6.3.2 Selection of Total Assets Variables

A total of 15 variables belonging to the three asset categories (durable goods, access to infrastructure, and housing condition) were included in the original data set.

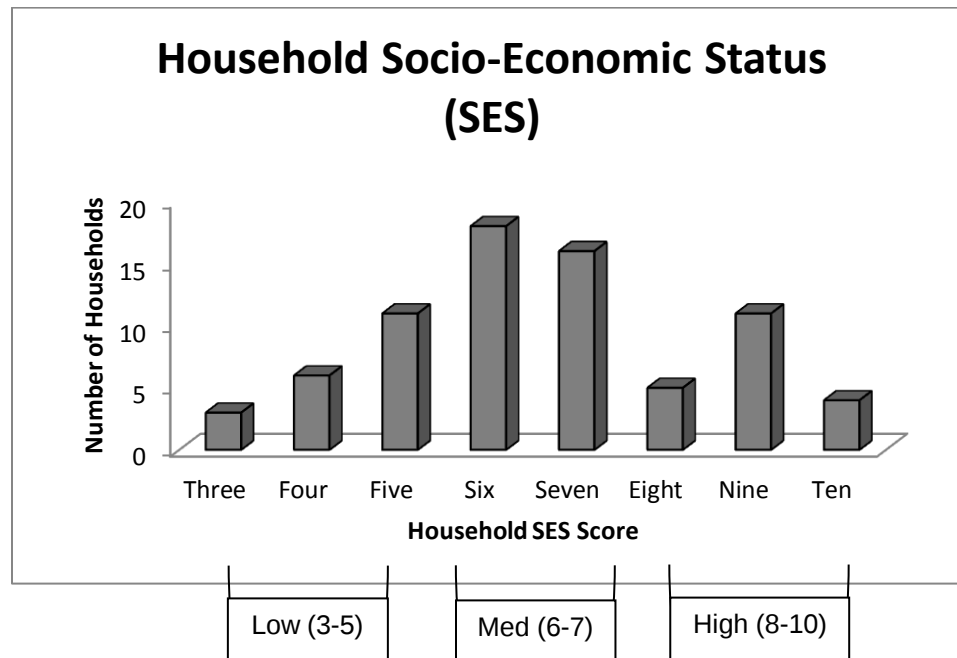
Using the process described by Bernard (2006) as a guide, we tested the coefficient of reproducibility (*CR*) for each of the three asset categories. Results suggested we should a) drop three durable goods assets (fan, television, and wardrobe) none of which further explains variation or helps predict ownership of other items in this asset category, b) combine two other durable goods (buffalo and pig) into one asset (livestock), because only when ownership of either animal was considered was this asset predictive of the possession of other goods, and c) drop one housing condition (floor), which did not reliably predict the presence of any other housing condition. These adjustments resulted in a total assets Guttman scale that ranged from 0-10, with a combined *CR* of 0.86 [see double asterisks in Table 3].

6.3.3 *Socio-Economic Status*

Total assets were evaluated for all 75 households interviewed. SES scores ranged from 3-10 with a mean of 6.59 [Figure 8]. For analytical and discussion purposes, we considered total assets scores ranging from 3-5 as low SES, scores from 6-7 were medium-range, and high scores were those with a score of 8-10.

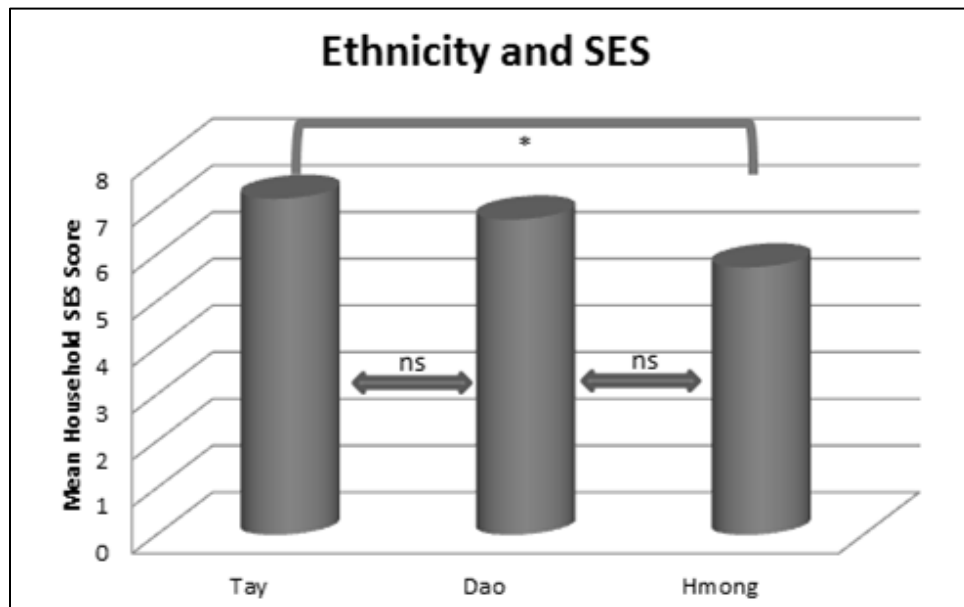
When we correlated the derived SES index with education level and off-farm employment, we observed patterns similar to those presented by Lan Vu et al. (2011). SES and mean ranked household education level exhibited a significant positive correlation ($r_s = 0.358, p \leq 0.01$). However, SES and mean household percentage of off-farm employment were not significantly correlated ($r_s = 0.121, ns$), showing only a weak positive relationship.

Figure 8. Histogram demonstrating respondent household socio-economic status index scores, as measured using total assets methodology.



We additionally compared the derived SES total assets index with self-ascribed ethnicity. Of the 75 household respondents, only two contained individuals of more than one ethnicity. In both cases, one ethnicity was clearly dominant (3 or 4 adults were of one ethnicity, while one was of another), so we evaluated the ethnicity variable based on the dominant household ethnicity. A series of three Mann-Whitney *U* tests demonstrated that while there was no significant difference between Tay and Dao or between Dao and Hmong dominant households, Tay-dominant households in the sample had significantly higher SES scores than Hmong ($p \leq 0.05$). In addition, the diagram in Figure 9 shows a clear negative progression in SES scores from Tay (highest mean derived SES), to Dao, to Hmong (lowest SES).

Figure 9. Significant (*) and insignificant (ns) differences between mean total assets scores for Tay ($\mu = 7.2$), Dao ($\mu = 6.8$), and Hmong ($\mu = 5.7$) households.



Given the strong but not exact relationship between SES scores and both education level and ethnicity, as well as a Guttman *CR* of 0.86, we considered the total assets index utilized here to be a very close approximation to real-world SES of the study population. We also opted to compare forest resource expertise with other SES variables (education, employment, and ethnicity) as well as with household location (commune) to ensure a thorough picture of factors that may contribute to varying levels of forest product knowledge.

6.3.4 Resource Use Categories

Households were asked to list wild forest plants that local people use in each of the seven usage categories specified above. Items listed were cross-referenced among the four languages present in the region and then standardized prior to data analysis.

The total number of items listed, mean list length, and total number of lists for each resource use category are shown in Table 5.

Table 5. Knowledge of seven human resource use categories was evaluated in this freelist study.

Resource Use Category	Total Number of Plant Taxa Mentioned	Mean List Length	Number of Lists (Number of Households)
Fuelwood	55	3.78	72
Construction	39	3.76	74
Distillation	15	2.24	33
Fodder	43	2.22	49
Food	49	3.08	64
Medicine	19	1.92	37
Trade	51	2.71	59

Whereas fuelwood and construction taxa would all be considered forest timber products, and those used for distillation were all non-timber forest products (NTFP's), plants used for fodder, food, medicine, and trade fell into both timber and NTFP groupings. A total of 72 timber plants and 106 NTFP's were listed during the household interviews [see Appendices A and B].

Fuelwood and Construction. The 75 interviews indicated trees harvested for fuelwood and construction had the highest mean list lengths ($\mu = 3.78$ and 3.76, respectively) and the largest number of respondents providing a list (96% and 99% of households), compared to other plant use categories. Size of lists, when offered, ranged from 1-12 in both timber use categories – but note that the single list length of 12 was an outlier and most lists ranged between 1-8 taxa. Therefore, this outlier was removed from further analysis. Still, when taken together, this information suggests that compared to other categories, various plants especially useful for fuel and construction

are well-known forest commodities within the community as a whole. Important to note, though, is that more than 40% of the fuelwood ($n = 35$) and construction ($n = 22$) taxa listed by household respondents were listed only once. This high percentage of infrequently mentioned plants may indicate either infrequent or passive use, or an individual family's distinct name for particular plant taxa (idiolect).

Distillation. A mere 15 wild NTFP's were listed as those selected for distilling rice wine and other locally brewed spirits. List length ranged from one to five plants, averaging 2.24 taxa. Significantly, only 33 households (44%) had any knowledge of plants used in the distillation process. This demonstrates a relatively low level of expertise in wine-making for most inhabitants of the study area. Wine and the plants used to make it are both readily available at local markets, so many (including at least 27% of respondents) buy their wine and/or wine-making materials and thus do not profess any knowledge on the subject.

Fodder, Food, Medicine and Trade. The remaining four categories are made up of both timber and NTFP's, but unlike with construction and sometimes fuel use, it is rare for the full plant to be harvested for these purposes. Fodder (8 trees, 35 NTFP's), food (13 trees, 36 NTFP's), medicine (6 trees, 13 NTFP's), and trade (21 trees, 30 NTFP's) showed mean list lengths ranging between 1.92 and 3.08. Most lists were two or three plant taxa long and maximum list size was between 5-8 plants in these categories. This, combined with a modest number of households providing lists for

each category, is indicative of a generally moderate level of knowledge about plants used as fodder, food, medicine, and trade items among the community members.

6.3.5 Socio-Economic Parameters and Resource Knowledge

Overall, each of the social parameters evaluated here were found to have a statistically significant relationship with one or more resource use categories.

Spearman's rank correlation coefficients (r_s) examining resource use categories and SES, education, and off-farm employment are shown in Table 6.

Table 6. Spearman's rank correlation coefficients (r_s) resulting from comparisons of resource use categories and socio-economic parameters, with degrees of freedom for each category provided (df).

Resource Use Category	Total Assets SES Score	Household Education Level	Percentage of Off-Farm Employment
Fuelwood ($df=70$)	$r_s = (-0.0283)$	$r_s = 0.191$	$r_s = 0.151$
Construction ($df=72$)	$r_s = 0.361^{***}$	$r_s = 0.229$	$r_s = 0.082$
Distillation ($df=31$)	$r_s = 0.106$	$r_s = 0.342^*$	$r_s = 0.077$
Fodder ($df=47$)	$r_s = (-0.329)^{***}$	$r_s = (-0.122)$	$r_s = 0.128$
Food ($df=64$)	$r_s = (-0.137)$	$r_s = 0.297^{**}$	$r_s = 0.208$
Medicine ($df=35$)	$r_s = (-0.091)$	$r_s = 0.192$	$r_s = 0.057$
Trade ($df=57$)	$r_s = 0.190$	$r_s = 0.128$	$r_s = 0.356^{***}$

* $p \leq 0.1$, ** $p \leq 0.05$, *** $p \leq 0.01$

Socio-Economic Status. The validated total assets SES score was strongly correlated to expertise in resources used for construction and fodder, but was not related to local knowledge of other use categories. High SES was indicative of a long list for construction timber resources ($r_s = 0.361$, $p \leq 0.01$), whereas greater SES demonstrated a robust negative relationship with knowledge of fodder resources ($r_s = -0.329$, $p \leq 0.01$), such that a more educated household knew less about plants that could be used to feed livestock.

Education Level. Mean household education level varied predictably with list length of two resource use categories: plants used in distillation and as food for human consumption. The positive relationship between education and distillation expertise ($r_s = 0.342, p \leq 0.1$), as well as that between education and food ($r_s = 0.297, p \leq 0.05$) shows that as mean household education level rises, knowledge of resources used as food or in making wine also increases.

Off-Farm Employment. Expertise in only one resource use category was significantly related to mean household percentage of off-farm employment. A strong positive correlation between trade and employment suggests that those who spend more time earning income are more knowledgeable about products available in market. This is not surprising given that those earning income have more money to spend.

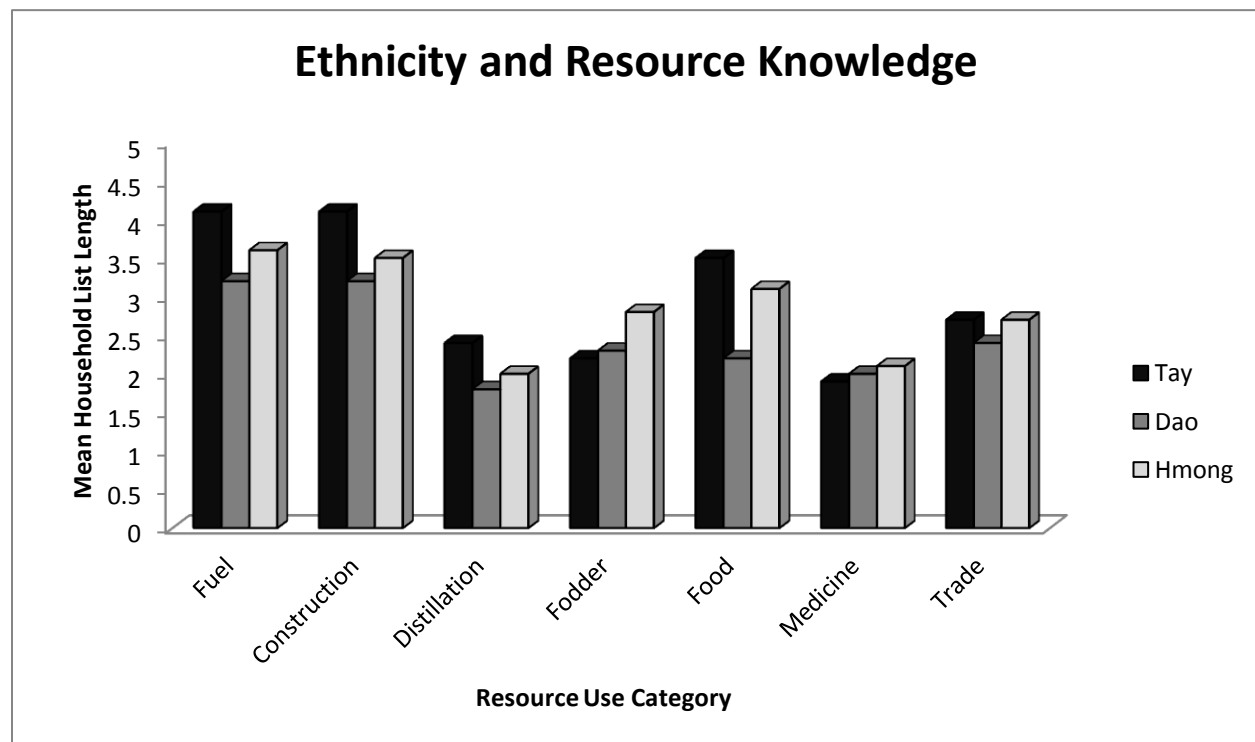
6.3.6 *Ethnicity, Location, and Resource Knowledge*

Two variables, self-ascribed dominant household ethnicity and the commune within which a family resides, were compared with resource use by employing a series of non-parametric Mann-Whitney U tests. Statistically significant relationships were found to exist between both ethnicity and commune, and list length for most resource use categories.

Ethnicity. Self-ascribed household ethnicity was a strong predictor of knowledge about fuel, construction, and food resources. As demonstrated in Figure 10 below, Tay households had significantly longer fuel and construction list lengths than Dao

respondents (fuel: $p = 0.0181$, construction: $p = 0.0346$), as well as longer fuel lists than Hmong (fuel: $p = 0.0273$). However, comparisons between Tay and Hmong construction lists, and between Dao and Hmong fuel and construction lists were not significant. The Dao people also demonstrated the least amount of knowledge about wild forest plants used for human consumption. Both Tay ($p = 0.003$) and Hmong ($p = 0.052$) household lists were significantly longer than those provided by Dao families. All remaining list length comparisons between communes were not significant.

Figure 10. Comparison of the three different local ethnic groups – Tay, Dao and Hmong – in terms of timber and non-timber forest product knowledge (as measured via list length).

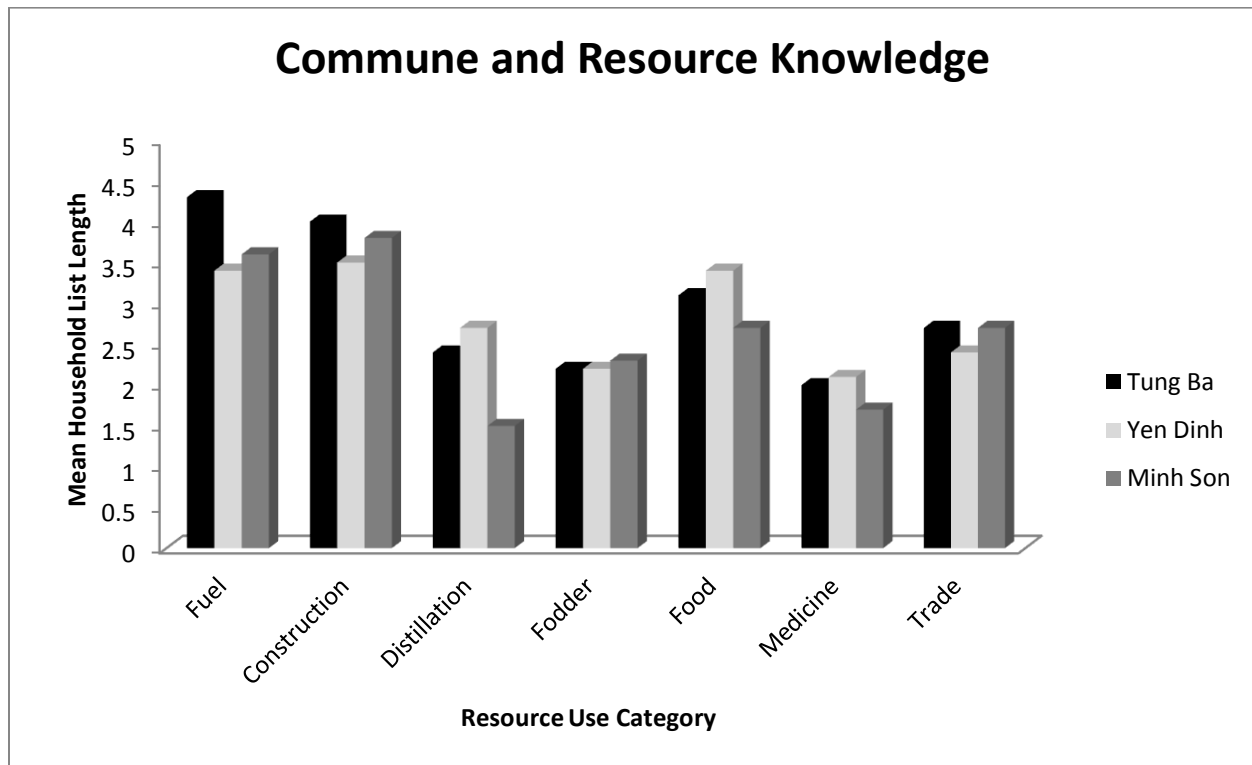


Also important to note is that the ethnic composition of the households sampled from the three communes varied, but may not be truly representative of the three populations. In Tung Ba and Yen Dinh, respondents were primarily Tay households

(67% and 76%, respectively) followed by Dao (25% and 19%, respectively) and Hmong (8% and 5%, respectively). On the contrary, interviews conducted in Minh Son were distributed similarly among all three ethnic groups (Tay = 25%, Dao = 29%, Hmong = 33.3%). The majority of Tay interviews took place in Tung Ba and Yen Dinh, most Hmong interviews occurred in Minh Son, and interviews with Dao households were conducted with comparable frequency in all three communes.

Commune (Household Location). The commune within which each household was located was also compared here, based on observations that list lengths for some resource categories varied by location during the interview process. Indeed, significant differences were detected between commune residents for fuel and distillation resource knowledge [Figure 11]. The size of fuel lists from respondents in Tung Ba commune were longer than those in Yen Dinh (fuel: $T = 64.0$, $p = 0.0728$) but the other two commune comparisons were not significant, nor was there any significant difference between construction list lengths among communes. Households in Tung Ba and Yen Dinh knew significantly more about plant products used in making wine and spirits than did those of Minh Son (Tung Ba – Minh Son: $p = 0.049$, Yen Dinh – Minh Son: $p = 0.042$). It is also important to note that Tung Ba residents accounted for 58% ($n=19$) of the 33 lists provided, whereas only six households from Yen Dinh and eight from Minh Son offered knowledge of one or more distillation resources. None of the other commune comparisons within each resource use category demonstrated a significant association.

Figure 11. Comparison of timber and non-timber forest product knowledge in households from Tung Ba, Minh Son, and Yen Dinh (as measured via list length).



6.4 Discussion

Each of the socio-ecological parameters evaluated in this study provided explanatory value for understanding variability in human knowledge of forest plant products. The only resource use category that was unrelated to any of the social variables researched was that of traditional medicine. As a resource use domain, medicine had the lowest mean list length and only about half of all household respondents could name even one wild plant used for medicinal purposes. When we probed for information about why medicinal knowledge was not higher, several households indicated that rather than learning usefulness of plants for preventing or curing ailments themselves, they were more likely to seek help from a local traditional

medicine expert. We interacted with one such individual – an elderly Dao man living in Minh Son commune – but when he asked for payment in return for his knowledge, we were unable to dig further as we had not secured approval or funds for providing financial compensation to respondents.

Familiarity with timber and non-timber forest products most useful for livestock fodder, human consumption, and for sale in local markets were each related to one or more socio-economic variables. The total assets SES score held strong explanatory value for fodder knowledge, wherein those with the lowest SES provided the longest lists of plants that could be fed to livestock. Indeed, many household respondents explained that using wild plants and grazing their goats, buffalo, and pigs “in the field” rather than feeding them with garden plants was largely based on economic need.

Households that demonstrated the most significant knowledge about food plants were highly educated or self-ascribed to the Tay or Hmong ethnic groups. Post-hoc Mann-Whitney *U* tests showed no statistically significant relationship between ethnicity and education level. In general, those with a high education level could potentially do better at remembering the names of the plants they eat, given their experience with rote memorization that is the foundation of the Vietnamese education system. However, more research is needed to better understand why higher education is related to food plant knowledge. The outcome demonstrating Dao people, whose education level varies widely, are least well-versed in the various food plants available in the region is surprising given their history of being known as agro-forestry experts. Rather than relying on agro-forestry to supplement rice and/or corn-based diets, the Tay and Hmong households interviewed depended more heavily on foods grown in nearby vegetable

gardens. Therefore, more research is required, here, to better understand this interesting ethnic difference in food list lengths.

During market days observed in the three communes, local and regional vendors offered their wares and local residents flocked to the area in large numbers. This was often the only time people were able to purchase items not locally available, and because market days were also a social event (involving donning traditional attire not often worn), household representation at market was more common than not. Those presenting long lists of forest items found in local markets were most commonly the same households that reported high off-farm employment levels. In other words, those with more cash in hand knew more about forest plant products available at market. Commune of residence provided some explanatory value, as well. People who lived in Minh Son had relatively low levels of knowledge about heavily traded wild plant products. This difference was significant between Yen Dinh and Minh Son communes but more research would be required to understand this variation.

Although local Tay people often claimed their ethnicity was a “rice wine culture,” ethnic group was not found to be significantly related to knowledge (list length) of plants useful in the distillation process. Instead, families reporting a high education level, as well as households located in Tung Ba and Yen Dinh, were those found to have the strongest relationship with distillation knowledge. Once again, the relationship with education level did not have a clear underlying explanation. However, insofar as random observations of the distillation process may serve as a proxy for brewing frequency variation from place to place, we did come across several wine-making

operations underway during interviews in Tung Ba and Yen Dinh [Figure 12a] but in Minh Son, only witnessed the purchase of locally brewed wine.

Figure 12. Photos of the rice wine distillation process (a) and of a traditional Tay wooden stilt home (b).



Household interviews indicated that compared to all other categories, timber forest products used for fuel and construction were quite well-known among most community members. Although SES scores had no relationship with fuelwood knowledge, ethnicity and commune could be used to predict fuel list length with some success. Familiarity with construction products was also related to ethnicity and commune. Of the three local ethnicities represented in the sample, it was the Tay people (who represent the ethnic majority in Tung Ba) that were best known for their beautiful, large wooden stilt homes [Figure 12b]. Because there was significant overlap in timber plants used for fuel and construction (20 of the 25 most salient trees reported as useful for construction were also included in fuelwood lists), it would not be surprising if people who took pride in constructing attractive wooden homes become familiar with

timber scraps that also work well as fuel. Unlike with fuelwood, however, construction and SES scores were strongly correlated. This may help explain why those with the highest total assets scores were typically the most well-versed in the variety of timber products utilized for building homes, outbuildings, and other items. Wealthy households prominently display their success by building bigger, more picturesque wooden stilt homes.

6.5 Conclusion

The goal of this research was three-fold. First, we aimed to evaluate the socio-economic status of 75 households in a northern Vietnamese community via total assets methodology. Using the Guttman scaling technique, we identified ten household assets [Table 3**] that strongly predicted variations in SES within this highly rural community. Another objective was to validate the assets methodology by comparing the scores with other measures of SES. We found strong correlations between the total assets SES scores and both education level and the three ethnic groups that can be anecdotally ranked from richest to poorest. Therefore, we propose that these ten assets can and should continue to be utilized in future research at this study site, especially when a rapid SES assessment is needed.

It is important to note, however, that the sample size for this study was not large, especially when considering the numerous dimensions considered in constructing a balanced convenience sample. The 75 interviews conducted represents about 2% of the approximately 3,500 households located within the three communes of interest. Therefore, results were analyzed, interpreted, and applied with caution.

Finally, this research was also designed to compare socio-economic variables with measures of human knowledge of different forest plant resources and then utilize results to help tailor conservation interventions for specific human target audiences. Households with comparatively high SES, who were very frequently of the Tay ethnicity, were more likely to build sizeable wooden stilt homes using large-boled trees most likely acquired from nearby primary forests. Therefore, when developing conservation interventions aimed at reducing use of wood for home construction, it will be important to focus on high SES households, as well as those self-ascribing to the Tay ethnic group. Tay households – especially those found in Tung Ba commune – will also be important to engage when implementing conservation activities aimed at reducing forest timber used for fuel. By applying what was learned here to future conservation activities in and around the Khau Ca forest in Ha Giang Province, Vietnam, we predict continued success in preserving the forest and the critically endangered species found within.

CHAPTER VII

HUMAN AND NONHUMAN PRIMATE RESOURCE IMPORTANCE AND OVERLAP: CONSERVATION IMPLICATIONS

Abstract

A significant threat to the critically endangered Tonkin snub-nosed monkeys of Khau Ca forest, Vietnam, is human use of forest resources. This study examines forest plant resource importance and overlap between local people and snub-nosed monkeys that both rely on forest resources for survival. We followed monkey groups as often as possible, attempting group follows at least 7 days per month from August 2011 through November 2012. During group follows, data regarding plants used for feeding, resting, and traveling was recorded. We compiled a full list of floral taxa used by the monkeys and ranked them based on proportional frequency of utilization. To assess human forest plant resource use, we conducted 75 household interviews between April 2012 and March 2013. During interviews, respondents listed plants useful for different purposes (fuelwood, construction, food, etc.). Resulting freelists were used to determine the salience rank of each plant taxa, a proxy for human resource importance. While the positive relationship between human and monkey resource use ranks was not significant, several timber genera were important for both primates. One tree in

particular – *Excentrodendron tonkinense* – was key for future Tonkin snub-nosed monkey survival, and should be the focus of future conservation interventions.

7.1 Introduction

Human species and nonhuman primates, including *Rhinopithecus* monkeys, have shared the landscape in northern Vietnam for at least 30,000 years, if not hundreds of thousands of years – or more (Takai et al., 2014). Even with this long shared history in this part of the world and elsewhere, few scientists have examined overlapping resource use and importance between humans and their nonhuman primate counterparts. Studies assessing resource overlap and niche partitioning are common among various nonhuman primate species (e.g., Terborgh, 1983; Chapman, 1988; Peres, 1993; Kinzey, 1997; Buzzard, 2006), between nonhuman primates and other mammals (e.g., Gautier-Hion et al., 1980; Ganzhorn, 1988; Khoehler and Hornocker, 1991; Arletazz, 1999; Sushma and Singh, 2006), and between nonhuman primates and phylogenetically distant taxa (e.g., Poulsen et al., 2002). Such research typically hypothesizes that observed differences between species in terms of dietary selection, feeding behavior, ranging patterns, and other resource use variables are largely the result of co-existence with resource competitors. However, studies that include humans as important components of a shared dynamic ecosystem, and therefore as potential competitors, are rare.

Traditionally, western scientists studying the ecology of primates place humans outside of nature, almost certainly underplaying the role of anthropogenic influences on even the most pristine environments. Sponsel (1997) argued against this approach,

stating that more often than not, modern ecologists ignore humans and exclude them from the natural environment for analytical purposes, as if the presence of humans somehow contaminates nature. Fuentes and Hockings (2010) agreed, contending it is incorrect to assume that non-human primate populations have never been influenced by human activities in their recent evolutionary histories. While much is known about how humans as ecosystem “invaders” affect primate habitats by logging (Johns, 1985; Ganzhorn, 1995; Chapman et al., 2000; Songtao Guo et al., 2008), clearing land for agriculture (Johns and Skorupa, 1987; Yiming Li, 2004), and mining (Setiawan et al., 2009), for example, much less is understood about long-standing relationships between human and nonhuman primates as residents of the same ecosystem.

Nonhuman primates living in the same community often demonstrate important dietary differences. This is arguably one of the most important components of the competitive exclusion principle. Simply stated, this principle suggests that, “complete competitors cannot coexist,” (Hardin, 1960). Sympatric primates appear to be no exception. For example, some sympatric primates show differences in the plant species eaten, parts of plants ingested or in the degree of reliance on each plant species (Terborgh, 1983; Chapman, 1988). Species that share a habitat may also differ in the timing of resource utilization; for example, ingesting unripe fruit (Kinzey, 1997) or young leaves, which may be related to the ingestion of parts with differing chemical composition (Glander, 1981; Kay and Davies, 1994). Many of these forms of food resource partitioning have also been demonstrated amongst sympatric mammals in general (Gautier-Hion et al., 1980; Ganzhorn, 1988; Sushma and Singh, 2006) or between birds and primates (Poulsen et al., 2002). Therefore, it would not be surprising

if some level of similar resource partitioning was also present between primarily subsistence-based humans and nonhuman primates who may have relied on the same wild plant resources for thousands of years.

One potential barrier to undertaking research that simultaneously evaluates human and nonhuman exploiting resources from the same ecosystem is the challenge of employing methods that work equally well for both primate species. The difficulty, here, stems largely from a significant need to not only employ standard nonhuman primate quantitative sampling methodology (Altmann, 1974), but to also incorporate more qualitative aspects of human resource procurement patterns. However, by looking outside the bounds of traditional primatological research methodology and employing a mixed methods toolkit (Driscoll et al., 2007; Riley, 2007), it is clear that scientifically rigorous options for this type of comparative research are available.

7.1.1. Assessing Human Forest Resource Importance

For humans, one method that has been successfully applied by ethnobotanists to understand resource importance within cultural groups is resource salience. This measure is typically obtained via a data collection method called freelisting. In analyzing cultural domains (or how people within a community think about different groups of things), salience has been demonstrated to be a strong proxy for the importance of the items that belong to each domain. Vital for successful analysis of domain salience, however, is sufficient focus of the domain in question (Quinlan, 2005). Therefore, data collection methodology should hone in on sub-domains to ensure items

are not missed by respondents due to the domain being too broad for accurate data collection and analysis.

The freelisting technique is an anthropological method often used to examine cultural domains (Smith, 1993; Bernard, 2006; Schrauf and Sanchez, 2008; Riley, 2007), including the broad domain of human use of forest plant resources (e.g., Quinlan, 2005; Castaneda and Stepp, 2007; Ghorbani et al., 2012). This quantitative, efficient, and simple research methodology can indicate areas of consensus and variation within a community. Data is collected by asking respondents to list all of the things they can think of within a particular domain. By taking the sum of each listed item's percentile rank and dividing the sum by the total number of lists in the sample, a salience score represents group consensus. In mathematical terms, the formula can be represented as follows: $S = \{[\sum (L - R_j + 1)] / L\} / N$, where S is the average rank of an item across all lists in the sample weighted by list length; L = the number of items in a list; R_j = the rank of item j in the list; and N = the number of lists in the sample (Smith, 1993).

Differences in freelist content and length, however, can be indicative of domain variability. For example, freelist length can act as a surrogate for depth of knowledge of a particular category of information, such that experts' lists are longer than novices' (Quinlan, 2005). And salience has been demonstrated to be a robust proxy for human resource importance in several recent studies (Quinlan, 2005; Castaneda and Stepp, 2007; Riley, 2007).

A weakness of the freelisting salience methodology has to do with the exhaustiveness of the information provided. Other, more time-consuming methods,

such as completing forest walks with expert informants or conducting lengthy interviews with a few key respondents can increase list exhaustiveness. In addition, informants may provide a short freelist with a goal of ending the interview quickly; or they may decide to intentionally not share items they know as a way of protecting their traditional ecological knowledge. It is also important to consider that respondents can most likely recognize more items than they are able to name. Probing however, such as with redundant questioning or by simply remaining silent (Bernard, 2006), can help maximize freelist recall output (Quinlan, 2005).

There are two important assumptions at play in applying salience as a proxy for resource importance: 1) the assumption that respondents will name important resources more often than un-important ones, and 2) the assumption that people will name more important resources before those that are less important. Borgatti (2002) demonstrated that freelisted “core items” both occur on most respondents’ lists and are typically mentioned first. Also, ethnobotanists have determined that, “If one wants to find the most culturally salient plants of a particular sort (medicinal, agricultural, etc.)... the freelist method is ideal,” (Quinlan, 2005). Therefore, we consider these assumptions reasonable and expect a freelist derived salience index will be a strong representation of real-world human resource importance at our study site.

7.1.2. Assessing Nonhuman Primate Resource Importance

Plants essential to arboreal primates (like the Tonkin snub-nosed monkey) are not only those used as food (Chapman and Fedigan, 1990; Yiming Li, 2006; Marshall et. al., 2009), but also those used for rest or sleep (Albert et. al., 2011; Bernard et. al.,

2011), and for travel (Fleagle and Mittermeier, 1980; McGraw, 1996; Youlatos, 1999). Although it is possible to measure dietary resource importance by evaluating fecal content proportions (e.g. Tutin et al., 1991), this method will not shed light on other use categories such as rest and travel. Perhaps the most common method for assessing resource importance is by observing nonhuman primate behavior and calculating the proportion of resource use over time (Chapman and Fedigan, 1990; Yiming Li, 2006; Guo et al., 2007; Riley, 2007; Felton et al., 2008). Most authors using this approach have employed an instantaneous point-time sampling technique (Altman, 1974) to capture information about resource use. Use patterns are then evaluated by calculating the percentage of samples study subjects spent in a specific activity; the higher the percentage, the more important the resource.

7.1.3. Human-Nonhuman Primate Overlap

Researchers have applied several methodological approaches to demonstrate the degree of dietary and/or niche overlap of sympatric species and to test the competitive exclusion hypothesis. Niche overlap is defined by Colwell and Futuyma (1971, p. 567) as, “The joint use of a resource, or resources, by two or more species.” While commonly used (Chapman, 1987; Buzzard, 2006), it is argued that simply calculating dietary overlap via summing the number of shared resources is not sufficient and can lead to inaccurate estimates of overlap (Poulsen et al., 2002). Therefore, methods that incorporate the proportional use of resources are expected to be more robust (e.g. Schoener’s dietary overlap index: Peres, 1996; Morisita’s measure of niche overlap: Sushma and Singh, 2006; and Pianka’s resource use overlap index: Wahungu

et al., 1998). But because the information collected on the two primate species (monkeys and humans) in the current study are not the same type of data, use of common proportional overlap indices is inappropriate with this data set. To compare resource overlap in a study containing data derived via different collection methods, a viable alternative for statistical evaluation of overlap is to assess the non-parametric correlation coefficient of resource importance ranks for all overlapping plant species.

7.1.4. Northern Vietnam: An Ideal Study Site

Ha Giang Province – Vietnam’s northern-most province – is a prime setting for a study regarding human-nonhuman primate resource overlap. The sympatric association of human and nonhuman primates in this part of the world is quite long-lived. Good evidence exists showing that colobine primates closely related to living *Rhinopithecus* were present in southern China during the Pleistocene epoch, 2.5 million – 11,700 years ago (Delson, 1994; Takai et al., 2014). Takai and colleagues recently found both *Rhinopithecus* and *Homo* teeth in the same caves in southern China, which dated throughout the Pleistocene. Sterling et al. (2006) suggest that modern humans were likely present in Vietnam at least 30,000 years ago. The same authors cite undisputed evidence that humans lived in limestone rock shelters and caves of northern-most Vietnam between 9,000 and 18,000 years ago. And while the ancestry of the original inhabitants of northern Vietnam is unclear, immigration timing of different ethnic groups is less ambiguous. Although Hmong people most likely moved into Vietnam from southern China 100-300 years ago (Lee and Pfeifer, 2006), evidence suggests that people of the dominant ethnic group (Tay) have occupied the region since

before written records (Tran Duc Vien, 2003). All of this information supports the antiquity of the human – nonhuman primate relationship in southern China and northern Vietnam.

In addition to a long history in the same part of the world, current patterns of human forest resource use are likely very similar to historical resource use dynamics spanning centuries (Rambo and Jameison, 2003). Sterling et al. (2006) note that northern Vietnam is one of the oldest continuously (anthropogenically) modified environments in the world, although evidence of rice cultivation does not appear in the archaeological record until 2-3,000 years ago. Prior to this time, evidence supports a hunting and gathering lifestyle. Today, local people are primarily subsistence-based, still relying on water buffalo and manpower – as opposed to modern machinery – for crop production and harvest. In addition, forest exploitation remains a common practice both for subsistence and for income supplementation (Ha Giang FPD et al., 2008).

There is also recent evidence pointing to some degree of forest resource overlap between critically endangered Tonkin snub-nosed monkeys (TSNM) and humans living near and within their forest homes. For example, *Excentrodendron tonkinense* is thought to be an important TSNM resource and these forest trees are also used as fuelwood by local people (Le Khac Quyet et al., 2007; Ha Giang FPD et al., 2008). In Tuyen Quang Province, TSNM and humans demonstrate similar overlap with respect to species the monkeys relied upon for food; namely, bamboo and fruit species (Boonratana and Le Xuan Canh, 1998b). In the Khau Ca region, bamboo is commonly used to build fencing, tree boles are felled for construction, orchids are taken as decorations, *Phrynium* leaves are harvested for consumption during the *Tet* holiday,

leaves and flowers of numerous plants are gathered for the distillation and flavoring of alcohol, and wild fruits and vegetables are collected as dietary supplements (Ha Giang FPD et al., 2008). Indeed, Nguyen Nghia Thin (2006) found that 179 Khau Ca plants may be useful for traditional medicine, 70 forest trees can be harvested for fuel and construction, and 50 different species could be used for ornamental purposes. This author estimated that as many as 80 different species may be exploited by both TSNM and the local people.

Although wildlife hunting continues to be the primary liability to TSNM persistence in most areas where this rare primate can still be found (Boonratana and Le Xuan Canh, 1998a), it is not currently a major concern in Khau Ca. A 2005 gun confiscation program, the constant presence of researchers, and recent conservation education and awareness programs have limited hunting activities. The 2009 gazettelement of the TSNM Species and Habitat Conservation Area (SHCA) has afforded additional protection for the monkeys and their habitat. While technically illegal to enter the TSNM SHCA without permission, clear boundary demarcation and enforcement is lacking. A team of local Community Patrol Group (CPG) members are employed to patrol the forest and local communities but they do not have authority to take action against law-breakers. In April 2010, eight months after the establishment of the protected area, CPG members reported encountering people seven of every ten days spent patrolling the forest (Harrison Levine, unpublished data). Taken together, the evidence above suggests a dire need to better understand what specific plants are most important to both the monkeys and the people to help shape future conservation interventions.

7.1.5. Study Aims

There are three primary goals for the investigation described here. First, we aim to evaluate Tonkin snub-nosed monkey resource use and importance across the three broad resource use behaviors of feeding, traveling, and resting. Our second objective is to assess forest resource use and importance of the human population surrounding the TSNM habitat. For humans, forest product use and importance are evaluated across seven use categories: fuelwood, construction, trade, food, fodder, distillation, and medicine. Our ultimate goal, however, is to compare human and non-human primate forest resource use. Given these two primate species have most likely shared use of forest plants for thousands of years, we expect they will show some degree of niche separation, as is seen in other primate communities. To test this hypothesis, we compare synecological plant species use patterns and importance scores. Results will enhance future Tonkin snub-nosed monkey conservation strategies already underway in Ha Giang Province, Vietnam.

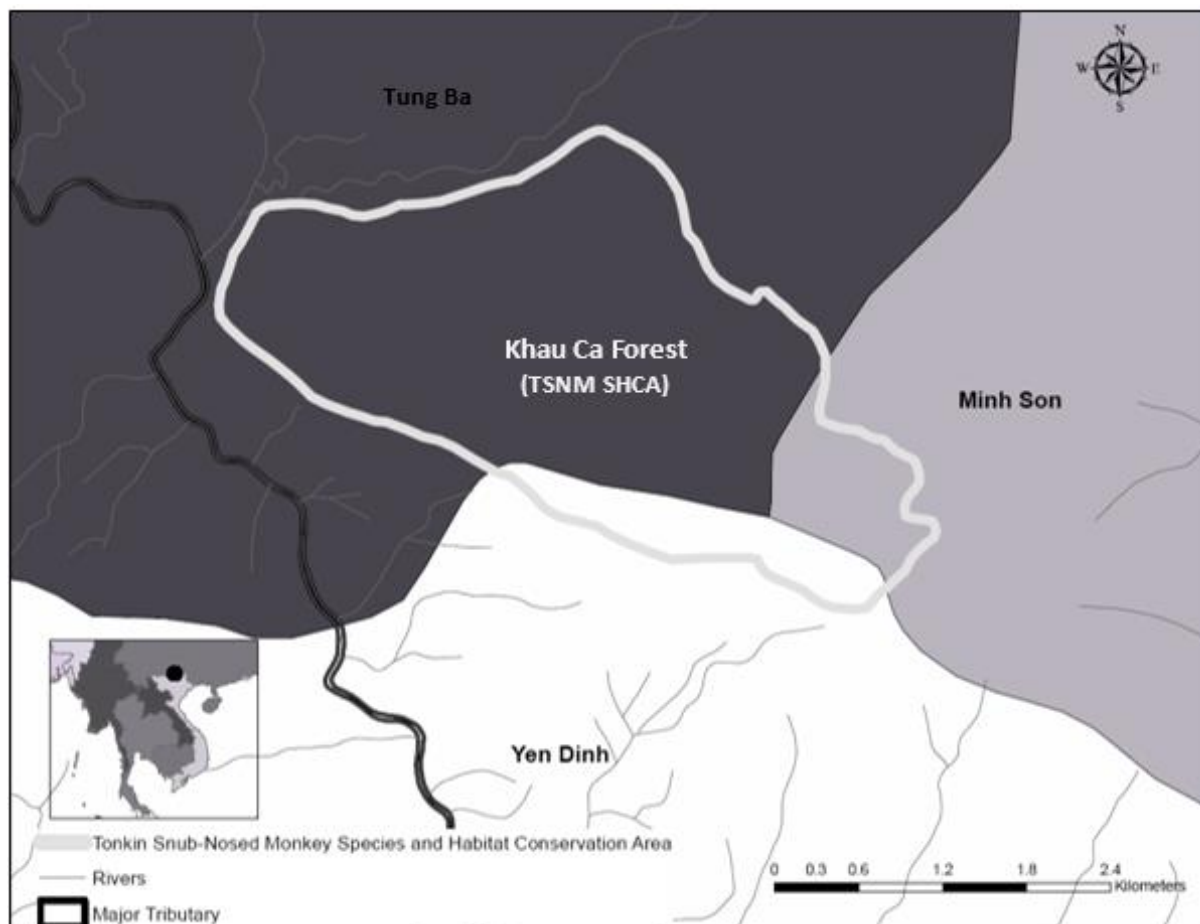
7.2 Methods and Materials

7.2.1. Study Site

Located within the Lo River watershed of northern Vietnam, Khau Ca forest (22° 50' N, 105° 07' E) rests atop a block of steep, rugged limestone karst, ranging in altitude from 600 to 1,400 m above sea level [Figure 13]. With an annual rainfall of about 2,300 mm, a mean temperature of 23.3°C, and average monthly humidity ranging from 35.5% to more than 87%, this 1,000 hectare forest is dominated by lower montane evergreen limestone forest and it is one of the least degraded and most intact examples of this

rare forest type left in Vietnam (Ha Giang FPD et al., 2008). Floral and faunal surveys of Khau Ca indicate this region is an important center for biodiversity conservation. A total of 471 plant species have been recorded within Khau Ca (Ha Giang FPD et al., 2008). And, a brief 12-day study led by Nguyen Nghia Thin (2006) determined that 29 plants at this site were endangered.

Figure 13. Study area map, showing locations of the three communes surrounding Khau Ca forest (the TSNM Species and Habitat Conservation Area).



A preliminary analysis of habitat structure within Khau Ca identified a few areas of anthropogenic habitat disturbance. The edges and lower, flat valley sections of the forest (600-700 m) were considered highly disturbed habitat (Ha Giang FPD et al.,

2008). Rather than the primary and secondary evergreen forest that typifies higher elevations within Khau Ca, authors note that these lower and edge areas are dominated by secondary scrub growth and vegetable crops, respectively. Thus, human activity such as agricultural practices and forest resource harvesting has had an effect on Khau Ca forest.

According to Le Khac Quyet (2014), plant species diversity within Khau Ca is quite high (Shannon-Wiener Index of diversity = 4.33). Among the most dominant species are broad-leaf evergreen trees from the *Polyalthia*, *Olea* and *Excentrodendron* genera. *Excentrodendron* trees also dominate in terms of total basal area, covering 27% of Khau Ca's total area. The same study outlined two peaks of significant young leaf presence in April and June that are contrasted by the observation of large numbers of fruit in the rainy months of June through September. With flowers being most commonly available from March to May, months falling between June and March may be times of relatively low phenological activity for plants of Khau Ca forest.

7.2.2. Study Subjects

Human Communities. There are three communes within Ha Giang Province that surround the Khau Ca forest, also known as the Tonkin Snub-Nosed Monkey Species and Habitat Conservation Area. The approximately 10,000 inhabitants of Minh Son, Tung Ba, and Yen Dinh communes participate in a primarily subsistence-based economy and consider themselves farmers, even if they are engaged in significant off-farm employment. The local people hail from three of Vietnam's 53 ethnic minorities. The dominant ethnic group in this part of Ha Giang Province is the Tay people, with

over 7,500 individuals (Ha Giang FPD et al., 2008). Tay inhabitants have lived in the region since before written records and most often live at lower elevations in the flat fertile valleys (Tran Duc Vien, 2003). People of the Dao ethnic group (over 1,450 individuals) commonly practice agroforestry in the mid-level altitudes of the region and are known for their breadth of knowledge of wild medicinal plants (ICEM and PADP, 2003). Those ascribing to the Hmong group (nearly 650 individuals) tend to be the poorest and most marginalized ethnic group, and are also the most recent immigrants to the area, having arrived 100-300 years ago from China (Lee and Pfeifer, 2006). In Ha Giang, they live mainly at higher elevations and practice a combination of shifting, slope-side agriculture and forest product procurement (Tran Duc Vien, 2003).

The vast majority of people living in these communes grow and make the majority of the things they need to survive. Traditional wooden homes, whether resting on stilts or on the ground, are made by the people that dwell in them. The walls and floors of most households are made of wooden slats or woven bamboo and roofing material is typically thatched palm. The same materials are also used to construct outbuildings, fencing, and household implements. Fuelwood, almost always burned within a traditional open hearth inside the home, is used to cook food for people and livestock, to sanitize water, and to heat the home in cooler months. Local people distill their own rice wine and other spirits and forest plants are indispensable in the process. Although most area residents have vegetable and fruit tree gardens, wild timber and non-timber forest products are also regularly collected for livestock fodder, human consumption, traditional medicine, and for trade or sale in local markets. In other

words, harvesting of forest plants plays a significant role in daily life for most people living in these three communes of Ha Giang Province.

Tonkin Snub-Nosed Monkeys. The Tonkin snub-nosed monkey (Dollman, 1912) has not only been one of the world's top 25 most endangered primate species since the list's inception in 2000, (Schwitzer et al., 2016), it was also named one of the 100 most endangered species on the planet (Baillie and Butcher, 2012). This once thought extinct species (Mittermeier and Cheney, 1987) was believed to be maintaining a population of approximately 300 individuals living in three isolated habitats as recently as 2005 (Mittermeier et al., 2006). Currently, Schwitzer and colleagues (2016) estimate that less than 250 TSNM (*Rhinopithecus avunculus*), and perhaps as few as 122-224 (Covert et al., 2011), are spread among five subpopulations. Two of those populations occur in Ha Giang, and the monkeys found in Khau Ca appear to be the single remaining viable population. Discovered in 2002, the estimated number of individuals in Khau Ca has grown from 60 to perhaps more than 125 individuals in just over ten years (Le Khac Quyet et al., 2006; Schwitzer et al., 2016).

One of five snub-nosed monkey species, the current knowledge base of *R. avunculus* is small but growing, owing largely to intensification of fieldwork in Vietnam over the last two decades. Scientists have been uncovering trends in TSNM social behavior (Boonratana and Le Xuan Canh, 1998b), locomotion and positional behavior (Covert et al., 2006; Le Khac Quyet, 2014), and diet (Le Khac Quyet et al., 2007). These studies indicate that TSNM in northern Vietnam tend to follow typical *Rhinopithecus* patterns of social organization, forming single-male units that often

congregate to create large multi-male, multi-female super-troops (Kirkpatrick, 2007; Grueter et al., 2009; Kirkpatrick and Grueter, 2010). However, they have surprised researchers studying locomotion and positional behavior by exhibiting a higher than expected frequency of suspensory behaviors, such as arm-swinging locomotion (Covert et al., 2006; Le Khac Quyet, 2014). *R. avunculus* are the only snub-nosed monkey species found in sub-tropical montane forest and they appear to have a diet similar to other colobine monkeys yet different from their *Rhinopithecus* congeners, eating a higher proportion of foods such as ripe and unripe fruit, seeds, young leaves, and leaf petioles (Boonratana and Le Xuan Canh, 1998b; Baoping Ren et al., 1998; Le Khac Quyet et al., 2007).

7.2.3. Data Collection

Human Communities. Data regarding the local human population was sampled via 75 semi-structured household interviews (Bernard, 2006), conducted in Vietnamese and approved by the principal investigator's Institutional Review Board. Because it was culturally unacceptable to exclude adult household members from participating, we conducted household interviews, wherein all household adults (18+ years) were allowed to participate.

To minimize cultural competency concerns (Teufel, 1997), and replicate methodology successfully employed in similar human resource use and importance research, a freelist technique was employed (Bernard, 2006; Riley, 2007). Household respondents were asked to list all of the wild forest plant resources that people in the region use, within each of seven use categories (fuelwood, construction,

distillation, fodder, food, medicine, and trade). Further questioning was then used to uncover reasons behind resource use decisions (Bernard, 2006). In addition, probing has been observed to increase accuracy and completeness of freelist recall by as much as 40% (Bernard, 2006), and was accomplished in this study via redundant questioning and semantic cues.

Tonkin Snub-Nosed Monkeys. To gather data on monkey behavior, one researcher (Le Van Dung) attempted to spend at least seven days per month in the forest locating and following TSNM groups between August 2011 and November 2012. Upon making contact with a group, and every 5 minutes thereafter, instantaneous point-time samples (Altman, 1974; Martin and Bateson, 1993) were conducted. The incredibly rugged limestone karst terrain of Khau Ca typically does not allow for all-day group follows; thus, sampling commenced upon group encounter and continued for as long as possible. During each sample, the estimated central point of group location was recorded using GPS and rangefinder, and the behavior of the individual furthest to the left was recorded (using four broad categories of behavior: feed, rest, travel, other/unknown). Whenever it was readily identifiable, plant species being used was noted, and the plant part ingested (fruit, seeds, young leaves, flowers) was also recorded for all feeding samples.

Plant samples. To identify as many human and TSNM forest plant resources as possible, we conducted several forest walks to collect samples. Samples were photographed, pressed, and labeled with the standardized vernacular plant name, and

then sent to a botanist at the University of Hanoi for identification to genus or species level whenever possible. Due to time, financial, and practicality constraints, combined with the large number of unidentified taxa included in the human resource data set, it was impossible to gather samples of all plants listed. Instead, we focused floral taxa collection and identification efforts on any new TSNM resources and on the top 25 plants we expected would be most salient for humans.

7.2.4. Data Analysis

To quantify the freelisted data, the number of resources listed for each category, the number of different uses for each plant taxa, and the total number of resources listed were used in subsequent analysis. After uploading interview data into ANTHROPAC 4.0, this software was employed to analyze salience scores for resources listed within each use-category. This software combines response frequency (the number of times an item appears on the list) and percentage (% of respondents who listed the item) to generate a rank score for each response. The rank score is then divided by the total number of different items in the list to create a salience score. Salience scores range from 0.0 (least salient) to 1.0 (most salient, or most important) and it is this score we used as a proxy for human resource use importance. Ideally, a domain will show a core set of items that the majority of respondents agree are most important or central in each category. The remaining items on the list are more representative of idiosyncratic views of individual respondents (Opalinski, 2011). Therefore, in most cases, a clear break (or elbow) in the salience scores will present

itself, although it is also common practice to report the top n number of items, where n is an arbitrary but useful number (Borghatti, 2002; Opalinski, 2011).

To determine relative importance of different plants used by TSNM during this study, we ranked floral taxa according to their proportional use frequency for each of the three broad categories of behavior observed (feed = 10 plants, rest = 11 plants, and travel = 11 plants). Although arboreal primates can readily find alternative plants upon which to rest or travel – provided they are sufficiently robust and able to support a 10-15 kg monkey – locating alternative food items may not be as easy. For this reason, we weighted the ranks of plants used as food, then calculated a mean rank score across all three behaviors to create an overall TSNM resource importance rank for each plant. The equation used for this calculation was as follows: $R_o = (R_f * 2) + R_t + R_r / 4$, where R is the rank of the plant for each behavior category, such that f = feed, t = travel, and r = rest, and R_o is the resulting overall rank.

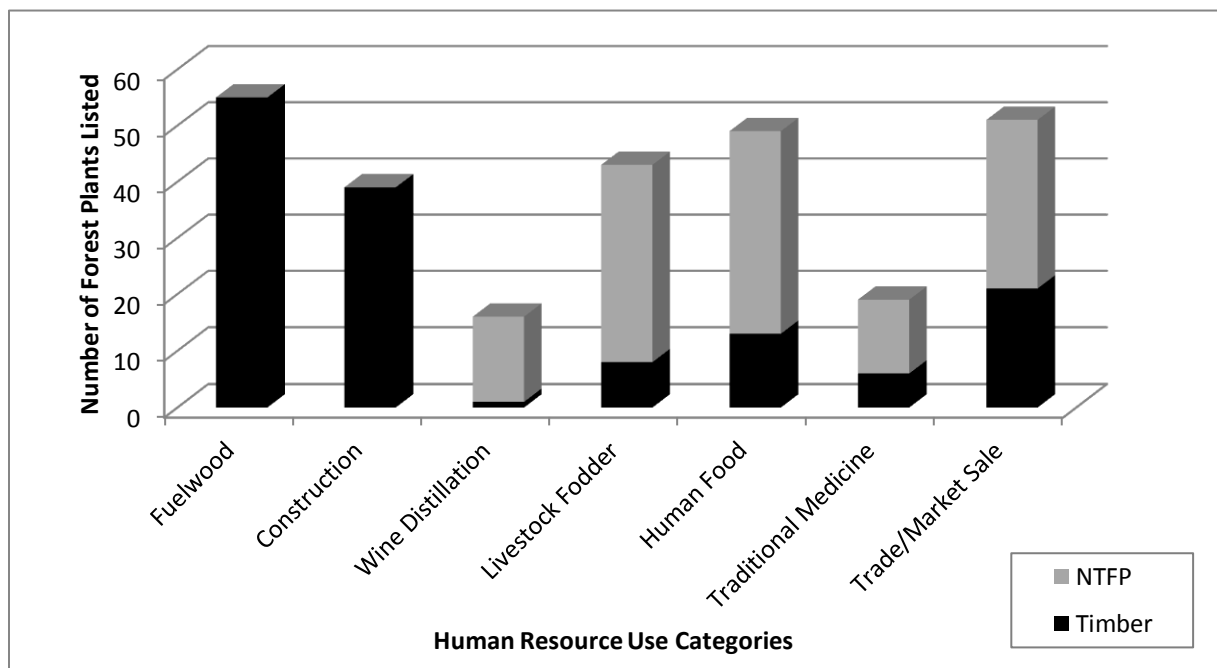
Ultimately, our goal was to examine resource use overlap and importance for humans as compared to monkeys sharing the same forest resources. To achieve this, we not only listed the total number of overlap plants, but also compared resource importance ranks statistically. By calculating the Spearman's non-parametric correlation coefficient for monkey and human resource importance ranks, we tested whether important TSNM plants were also the most important taxa freelisted by local people. Results were considered significant when $p \leq 0.1$.

7.3 Results

7.3.1. Human Resource Use and Importance

Interviews in Minh Son (24), Tung Ba (26) and Yen Dinh (25) were conducted between April 2012 and March 2013, and yielded large numbers of timber and non-forest timber products (NTFP's) listed as useful for resource use domains such as fuel, construction, distillation, fodder, food, medicine, and trade. A total of 72 different timber products [Appendix A] and 106 NTFP's [Appendix B] were listed by household respondents, but the number of plants named within each use category varied from 16 (distillation) to 55 (fuelwood) [Figure 14].

Figure 14. Number of timber and non-timber forest product (NTFP) plants listed in each of seven human resource use categories (domains).



Human resource importance was measured using salience scores calculated for all of the floral taxa listed in each use category. All plants named as useful for fuelwood and construction were timber [Table 7]. One forest tree stood out above the rest in terms of salience – a beech tree, called *Soi*, from the genus *Lithocarpus* (family

Table 7. Saliency scores for timber forest products included in the top ten resources for each human use category (note that the top ten plants in the latter five categories are also represented in Table 8).

Timber Taxa	Vietnamese Vernacular	Fuel Saliency	Construction Saliency	Trade Saliency	Food Saliency	Fodder Saliency	Medicine Saliency	Distillation Saliency
<i>Lithocarpus</i> sp.	Soi	.603	.470	.127	-	-	-	-
<i>Styrax</i> sp.	Bo de	.307	.003	.040	-	-	-	-
Lamiaceae sp.	Ba soi	.171	.021	-	-	-	-	-
<i>Engelhardtia roxburghiana</i>	Cheo	.159	.029	.017	-	-	-	-
Bambuseae sp.	Tre vau	.121	.163	.045	.104	.057	-	-
<i>Manglieta dandyi</i>	Mo	.077	.271	.023	-	-	-	-
<i>Ficus</i> sp.	Sung	.068	.200	.006	.011	.031	.027	-
<i>Phoebe</i> sp.	Khao da	.057	.193	.013	-	-	-	-
<i>Cassia</i> sp.	Muong	.053	.103	-	-	-	-	-
-	May ben	.043	-	-	-	-	-	-
<i>Excentrodendron tonkinense</i>	Nghien	.026	.381	.042	-	-	-	-
<i>Pometia pinnata</i>	Sang	.035	.205	.060	.016	-	-	-
<i>Garcinia</i> sp.	Trai	.023	.150	.024	.158	-	-	-
<i>Duabanga grandiflora</i>	Phay	.033	.099	.017	-	-	-	-
-	Ngoa	.008	.005	-	.062	.034	-	-
<i>Canarium</i> sp.	Tram	.006	.023	.049	.180	-	-	-
<i>Litchi chinensis</i>	Vai	.022	.022	.014	.104	-	-	-
<i>Dracontomelon duperreanum</i>	Sau	.020	.009	.063	.047	-	-	-
Moraceae sp.	Dau	.035	.037	.068	.011	-	.027	-
<i>Markhamia stipulata</i>	Dinh	-	.060	.062	-	-	-	-
-	Guot	-	-	.066	-	-	.027	-
-	Ca tap	.014	-	-	-	-	.054	-
<i>Eucalyptus</i> sp.	May trang	-	.008	.017	-	-	.027	-
Arecaceae sp.	May co	.014	.002	.016	-	.017	-	.121
Rutaceae sp.	May khen	.008	-	-	-	-	-	.113

Fagaceae) had the highest fuelwood ($S = 0.603$) and construction ($S = 0.470$) scores, and was also the most important trade plant ($S = 0.127$). *Nghien* (a linden tree; genus *Excentrodendron*, family Tiliaceae) was the second most important plant used in construction ($S = 0.381$), and like *Lithocarpus*, was also reportedly used as fuel ($S = 0.026$) and in trade ($S = 0.042$). Other timber genera with comparatively high saliency scores included *Styrax* (Styracaceae), with a fuelwood saliency of $S = 0.307$, *Manglieta* (Magnoliaceae), with a construction saliency of $S = 0.271$, *Pometia* (Sapindaceae), with a construction saliency of $S = 0.205$, and *Ficus* (Moraceae), with a

construction salience of $S = 0.200$. Together, the top ten timber taxa for each use category yield a list of 25 important trees [Table 7].

When combined, the top ten NTFP's for each human use category total 23 different plants [Table 8]. Six plants that stand out in the human NTFP list include the following genera: 1) *Psychotria* (Rubiaceae; $S = 0.616$), which is indispensable for rice wine distillation, 2) *Musa* (Musaceae), the banana plant, an important fodder taxa ($S = 0.571$), 3) *Phyllanthus*, a medicinal plant from the Phyllanthaceae family used to treat bleeding wounds ($S = 0.290$), 4) *Meliantha* (Asteraceae), the most important human food plant – similar to endive ($S = 0.267$), 5) *Schefflera*, a leafy green food plant from the Araliaceae family ($S = 0.255$), and 6) *Pueraria* (Fabaceae), a plant used in

Table 8. Salience scores for non-timber forest products (NTFP's) included in the top ten resources for each human use category (note that all plants in fuel and construction lists were trees).

NTFP taxa*	Vietnamese Vernacular	Trade Salience	Food Salience	Fodder Salience	Medicine Salience	Distillation Salience
<i>Schefflera</i> sp.	Rau dang	.093	.255	-	-	-
Orchidaceae sp.	Phong lan	.082	-	-	.027	-
<i>Meliantha suavis</i>	Rau ngot	.071	.267	-	-	-
<i>Knema globularia</i>	Mau cho	.063	-	-	-	-
<i>Diplazium esculentum</i>	Rau don	.006	.199	.026	.014	-
<i>Erythralum scandens</i>	Rau khai	.023	.164	-	-	-
<i>Musa</i> sp.	Chuo	-	.032	.571	-	-
<i>Thysanolaena maxima</i>	Co chit	.034	-	.138	-	-
-	Nha nhung	-	-	.130	-	-
Araceae sp.	Khoai	-	-	.128	-	-
<i>Pueraria</i> sp	Day rung	.045	.016	.052	.027	.225
-	May man	-	-	.045	-	-
-	Bong lau	-	-	.042	-	-
<i>Phyllanthus</i> sp.	Cho de	-	-	-	.290	-
Smilacaceae sp.	Khuc khac	.052	-	-	.081	-
<i>Camellia sinensis</i>	Che	-	-	-	.027	-
-	Ta po da	.014	-	-	.027	-
<i>Psychotria</i> sp.	Cay men	-	-	-	-	.616
<i>Languas officinarum</i>	Gieng	-	-	-	-	.179
-	Ba lang	-	-	-	-	.080
-	Nhan tran	.027	-	-	-	.066
<i>Homalomena aromatica</i>	Vat veo	.025	-	-	-	.065
-	Nha hung meo	-	-	-	-	.018

distillation, specifically to minimize reactions to alcohol consumption ($S = 0.225$). The latter genus also happens to be the only NTFP listed by respondents as useful in all five categories.

Fuelwood, construction and food categories each present a clear break in the data after the top two most salient plant genera (fuel: *Lithocarpus* and *Mangalieta*; construction: *Lithocarpus* and *Excentrodendron*; food: *Meliantha* and *Schefflera*). Floral taxa listed as the most useful for trade, fodder, medicine, and distillation showed a break after just one plant (trade: *Lithocarpus*; fodder: *Musa*; medicine: *Phyllanthus*; distillation: *Psychotria*). In also applying the practice of selecting an arbitrary but useful n number of most important plants, the top 25 salience scores, which include all scores where $S \geq 0.1$, are presented in Table 9.

We followed monkey groups as often as possible, attempting group follows at least seven days per month from August 2011 through November 2012, yielding 48.5 observation hours, a number not at all dissimilar from that achieved by Boonratana and Le Xuan Canh for the same primate (1998b). The monkeys were observed using a total of 18 different forest plants, ingesting food items from 10 different plant genera and utilizing 11 different trees for both resting and traveling (albeit not the same 11 genera were used for these latter two behaviors) [Figure 15]. It is not too surprising that approximately one quarter of all travel samples were recorded as having occurred in unknown plants, as observers did not have time for tree identification while monkeys were on the move. Overall, only 13.5% of the 550 instantaneous samples recorded took place in unknown genera. Because the plants were unknown, these 74 samples were removed from further analysis, including the two samples recorded where monkey

behavior was also not detectable. The remaining 476 diurnal samples occurred within readily identifiable plants. The monkeys spent most of their time resting (57.1%) or traveling (36.6%), and feeding comprised 7.3% of the observations.

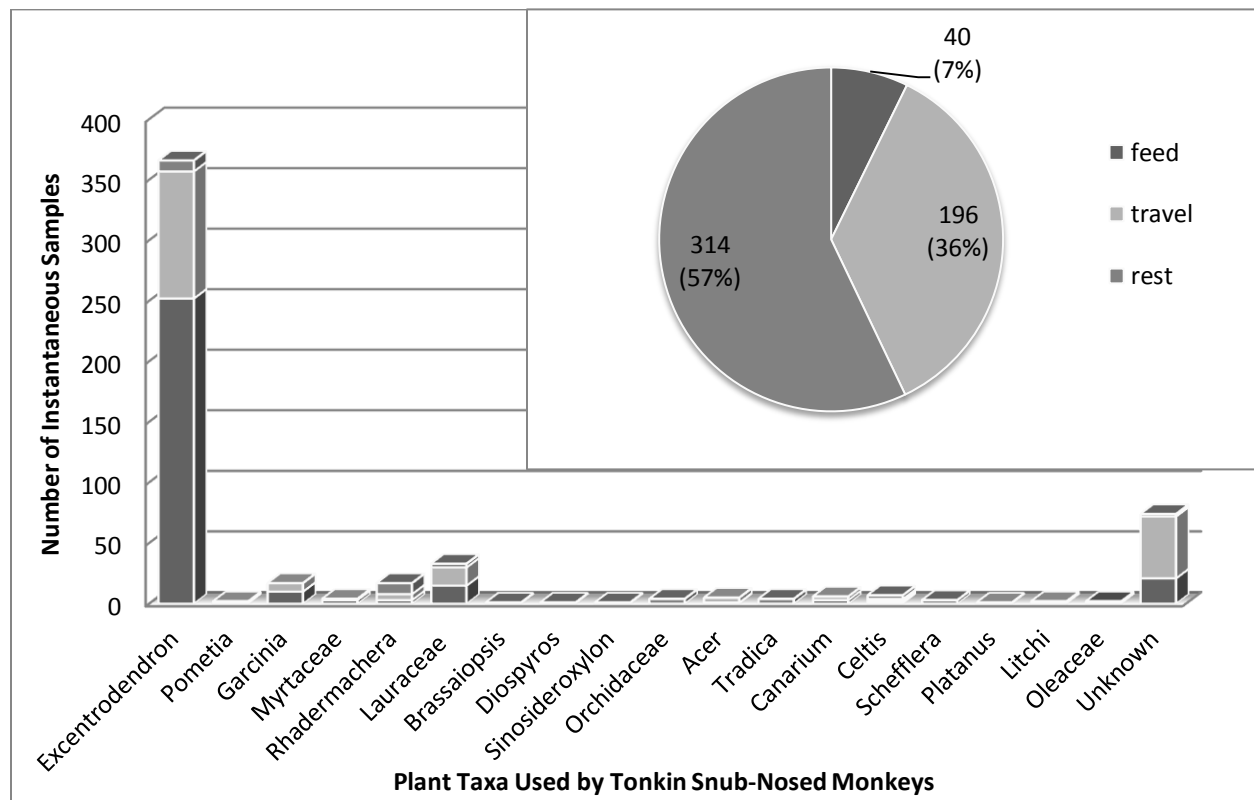
Table 9. Forest plants (timber and non-timber forest products, NTFP's) with the highest salience scores ($S \geq 0.1$) across all human resource use categories.

Rank	Plant Taxa	Vietnamese Vernacular	Use Category	Timber / NTFP	Salience
1	<i>Psychotria</i> sp.	Cay men	Distillation	NTFP	0.616
2	<i>Lithocarpus</i> sp.	Soi	Fuelwood	Timber	0.603
3	<i>Musa</i> sp.	Chuoï	Fodder	NTFP	0.571
4	<i>Lithocarpus</i> sp.	Soi	Construction	Timber	0.470
5	<i>Excentrodendron tonkinense</i>	Nghien	Construction	Timber	0.381
6	<i>Styrax</i> sp.	Bo de	Fuelwood	Timber	0.307
7	<i>Phyllanthus</i> sp.	Cho de	Medicine	NTFP	0.290
8	<i>Mangalieta dandyi</i>	Mo	Construction	Timber	0.271
9	<i>Meliantha suavis</i>	Rau ngot	Food	NTFP	0.267
10	<i>Schefflera</i> sp.	Rau dang	Food	NTFP	0.255
11	<i>Pueraria</i> sp.	Day rung	Distillation	NTFP	0.225
12	<i>Pometia pinnata</i>	Sang	Construction	Timber	0.205
13	<i>Ficus</i> sp.	Sung	Construction	Timber	0.200
14	<i>Diplazium esculentum</i>	Rau don	Food	NTFP	0.199
15	<i>Phoebe</i> sp.	Khao da	Construction	Timber	0.193
16	<i>Canarium</i> sp.	Tram	Food	Timber	0.180
17	<i>Languas officinarum</i>	Gieng	Distillation	NTFP	0.179
18	Lamiaceae sp.	Ba soi	Fuelwood	Timber	0.171
19	<i>Erythralum scandens</i>	Rau khai	Food	NTFP	0.164
20	Bambuseae sp.	Tre vau	Construction	Timber	0.163
21	<i>Engelhardtia roxburghian</i>	Cheo	Fuelwood	Timber	0.159
22	<i>Garcinia</i> sp.	Trai	Food	Timber	0.158
23	<i>Garcinia</i> sp.	Trai	Construction	Timber	0.150
24	Bambuseae sp.	Tre vau	Fuelwood	Timber	0.121
25	<i>Litchi chinensis</i>	Vai	Food	Timber	0.104

7.3.2. Monkey Resource Use and Importance

The frequency with which TSNM were observed utilizing each plant is outlined in Table 10. The two most frequently consumed food items were *Excentrodendron tonkinense* fruit and the young leaves of *Rhadermachera* trees, which together

Figure 15. Forest plants used by Tonkin snub-nosed monkeys during the current study for feeding (darkest shading), traveling (lightest shading) and resting (medium-tone shading); *See Table 11 for plant taxa Latin and English names.



comprised nearly half (45%) of all recorded feeding samples. *E. tonkinense* trees were also the most important forest plants for TSNM resting and traveling behaviors. Over 80% of all resting samples occurred in these trees, as well as over 50% of all traveling records. The overall weighted rank for each taxa, which emphasizes the importance of feeding resources, clearly identifies *E. tonkinense* as the most important forest plant utilized in this study ($R_o = 1.3$). *Rhadermachera* (an important feeding tree; $R_o = 3.0$) and Lauracea trees (which ranked relatively high for feeding, resting, and traveling; $R_o = 4.0$), were the only other forest plants with weighted ranks lower than 6.

Table 10. Proportional use frequencies (% of samples) and ranks for all 18 identifiable monkey forest plant resources, within each behavior category; *See Table 11 for Latin and English plant names.

Plant Name*	Vietnamese Vernacular	Feed % (n=40)	Feed Rank	Rest % (n=314)	Rest Rank	Travel % (n=196)	Travel Rank	Overall Weighted Rank (R _o)
<i>Platanus</i> sp.	Cho than	-	-	-	-	0.5	9.5	13.4
<i>Brassiopsis</i> sp.	Du du	2.5	9	-	-	-	-	12.0
<i>Phoebe</i> sp.	Khao da	7.5	6	4.8	2	7.7	2	4.0
<i>Rhadermachersa</i> sp.	May det	22.5	1.5	1.0	5	2.6	4	3.0
<i>Diospyros</i> sp.	May rec	2.5	9	-	-	-	-	12.0
<i>Excentrodendron</i> sp.	Nghien	22.5	1.5	80.3	1	53.6	1	1.3
<i>Schefflera</i> sp.	Ngu gia bi	7.5	6	-	-	-	-	10.5
<i>Orchidaceae</i> sp.	Phong lan	10.0	3.5	-	-	-	-	9.3
<i>Triadica</i> sp.	Rac ma	10.0	3.5	-	-	-	-	9.3
<i>Pometia</i> sp.	Sang*	-	-	0.3	10	0.5	9.5	12.1
<i>Sinosideroxylon</i> sp.	Sen dat	2.5	9	-	-	-	-	12.0
<i>Celtis</i> sp.	Seu	7.5	6	0.6	7.5	1.0	7	6.6
<i>Acer</i> sp.	Thich*	-	-	0.3	10	2.0	5	11.0
<i>Garcinia</i> sp.	Trai*	-	-	3.2	3	3.6	3	8.8
<i>Canarium</i> sp.	Tram	-	-	1.0	5	1.5	6	10.0
<i>Oleaceae</i> sp.	Tro*	-	-	0.6	7.5	-	-	12.9
<i>Litchi</i> sp.	Vai	-	-	0.3	10	0.5	9.5	12.1
<i>Myrtaceae</i> sp.	Vo gay	-	-	1.0	5	0.5	9.5	10.9

*Although the monkeys did not ingest plant parts from these taxa during the current study, they are among 32 currently known TSNM food plants, based on a previous study conducted in the same forest by Le Khac Quyet (2007).

7.3.3. Resource Use Overlap and Comparative Importance

Of the 18 different plants used by the monkeys during the present study [Table 11], more than half (10) were also reported as useful for local people. Most of the plants used by both were trees that humans harvested either in whole or in part for fuel, construction, food, fodder, and/or trade. The monkeys used ten different taxa for feeding during the investigation, five of which (*Brassiopsis* sp., *Phoebe* sp., *Orchidaceae* sp., *Sinosideroxylon wrightianum*, and *E. tonkinense*) were also noted as useful for humans. In other words, 55.5% of all flora used by TSNM in this study, as well as 50% of all TSNM food plants, were listed as useful for local people.

Table 11. Forest plant taxa overlap between monkeys and people: of the 18 identifiable plants used by TSNM in the current study, 10 (56%) are also used by local people.

Latin Name (English Common Name)	Vietnamese Family/ Common Name	Timber or NTFP*	TSNM Use Behaviors**	Human Use Categories
Aceraceae (Maple)	Họ Thích			
<i>Acer tonkinensis</i> [‡]	Thích	Timber	RE, TR	Fuel, construction, trade
Araliaceae (Papaya/Umbrella)	Họ Ngũ gia bì			
<i>Brassaiopsis</i> sp. [‡]	Đu đủ	Timber	FE	Fuel, construction, fodder
<i>Schefflera</i> sp. [‡]	Ngũ gia bì***	NTFP	FE [#]	-
Bigoniaceae (Begonia)	Họ Núc nác			
<i>Rhadermachera</i> sp. [‡]	Mây dẹt	Timber	FE, RE, TR	-
Burseraceae (Olive)	Họ Trám			
<i>Canarium</i> sp.	Trám	Timber	RE, TR	Fuel, construction, food, trade
Cannabaceae (Hackberry)	Họ Du			
<i>Celtis</i> sp.	Sếu	Timber	FE [#] , RE, TR	-
Clusiaceae (Mangosteen)	Họ Bứa			
<i>Garcinia</i> sp. [‡]	Trái	Timber	RE, TR	Fuel, construction, food, trade
Euphorbiaceae (Tallow)	Họ Thầu dầu			
<i>Triadica rotundifolia</i> [‡]	Rác má	Timber	FE	-
Ebenaceae (Persimmon)	Họ Thị			
<i>Diospyros</i> sp. [‡]	Mây rọc	Timber	FE	-
Lauraceae (Laurel)	Họ Long não			
<i>Phoebe</i> sp. [‡]	Kháo đá	Timber	FE, RE, TR	Fuel, construction, trade
Myrtaceae (Paperbark)	Họ Vỏ giấy			
<i>Myrtaceae</i> sp.	Vỏ giấy	Timber	RE, TR	-
Orchidaceae (Orchid)	Họ Lan			
<i>Bulbophyllum</i> sp. [‡]	Phong lan***	NTFP	FE	Trade
Oleaceae (Ash)	Họ Nhài			
<i>Olea</i> sp. [‡]	Trò	Timber	RE, TR	-
Platanaceae (Sycamore)	Họ Chò			
<i>Platanus</i> sp.	Chò than	Timber	TR	-
Sapindaceae (Lychee)	Họ Bồ hòn			
<i>Pometia pinnata</i> [‡]	Sâng	Timber	RE, TR	Fuel, construction, trade
<i>Litchi chinensis</i>	Vải	Timber	RE	Fuel, construction
Sapotaceae (Bully Tree)	Họ Hồng xiêm			
<i>Sinosideroxylon wrightianum</i> [‡]	Sến đất	Timber	FE	Fuel, construction, trade
Tiliaceae (Linden)	Họ Đay			
<i>Excentrodendron tonkinense</i> [‡]	Nghiến	Timber	FE, RE, TR	Fuel, construction, trade

*NTFP = non-timber forest product; **TSNM use behaviors: RE = rest, TR = travel, FE = feed; ***Phong lan and Ngũ gia bì often grow on Nghiến trees; [‡]plants also included as food trees in Le Khac Quyet et al., 2007; [#]new TSNM food items.

Looking back at the 25 most important human resources [Table 9], the four highest plant-use category salience scores belong to plant taxa that were not used by TSNM in this study. The *Lithocarpus* tree had the second and fourth highest salience ranks (for fuelwood and construction lists, respectively), but it was not utilized by TSNM for food, travel, or rest (although it could possibly have been included as an unknown plant). Neither the plant with the highest salience score, *Psychotria* sp. (distillation), nor the third-ranking plant taxa, *Musa* sp. (fodder), were used by the monkeys. The genus with the highest salience that was also used (extensively) by the nonhuman study subjects was *Excentrodendron*, which ranked fifth for construction.

Further analyses, however, show that five plants (*Phoebe* sp., *E. tonkinense*, *Pometia pinnata*, *Garcinia* sp. and *Canarium tramdenum*) used by both people and monkeys not only comprise over 45% of the TSNM diet during this study, they are also within the top 9% of the highest human salience scores [Figure 16]. In looking at all ten human-nonhuman primate overlap taxa [Table 11], every single one falls within the top 25% of all salience ranks. All of the plants used by both humans and monkeys are important to the local people, but a Spearman's rank correlation coefficient comparing human resource salience ranks and TSNM overall importance ranks ($r_s = 0.4924$) was not significant [Figure 17].

7.4 Discussion

7.4.1 Monkey Resource Use

Throughout the study, the Tonkin snub-nosed monkeys used a very small number of identifiable plants. Only 18 different genera, from 16 different families were

Figure 16. Importance ranks of five of the most salient plants used by both humans and monkeys.

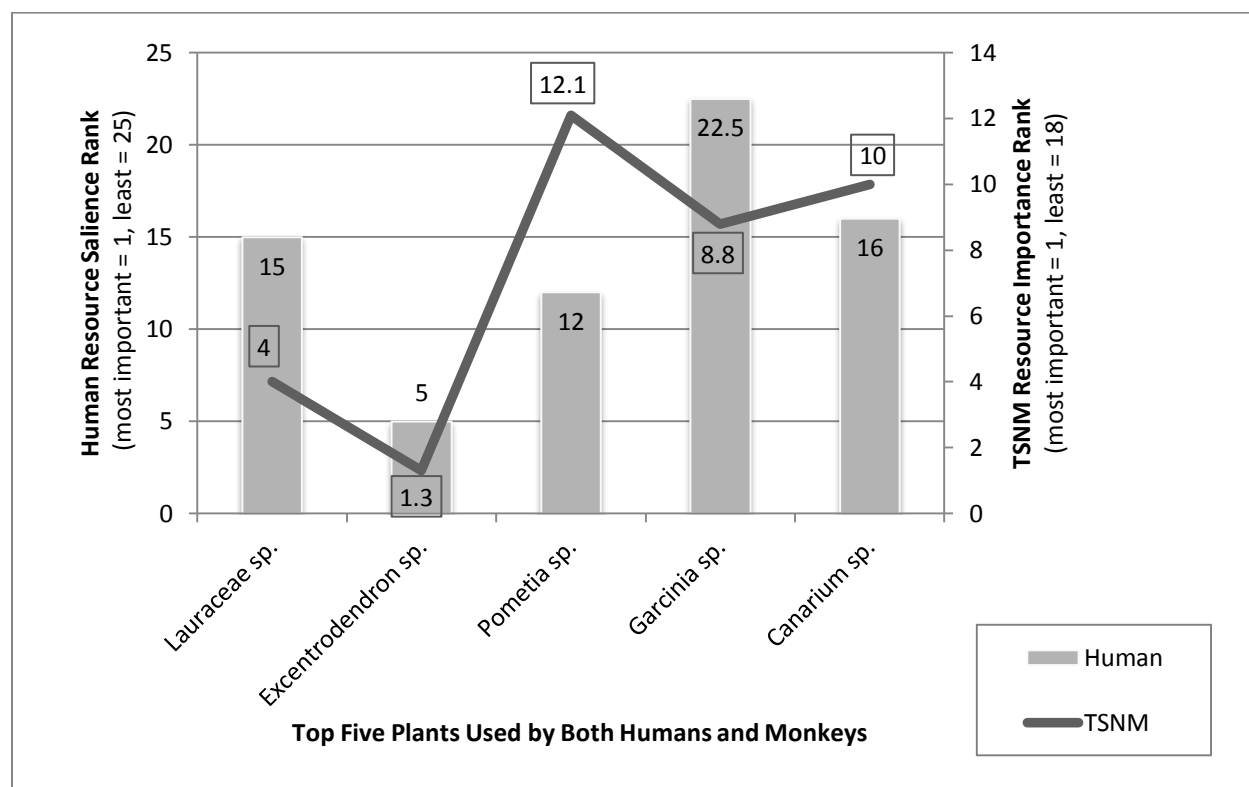
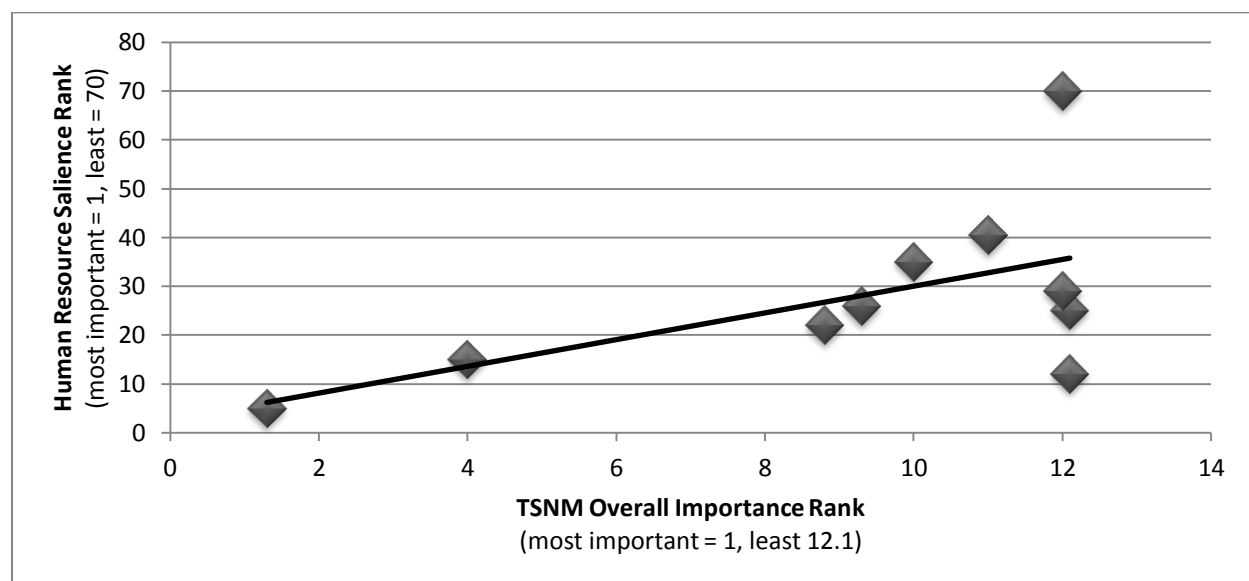


Figure 17. Spearman's nonparametric rank correlation of human and monkey resource importance for all 10 overlap plant taxa.



recorded as plants within which TSNM behaviors took place. The monkeys consumed plant parts (mainly fruit, leaves, and flowers) from 10 different taxa, but these food plants differed substantially from those most frequently ingested during a previous study at the same site (Le Khac Quyet et al., 2007).

None of the top five food items identified in the 2007 study were important dietary components during the current investigation. *E. tonkinense* fruit and young leaves from *Rhadernmachera* trees were the top two food items here, each accounting for 22.5% of dietary intake. Orchid (Orchidaceae sp.) and *Triadica rotundifolia* flowers each contributed 10% of these more recent TSNM feeding samples. While the current results confirm the 2007 finding that fruits (unripe and ripe) are among the most important TSNM food items (33.3% in this study), it was young leaves (30.8%) and flowers (25.6%) that were of comparable import here, rather than leaf petioles, which comprised only 10.3% of the feeding samples compared to 22.2% in 2007.

The petioles of both *Acer tonkinensis* and *Garcinia fagraeoides* were included in the list of the top five food items in Le Khac Quyet's 2007 research but these were not ingested during the current investigation. Interestingly, *Acer* and *Garcinia* trees (along with *Olea* plants, another known but less important TSNM food tree) were visited by the monkeys during the current study, but the monkeys were only seen resting and traveling in these trees, not eating. This may be evidence of TSNM monitoring food availability by regularly visiting those plants, even when edible items were not in season. Because these monkeys have been described as selective feeders (ingesting parts of only 13% of tree genera found in Khau Ca according to the 2007 research), it would not be surprising for them to regularly assess preferred feeding sites.

There is little question that the most vital resource for Tonkin snub-nosed monkeys was *E. tonkinense*, which was the most commonly utilized plant for resting and traveling. Parts of this linden tree were also ingested but in the current investigation, *E. tonkinense* fruit were equally as important as the young leaves of *Rhadermachera*. That said, at least two additional TSNM food items (*Schefflera* petioles and the Orchidaceae flowers the monkeys were observed eating) were often found growing on *Excentrodendron* trees in Khau Ca. Given this plant interdependence, the loss of a significant number of these sizeable linden trees (mean diameter at breast height = 78cm), would not only force the monkeys to locate alternate travel paths and resting places, it would challenge them to find substitute food items for at least three consistent dietary components. Given that, to date, a total of only 33 different taxa are known TSNM food plants, and that the three plants above (*Schefflera*, *Excentrodendron*, and Orchidaceae) comprised over 40% of the TSNM diet in the current study, the loss of even a few *E. tonkinense* trees could have devastating impacts. The finding that *E. tonkinense* is essential for the persistence of Tonkin snub-nosed monkeys at Khau Ca is not surprising, as this now substantiated fact has been suspected anecdotally by researchers for many years.

7.4.2 Human Resource Use

In contrast to the small number of plant taxa included in TSNM observations, local people reported harvesting a large number of wild forest plants – a total of 72 different timber plants and 106 non-timber forest products. It is possible that this high number of floral taxa is inflated given the various languages and idiolects used in the

area. For example, the *Sinosideroxylon* tree (known in the U.S.A. as a bully tree) was referred to by most respondents as *Sen dat*, but was also called *Sen* or *Sen da*, or was listed using the dominant ethnic Tay language, where it is named *Lau da*, or named using yet another ethnic language – Dao – where it is *May Lau Pia*. Respondents used up to six different vernacular terms for each plant. However, every effort was made to cross-translate plant names by gathering key informants fluent in Vietnamese and at least one ethnic language (Tay, Dao and/or Hmong) together simultaneously and filtering through the lists together. These translation exercises resulted in standardized names for each plant, shortening the timber list length from 169 to 72 and the NTFP list from 170 to 106 different plants. Given that the research of Nguyen Nghia Thin et al. (2006) suggests that the people living in the three communes surrounding Khau Ca forest may utilize up to 300 plant taxa found in the forest, the fact that freelists resulted in a minimum of 178 plants is not surprising.

Although not as pronounced as the significance of *E. tonkinense* for TSNM, freelisted interview data confirmed *Lithocarpus* was a key forest plant genus in terms of human resource importance. The salience of this wild beech tree, locally known as *Soi*, showed it was not only the most important fuelwood resource but was the most vital for construction purposes, as well. Other wild forest plants important for local people included the *Psychotria* plant, a crucial component in rice wine distillation, and the banana plant (*Musa* sp.), popular as livestock fodder. *E. tonkinense* – used primarily in home construction – ranked as the fifth most salient forest resource for any use category.

Of the plant genera listed as useful to local people across the seven use categories, 25 plant-use combinations were found to be most salient. Forest plants listed as useful in local trade were the least important overall and those harvested frequently for construction were found to be most important to the local people. In addition, several timber plants often collected as fuelwood and a number of wild food items were also highly salient among respondents. While the harvest of wild forest products for trade and traditional medicine did not seem to be important to the vast majority of local people in northern Vietnam, the significance of forest plants for construction, food, fuelwood, distillation, and fodder was considerable. There is little question that human reliance on forest resources remains substantial in this largely subsistence-based society.

7.4.3 Comparison of Human and Nonhuman Resource Use

Local people reported using 178 different wild forest plant products, but only 49 of those were food items. In this study, TSNM were observed ingesting plant parts from only 10 floral taxa; however, this nonhuman primate is currently known to feed from a total of 33 different types of plant [Table 2]. With 268 plant genera having been identified within Khau Ca (Nguyen Anh Duc et al., 2006), TSNM feed upon 12.3% and humans eat 18.2% of available resources. Both primates would, therefore, be considered quite selective, and to have narrow dietary niche breadths with respect to forest plants ingested. However, dietary components are only one aspect of niche breadth. Here, TSNM were observed feeding, resting, and traveling in a total of up to 60 different forest plant genera (including unidentified plants), or 22% of available flora.

Local people, on the other hand, reported using perhaps as many as 67% of available forest plants for their daily needs. In this respect, TSNM demonstrate a much narrower forest taxa niche breadth compared to humans.

Ten of the 18 plants used by the monkeys were also useful for people (56%), but this simple comparison of the number of overlapping plants does not take into account the relative importance of the overlapping genera. Indeed, Tonkin snub nosed monkeys have never been observed to use several of the most important, most salient human resources. The *Lithocarpus* tree, for example (a vital construction and fuelwood resource for people at this site), was not identified as one used by TSNM during this study; and neither were other highly salient human forest resources such as those from the *Psychotria* and *Musa* genera. Thus, there is some evidence of human-nonhuman primate niche separation in that the top four most salient plant taxa – human use category combinations were not plants also used by TSNM.

Although *Lithocarpus* trees (accounting for 2% of Khau Ca's forest timber along transects measured here) were not used by monkeys – not even for traveling or resting – the most important tree for TSNM, *E. tonkinense*, was also listed as the second-most important timber product used in construction by local people. Harvest of this linden tree for building purposes earned the fifth highest salience score across all taxa-use category combinations. *Excentrodendron tonkinense* also ranked 15th as a fuelwood product. This tree, as well as a mistletoe plant (Santalaceae family) always found growing upon it, were additionally relatively important trade plants, ranking 18th and 19th out of up to 60 traded taxa, respectively. We also learned in interviewing key informants that *E. tonkinense* trees were prized timber taxa, largely due to the beautiful wood grain

patterns of this durable hardwood, and were also often utilized for the fabrication of household items such as decorative vases and cutting boards. Thus, this level of overlap between TSNM importance and human salience and use of *E. tonkinense* and plants that depend upon this tree, is concerning.

Excentrodendron trees, which make up 27% of Khau Ca's total basal area (Le Khac Quyet, 2014), were one of ten floral taxa identified as those used by both monkeys and people. A comparison of those ten plants showed a non-significant, positive relationship between human salience and TSNM resource importance ranks. Although there was considerable overlap with regards to at least one important tree taxa, the extent to which these two primates shared resources from within Khau Ca forest was overall quite low. These results suggest that some degree of historical resource partitioning may have been at play, making it possible for humans and Tonkin snub-nosed monkeys to both rely heavily upon forest plants at this site in northern Vietnam.

7.4.4 Conservation Implications and Recommendations

Results of this research will be applied to the continuing success of Tonkin snub-nosed monkey conservation efforts in Ha Giang Province. Going forward, it will be essential to limit human harvesting of *Excentrodendron tonkinense* trees from Khau Ca forest, given its confirmed and critical role in TSNM survival. Other trees, including *Phoebe* sp., *Pometia pinnata* and *Garcinia* sp., given their importance as TSNM food plants and as human resources, should also be included as important taxa in conservation interventions undertaken in northern Vietnam. All four of these trees that

are used by both humans and monkeys are mainly used in construction by local people. Thus, alternative construction materials, such as fast-growing trees cultivated in tree gardens at homesteads may help reduce construction-based timber demand. In addition, some families have begun building more modern homes made primarily of concrete. While advocating for concrete home construction instead of using forest trees like *E. tonkinense* may aid TSNM conservation efforts in the short term, it would also be expected to increase limestone mining activities already underway in the region. These mining pursuits often destroy smaller forests dotting the village-agricultural valleys, which could force local people to rely more heavily on larger forests, like Khau Ca, for wild plant resource needs. This would be the opposite of a desirable conservation outcome.

While humans use these four Khau Ca forest tree taxa primarily in construction activities, they were also considered by respondents to be a decent source of fuelwood. Thus, an additional conservation intervention that should be considered is the implementation of more efficient fuelwood stove technology. Just such a project has already begun in the region, but it is clear from this research that reduction of fuelwood timber demand will not be sufficient to maintain essential tree resources the monkeys rely upon for the majority of their basic needs.

Entrance into the Tonkin snub-nosed monkey Species and Habitat Conservation Area (Khau Ca forest) is technically illegal, but enforcement is lacking. Although staff members have been employed to frequently patrol the forest and to regularly observe the monkeys, these Community Patrol Group members and Research Assistants do not have authority to take action when laws are broken. In addition, protected area

boundaries are not well marked and as a result, human use of the forest still occurs on a regular basis. Together, staffing the protected area with park rangers that have law-enforcement capabilities and clearly demarcating the forest boundary, will certainly serve to enhance interventions focused on reduction of timber harvesting activities. It is this kind of multi-pronged strategy that will be most effective for continuing Tonkin snub-nosed monkey conservation success in northern Vietnam.

CHAPTER VIII

DIFFERENTIAL FOREST USE PATTERNS IN HUMANS AND TONKIN SNUB-NOSED MONKEYS

Abstract

The myriad ways in which co-occurring primates partition habitats is distinctive to each specific context and community, and knowledge about this subject has vast potential for augmenting conservation success. The goal of this study is to clarify differential forest use patterns of two primates sharing the Khau Ca forest in northern Vietnam: modern humans (*Homo sapiens*) and the critically endangered Tonkin snub-nosed monkey (*Rhinopithecus avunculus*). Here, quantitative and qualitative data regarding the spatial and temporal use of Khau Ca was gathered simultaneously for both humans and monkeys. Direct observations of monkey and human behavior, as well as household interviews, were conducted between August 2011 and March 2013. While human and *R. avunculus* habitat use (in terms of seasonal use and ruggedness) was not suggestive of monkey avoidance of humans as predators, the north and southwestern forest borders were notable hotspots of human activity. Evidenced by both quantitative and qualitative data, significant temporal variation in human forest use was also discovered. Local people preferred to visit Khau Ca during the cool, dry season, which they referred to as “free time,” and were especially frequently observed harvesting forest resources at the end of the month in the middle of the dry season.

These results not only have direct relevance for the enhancement of Tonkin snub-nosed monkey conservation interventions such as forest patrols, they also bolster the focal argument within the subfield known as ethnoprimateology, which contends that primatologists should aim to include humans in community-level studies of primate ecology and conservation.

8.1 Introduction

Differential forest use can play a significant role in resource partitioning, especially in phylogenetically related or ecologically similar taxa (Terborgh, 1983; Porter, 2003). When it comes to primate communities, however, it is all too often that human primates are excluded from such analyses (Sponsel, 1997; Fuentes, 2006; Riley and Fuentes, 2011). This is unfortunate because the study of human and nonhuman primates sharing forest resources can not only provide a natural experiment for comparing the ecology and behavior of spatio-temporally co-occurring primate species (Fleagle and Mittermeier, 1980), it can also clarify the complex socio-ecological context within which successful nonhuman primate conservation strategies are implemented (Riley and Fuentes, 2011).

Species-level primate habitat use dynamics are often best explained by spatial and temporal variation in resource abundance and distribution (Clutton-Brock, 1977, Rasmussen, 1979; Coughenour et al. 1985; Terborgh and Janson, 1986; Chapman, 1987; Garber, 1993; Peres, 1994; Olupot et al., 1997; Pontes, 1997; Sauther, 1994; Bird and Bird, 2005; Wallace 2006). Other factors, such as climactic extremes (Ze Hua Liu and Qi Kun Zhao, 2004; Xiang, et al., 2007; van Doorn et al., 2010), territorial defense

(Mitani and Rodman, 1979; Cashdan, 1983; Garber et al., 1993) and perceived predation risk (Cowlshaw, 1997; Zhaoyuan Li and Rogers, 2005; Miller and Treves, 2011; Nowak, 2012), also appear to influence habitat use patterns for several species. And where humans are concerned, cultural variables may also play a significant role in the spatio-temporal use of landscapes (Cormier, 2002; Barrera-Bassols and Toledo, 2005; Riley, 2007). Here, such factors will be examined in an effort to describe differential forest use by co-occurring humans and the nonhuman primate, *Rhinopithecus avunculus*.

8.1.1 Seasonality

Seasonal patterns of habitat use by sympatric species have been thoroughly studied for many nonhuman primates over the past three decades (Terborgh and Janson, 1986; Chapman, 1987; Sussman, 1987; Garber, 1993; Peres, 1994; Sauther, et al., 1999; Wallace, 2006). Investigations into the effect of seasonality on human land use are also common (Coughenour et al. 1985; Bird and Bird, 2005). However, there remain some nonhuman primate species for whom seasonal habitat use is poorly understood; for example, the critically endangered Tonkin snub-nosed monkey (*R. avunculus*).

In tropical and subtropical regions, abiotic factors that may vary by season throughout the year include temperature, rainfall, and day length. These, in turn, affect biotic factors such as resource dispersion and availability – including the abundance of specific plant parts, also known as plant phenology (van Schaik and Brockman, 2005). When preferred food items become scarce as a result of seasonal fluctuation of abiotic

environmental factors, human and non-human primates must adapt some aspect of their behavioral ecology to maximize access to essential resources. While some primates (including human groups) respond by traveling further to acquire necessary resources, another option is to move less, switch to other food items, and rest more when key resources are less readily available (van Schaik et al., 1993; van Schaik and Brockman, 2005). Either of these strategies may also be combined with seasonally altering habitats or dietary components – or both.

Nonhuman primates that tend to shift habitats in response to seasonal variability need not move entirely out of their typical range. Rather, habitat shifters are those whose spatio-temporal use of a range demonstrates seasonally distinct patterns (van Schaik and Brockman, 2005). Most species that shift ranges are large in body size and exhibit low levels of territorial defense behavior (Hemingway and Byrnum, 2005). They also tend to inhabit topographically complex landscapes (van Schaik and Brockman, 2005). Smaller species may be more at risk of predation if they were to respond via habitat shifting given the challenge of habitat unfamiliarity. In addition, some nonhuman primates are known to move to different habitats in order to acquire a specific, target resource (Furuichi et al. 2001; Defler and Defler, 1996), and a meta-analysis conducted by Hemingway and Byrnum (2005) showed that habitat shifting was often correlated with dietary switching (van Schaik et al. 1993); so the two are not mutually exclusive.

Both Tonkin snub-nosed monkeys (TSNM) and humans exhibit adaptations that are potentially well-suited for habitat shifts. Humans are very large-bodied primates, but *R. avunculus* are also large, weighing in between 8.3 kg (female average) and 14.5 kg (male average). While the degree of human territoriality is both variable and debatable

(Dyson-Hudson and Smith, 1978; Hames and Vickers, 1982; Sack, 1983; Elden, 2010), TSNM do not exhibit high levels of territorial defense behavior (Kirkpatrick, 2011). Therefore, both species could potentially employ habitat switching as a strategy to deal with seasonality.

8.1.2 Rugged Habitat Use

When faced with predation pressure rather than seasonal variation, prey animals have several choices. Directly faced with a predator, prey animals must choose a path of either fight or flight. However, another type of anti-predator behavior that has been thoroughly researched for primates in recent years is avoidance (Miller and Treves, 2011). Strategies such as proactively selecting cryptic habitats and/or foraging alone, in small groups, or at night are likely more effective anti-predator behaviors for small-bodied primates (Wright, 1998; Miller and Treves, 2011). Larger species, such as *R. avunculus*, may be more successful at avoiding predator encounters altogether via the use of refuge habitats that are inaccessible to predators (Treves, 2002).

Authors have posited that selection of rugged terrain may be an anti-predation strategy for some wildlife species. Ruggedness – a topographical habitat feature which takes into account both the slope and the aspect of an area – can be an important variable that may help to distinguish preferred habitats for many species (Riley et al., 1999; Sappington et al., 2007; Bragin et al., 2013; Ahmad et al., 2016). In addition, Ciuti et al. (2012) found that for Canadian elk, increased terrain ruggedness was correlated with decreased vigilance, an anti-predator behavior. And there are similar findings in the Primate order, as well. In the face of potential leopard predation,

baboons (*Papio cynocephalus*) have been known to escape to cliff faces, purportedly as refuges from the threat of being hunted [Cowlshaw, 1997]. Similar anti-predator explanations for the use of cliff-side caves and shear rock faces have been reported for other primates, such as ring-tailed lemurs (*Lemur catta*), white-headed langurs (*Trachypithecus poliocephalus*) and Delacour's langurs (*T. delacouri*) [Sauther et al., 2013; Zhaoyuan Li and Rogers, 2005; and Workman, 2010; respectively].

Terrain that is especially rugged may also provide some level of protection from extreme climactic factors. Indeed, Ze Hua Liu and Qi Kun Zhao (2004) determined that black and white snub-nosed monkeys (*Rhinopithecus bieti*) often chose sleeping sites located in mid-elevations of markedly sloped terrain. This positioning, they hypothesized, may act as protection from strong winds, while also providing more sun and warmth in their temperate habitat than the even more wind-sheltered valley floor below.

Scientific measures of terrain ruggedness are just starting to appear in the literature as a habitat selection factor for primates (da Silva et al., 2015); however, to our knowledge, the idea that significantly rugged terrain (landscapes that are steep and also highly topographically variable) may act as potential refuge from climactic extremes and/or predation has not been evaluated for primates in the same way cliff-side caves and shear rock faces have been examined. Lack of quantitative ruggedness measures, however, did not stop Abwe and Morgan (2008) from hypothesizing that chimpanzees most often build sleeping nests on topographically steep and irregular landscapes because of frequent human night-hunting taking place in the Cameroon forest. Rugged

terrain – especially for an agile arboreal nonhuman primate – may indeed provide some level of protection from predators, including bipedal human hunters.

8.1.3 Culture

Few would question the idea that the ecology of human primates is an incredibly complex subject (Kormondy and Brown, 1998). While factors such as spatio-temporal seasonality and landscape ruggedness may contribute to human use of forest landscapes, the adaptive importance of human technology and culture should not be overlooked. Resource acquisition and processing technologies like cooking, farming, and the use of tools and projectile weapons, certainly allow humans access to foods and other resources they would not otherwise be able to obtain (Kormondy and Brown, 1998; Urbani, 2005; Miller and Treves, 2011).

Cultural elements such as human belief systems and traditional ecological knowledge also influence human natural resource use dynamics in significant ways (Sponsel, 1997; Barrera-Bassols and Toledo, 2005). Traditional ecological knowledge has been defined as the body of knowledge and beliefs about, “the relationship of living beings (including humans) with one another and with their environment,” that exists in non-industrial indigenous societies, and which is passed from generation to generation via cultural transmission (Berkes, 1993, p.3). Unlike more rigorous scientific methods for understanding ecology, traditional ecological knowledge includes and is influenced by a group’s world view, oral history, mythology, and symbolism.

Cultural taboos, rituals, and religious beliefs described by authors such as Cormier, Riley, and Barrera-Bassols and Toledo, often feed heavily into human

resource use (or non-use) choices – and may originally have functioned well to ensure sustainable use. In Brazil, for instance, Cormier (2002) found that the hunting-fishing patterns exhibited by indigenous Guaja people could not be attributed to ecology alone; rather, high percentages of howler monkeys in the diet was more likely the result of symbolic cannibalism. In Indonesia, human cultural taboos against felling strangler figs has probably helped sustain these floral resources for humans and wildlife, alike (Riley, 2007). And Barrera-Bassols and Toledo (2005) examined the ethnoecology of the Mexican Maya and demonstrated strong links between religious beliefs (land is a living being that must be cared for), rituals (people offer gifts to the land to maintain health) and natural resource management (ritual animal sacrifices are buried and increase land productivity). Thus, in addition to ensuring sustainable resource use, cultural elements such as those described above may also serve to maximize human resource acquisition.

8.1.4 Research Objectives

The aim of this research is to investigate variables that may help explain the differential forest use of two primates that both rely upon forest and timber resources for survival: humans, and critically endangered Tonkin snub-nosed monkeys. Qualitative and quantitative data will be used to address the following core questions:

- 1) Do humans and monkeys use the same parts of the forest at the same time of year?
- 2) Are humans and monkeys similar in terms of the frequency with which they access rugged terrain?

3) What cultural factors contribute to human spatio-temporal forest use?

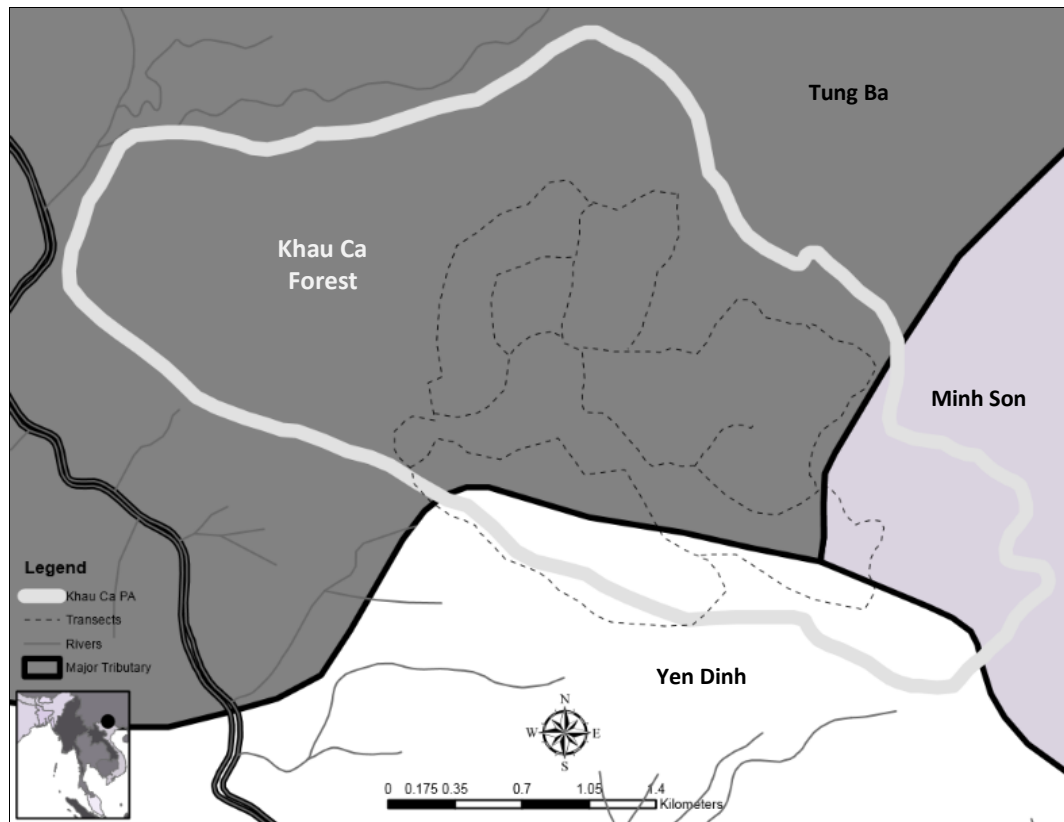
The results of this study will be used to refine conservation interventions already underway in northern Vietnam where these two primate species have co-existed for thousands of years.

8.2 Materials and Methods

8.2.1 Study Site

Located within the sub-tropical monsoon region of northern Vietnam (22° 50' N, 105° 07' E), Khau Ca forest was awarded legal protected status as a Species and Habitat Conservation Area (TSNM SHCA) in August, 2009 [Figure 18]. The approximately 1,000 hectare forest rests atop a block of sheer, porous limestone karst, ranging in altitude from 600 m to 1,400 m. The forest floor is steep and irregular, with an average slope of 30°. Here, the mean annual temperature is 23°C, ranging from an average high of 15°C in January, to 30°C in August. Mean monthly humidity ranges from 35.5% to more than 87%, and annual rainfall averages 2,300 mm/year with pronounced wet (April – September) and dry (October – March) seasons. Between 2000-2012, mean precipitation in Ha Giang Province for the early dry season (48.2 mm) and late dry season (32.7 mm) differed substantially from that recorded during the early wet (165.9 mm) and late wet seasons (221.6 mm) [WWO, 2016]. However, the average number of days during which some precipitation was recorded each quarter was similar from the early dry to the late wet season (14.6, 18.3, 19.6, and 21 days, respectively). Most days, it rains at least a little bit in Khau Ca forest.

Figure 18. Study area map showing locations of the three communes, as well as the trails present and regularly monitored within Khau Ca forest.



Khau Ca is dominated by sub-tropical limestone karst forest. Recent studies of the floral community identified 471 plant taxa from 113 families and 4 phyla (Ha Giang FPD et al., 2008). These plant communities have been ascribed to five distinct habitat types (Nguyen Anh Duc et al., 2006). Primary broad-leaf evergreen montane forest is the dominant habitat type on the steep limestone slopes. Many important *R. avunculus* food trees [see Chapter 7] are found in this habitat, including trees from the *Excentrodendron*, *Pometia*, and *Acer* genera. A secondary limestone-based evergreen forest can typically be found between the primary forest and either a) secondary scrub savannah or b) secondary grassland, both of which occupy the lower flatter valleys.

Actively cultivated vegetation plots – the fifth and final vegetation type distinguished within Khau Ca – are often found along the protected area boundary.

Regardless of habitat type, the marked climactic seasonality observed in Ha Giang Province has impacts on plant productivity in Khau Ca. Le Khac Quyet (2014) demonstrated that while the production of tree-borne young leaves peaked between March and June, and that of flowers from March to May, tree fruits were more often available in the heart of the rainy season, June through September. Thus, tree-based food items in Khau Ca forest are most highly available to human and non-human primates between March and September, leaving a period of relatively low food availability in the coldest, wettest months of October through February.

8.2.2 Nonhuman Primate Study Subjects

Recognized as one of the world's top 25 most critically endangered primate species for the last 16 years (Schwitzer et al., 2016), it is currently believed there may be fewer than 250 Tonkin snub-nosed monkeys alive today. The remaining individuals survive in five fragmented and isolated populations within Vietnam, the largest of which – approximately 125 monkeys – is found in the Khau Ca forest. The Khau Ca population is by all accounts the single remaining viable population of *Rhinopithecus avunculus*.

One of five species belonging to the snub-nosed monkey genus *Rhinopithecus*, research regarding the TSNM has intensified over the past two decades. Studies indicate that much like other snub-nosed monkeys in China and Myanmar, *R. avunculus* demonstrate a multi-level social structure, in which single-male, multi-female units often

coalesce (Kirkpatrick, 2007; Grueter et al., 2009; Kirkpatrick and Grueter, 2010; Yixin Chen et al., 2015).

Tonkin snub-nosed monkeys, however, are the only *Rhinopithecus* species found in sub-tropical montane forest. They appear to have a diet similar to other colobine monkeys yet distinct from snub-nosed monkeys found in the temperate mountains of China and Myanmar (Boonratana and Le Xuan Canh, 1998b; Baoping Ren et al., 1998; Le Khac Quyet et al., 2007). A primate whose mandibular anatomy supports a feeding regime comprised largely of tough food items (Wright et al., 2008; Ruliang Pan et al., 2008), *R. avunculus* have been reported to consume a variety of plant parts. In 2007, Le Khac Quyet reported a diet that primarily consisted of ripe and unripe fruit (47.2%) and leaf stems (22.2%) but also contained young leaves, flowers, seeds, and piths. Tonkin snub-nosed monkeys at Khau Ca also appear to be quite selective, choosing to feed from only 13% of 93 tree genera identified along forest transects. Observations in 2011-2012 further indicate the monkeys spent most of their time in or near important food trees; especially those from the *Excentrodendron*, *Garcinia*, and *Machilus* genera (Le Van Dung et al., 2014). To date, researchers have identified a total of 33 Khau Ca plant taxa from which TSNM are known to feed [Table 2].

Although some *Rhinopithecus* species spend a notable portion of their time on the ground (*R. brelichi*: Bleisch et al., 1993; *R. bieti*: Ze Hua Liu and Qi Kun Zhao, 2004; but *not* *R. roxellana*: Yiming Li, 2002), *R. avunculus* are highly arboreal. Recent research describing TSNM locomotion and positional behavior indicate the species is predominantly an arboreal quadruped that also uses leaping, climbing, dropping, and below-branch arm-swinging during travel (Le Khac Quyet, 2014). A relatively large tree-

dwelling primate, it is not surprising that they prefer solid substrates during travel, using more flexible branches and lianas mostly while searching for or consuming food. Le Khac Quyet also found that TSNM spend more time sitting during drier, cooler months – perhaps as an energy saving measure.

Beyond the data presented above, not much is known about seasonal influences on the behavioral ecology of *R. avunculus*. Dong Thanh Hai (2008) found that *R. avunculus* increased consumption of fruits in the wet season. This result is supported by Le Khac Quyet's 2014 research that shows TSNM in Khau Ca spent more time climbing on flexible supports in the wet season, possibly due to a dietary shift to increased frugivory in conjunction with the peak fruiting season. While time spent feeding and foraging increased in the dry season, *R. avunculus* traveled and rested more in the wet season (Le Khac Quyet, 2014). In other words, TSNM of Khau Ca trend towards increasing time spent feeding and foraging in the dry season of low food availability, but move longer distances and use less stable supports to maximize foraging success in the wet season, when fruits and other food items are more readily available.

8.2.3 Human Study Subjects

In addition to Tonkin snub-nosed monkeys, perhaps as many as 13,000 people (about 3,700 households) currently live within the three communes in and around Khau Ca forest: Minh Son, Tung Ba, and Yen Dinh. With little exception, local residents identify as farmers, even if they spend a great deal of time in off-farm employment. The vast majority of people living in these communes grow and make most of what they

need to survive. In addition to cultivating crops and rearing livestock, most area residents also rely on timber and non-timber forest products for supplemental food, fodder, and medicine, as well as for essential fuelwood and construction materials. Thus, forest resources play a significant role in the daily lives of most people living within these three communes.

Nearly all of the regional human inhabitants are from three of Vietnam's 53 ethnic minority groups. Approximately 75% of the population is represented by people that self-ascribe to the Black Tay ethnicity. Tay people have lived in the area for thousands of years; their presence in the region pre-dates written records (Tran Duc Vien, 2003) and may date back to 500 BC (Vietnam Culture, 2016). Commonly inhabiting the lower flat and fertile valleys surrounding Khau Ca's limestone karst mountains, the Tay have long practiced fairly sustainable irrigated rice paddy cultivation combined with swidden agriculture (Tran Duc Vien, 2003). Robust home gardens provide preferred fruits and vegetables such as beans, cabbage, and chili peppers. Typically having more favorable socio-economic status than the other two ethnicities inhabiting the region, the Tay commonly own livestock such as water buffalo, pigs, goats, chickens, and ducks which are used as food and in the case of buffalo, in the manual labor required for wet rice cultivation. They identify primarily as a rice-farming and rice wine-drinking culture, but do not shy away from regaling tales of their hunting prowess prior to a local gun confiscation program implemented in 2005-2006. The Tay do not ascribe to a particular recognized religion; instead, their belief system focuses mainly on worshipping familial ancestors (Vietnam Culture, 2016).

Fifteen of the remaining 25% of the human population (perhaps 1,800 people today) belong to the Red Dao ethnic group. The Dao, sometimes known as jungle people, have been immigrating into Vietnam from China since the 12th or 13th century (Vietnam Culture, 2016). They typically practice swidden farming, wet-rice cultivation and rock-pocket agriculture (using rocks to divide slope-side crops) in the mid-level altitudes of the region. Recognized for their breadth of knowledge of wild medicinal plants, many Dao also practice agroforestry (ICEM and PADP, 2003) and hunting contributes to their group identity (Novellino, 2000). As with the Tay, Dao people worship their familial ancestors – especially the single ancestor of all Dao, called *Ban vuong*. Their religious beliefs, practices, and rituals are mixed with those of Confucianism, Buddhism, and Taoism and they also have a strong storytelling tradition, both oral and written (Vietnam Culture, 2016).

The remaining 10% of the local human population ascribes to the Flower Hmong group. The most recent immigrants to the area (having arrived just 100-300 years ago from China), the Hmong tend to be the poorest and most marginalized ethnic minority (Lee and Pfeifer, 2006). Hmong people are often referred to as savages and perceived to be backwards if not environmentally destructive (Blankston, 2007). Dwelling primarily at high elevations in compactly constructed villages, they practice shifting, slope-side agriculture and while rice is grown, as well, it is corn that is their primary cultivar. Like Dao and Tay people, the Hmong compliment cultivated crops with home gardens and by procuring forest resources (Tran Duc Vien, 2003). They primarily worship ancestors and spirits through rituals and charms, and there are many sacred places within the home (Vietnam Culture, 2016). Additionally, to the Hmong, natural

resources that are vital for human survival are protected by place-specific guardians who are worshipped and thanked during special ancestral rituals (Her, 2005).

8.2.4 Data Collection and Analysis

In this research, the goal was to assess human and nonhuman forest use patterns simultaneously. Therefore, a variety of quantitative and qualitative methods were employed between August 2011 and March 2013. Two teams, a forest research team (Le Van Dung and one of four additional local research assistants) and an interview team (Luu Tuong Bach, Amy Harrison Levine, and one of five local assistants), collaborated to gather and verify data. Permits for working in the region were secured with the local Commune People's Committees, as well as the Ha Giang Province Forestry Protection Department. The two lead interviewers were trained in human subjects research and interview protocols were approved by the primary author's Human Subjects Institutional Review Board.

The forest research team spent approximately 10 days at the Khau Ca research station each month (August 2011 through November 2012). Every day it was safe to enter the forest (1-11 days/month, due to rainy conditions rendering the field site incredibly hazardous), the team gathered plant transect phenology data, attempted to locate and follow a TSNM group, or both.

Phenology. Two established, non-linear, random phenology transects (1 km x 2 m) that were previously determined to be representative of the TSNM diet within Khau Ca (Le Khac Quyet, 2007; Covert et al., 2008), were monitored monthly. Four hundred

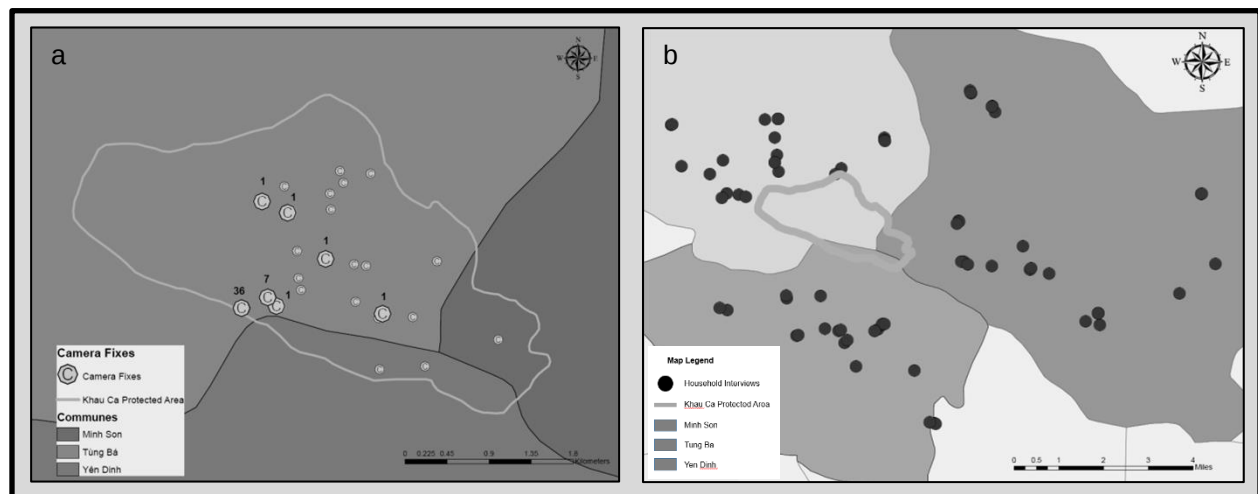
eighty four (484) trees (> 10 cm DBH, or diameter at breast height) were evaluated, using binoculars (Bushnell H20 10x42), for the presence or absence of fruit, flowers, and young leaves. If at any time during phenology sampling, a monkey group was encountered, the team diverted to following the monkey group.

Monkey Behavior and Ranging. The difficult terrain of the karst habitat in Northern Vietnam (Boonratana and Le Xuan Canh, 2013) does not often allow for all-day group follows; therefore, any time the forest research team made contact with a group of *R. avunculus*, they began recording instantaneous scan samples to capture monkey behavior, feeding, and ranging patterns (Altman, 1974; Martin and Bateson, 1993). Every five minutes, the date, time, and estimated central point of group location was recorded using a Garmin GPSmap 60CSx GPS unit and a Bushnell ARC Rangefinder. Moving left to right, the behavior of the first three individuals in sight was then recorded (we evaluated four, mutually exclusive broad behavior categories: feed, rest, travel, or other). Whenever known, the plant taxa and plant part being used was also noted for all samples.

Evidence of Human Presence. Data regarding human use of the forest were sampled, in part, via direct observation of evidence of human presence in the forest. Two methods were employed to gather direct evidence of human presence: 1) the use of camera trap photos to evaluate human traffic (Griffiths and van Schaik, 1993) and 2) monthly surveys of all transects and trails in the forest (Olupot et al., 2009; Vaidyanathan et al., 2010; Wiafe, 2010). A total of 20 camera traps (Bushnell 8MP

Trophy Cam) were deployed and monitored by the forest research team; the majority were spatially distributed among existing footpaths within the heart of Khau Ca, but a few were reserved for locations where human activity was expected to be high (at known entry points into the forest, and near recently cut tree trunks). In an attempt to balance camera trap spatial distribution, some cameras were moved when trap loss occurred due to theft or malfunction, resulting in a total of 25 different trap locations [Figure 19a]. Like other animals, humans may make efforts to evade camera traps (Sequin et al., 2003), but given the dangers of venturing off trails in this particularly dangerous terrain, it is reasonable to assume most people who enter the forest stay on existing footpaths. Camera trap photos were filtered to exclude images of the same individual or group on the same day (Tobler et al., 2008).

Figure 19. Maps of camera trap (a) and household interview (b) locations in relation to the Khau Ca forest boundary (number of human fixes noted per trap on map a)



While monitoring camera traps, searching for monkey groups, and recording phenological data, the forest research team surveyed all forest trails at least once per

quarter (late dry season: January-March, early wet: April-June, late wet: July-September, early dry: October-December). During trail surveys, any new evidence of human presence – new tree-cuttings, garbage, fire pits, traps, or encounters with people, for example – was recorded on an all-occurrence basis, and the date, time, activity, number of people encountered, and/or GPS location noted.

Household Interviews. The direct observations of human presence in the forest described above were compared to qualitative reports of human forest use stemming from household interviews. The interview team conducted a total of 75 semi-structured interviews between May 2012 and March 2013. Every attempt was made to balance socio-economic variables (wealth and ethnicity) of households interviewed and to ensure an even distribution of household location (near and far from Khau Ca, as well as among the three communes) [Figure 19b]. In addition to capturing household GPS location, socio-economic status indicators, and demographics, respondents were asked to list all forest plant resources known to be used by local people. During this freelistings exercise, households were prompted to explain both why and when people utilize each wild plant listed. To accomplish the temporal line of questioning, a 12-month traditional lunar calendar was presented and respondents used it to indicate the months and/or weeks during which each forest resource was commonly harvested or used [Figure 20]. In addition to recording this information, the interview team also probed for and noted the rationale provided for preferred resource use timing. The team was also careful not to inquire specifically about location of forest use activities during interviews, to ensure ethical treatment of household respondents.

Figure 20. Photos of household interviews in process.



Data Analysis. Spatial data (GPS points) were uploaded into ArcGIS and cell size was set at 90 m². Seasonal location fixes for monkeys and people were compared using the minimum convex polygon method. The slope-aspect ruggedness index (SARI), a habitat ruggedness index, was calculated as follows: $SARI = (STDEV\ Slope) \times Variety\ of\ Aspect / (STDEV\ Slope + Variety\ of\ Aspect)$, after Bragin et al. (2013). Ruggedness index values resulting from these calculations ranged from 1 (least rugged) to 9 (most rugged). For statistical purposes, quantitative data presented here were evaluated using non-parametric Spearman's correlations and Wilcoxon's rank sum tests, executed using SPSS statistical software. Groups of monkeys (one-male, multi-female) and humans (households) were the primary units of analysis. Statistical results were considered significant when $p \leq 0.1$.

Qualitative information was compared to quantitative findings and was also used to further explain patterns observed in the quantitative data set.

8.3 Results

8.3.1 Seasonality

Phenology. Four hundred and eighty four trees were sampled for phenological state each month. The presence of young leaves peaked in April and May, with 60.9% and 49.1% of trees bearing new leaves at this time of year. Only between 9.4% and 34.8% of trees along the two transects presented with young leaves the rest of the year [Figure 21]. The percentage of trees with fruits or flowers present was always lower than that for young leaves. Flowers showed a clear apex in April and fruit availability was highest from July through October [Figure 22]. When compared with mean monthly rainfall estimates, Spearman's correlations between rainfall and the number of trees with fruit, flowers, or young leaves present were not significant ($r_s = 0.378$, $p = 0.2253$; $r_s = -0.088$, $p = 0.7848$; and $r_s = 0.315$, $p = 0.3191$, respectively).

Figure 21. Comparison of mean monthly rainfall and availability of young leaves in Khau Ca forest.

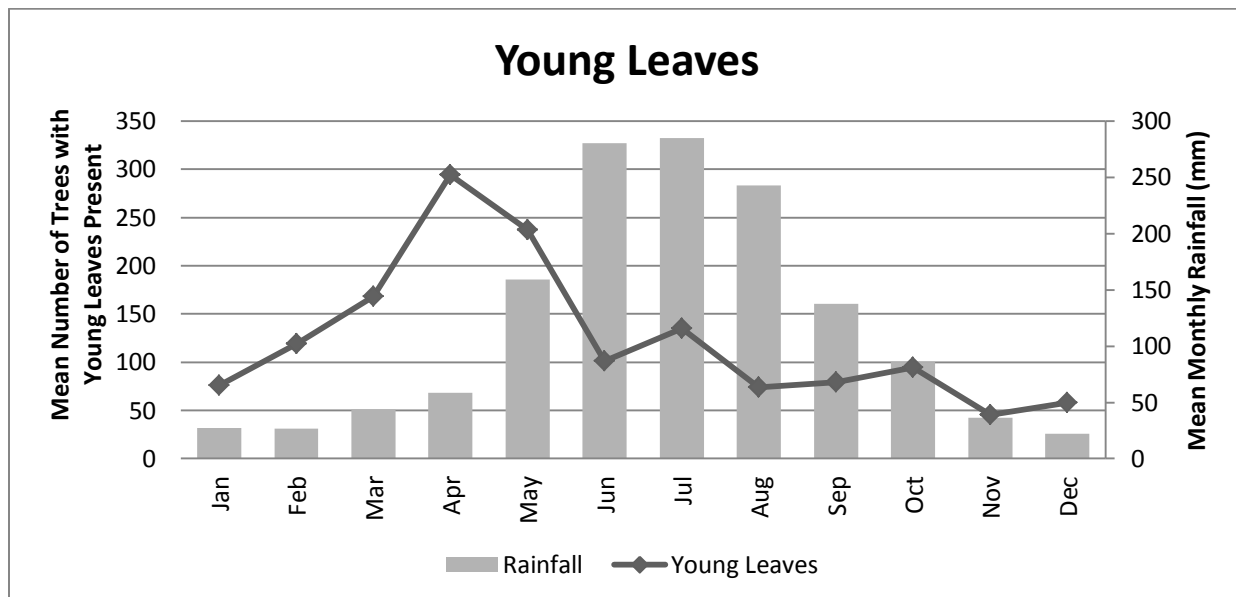
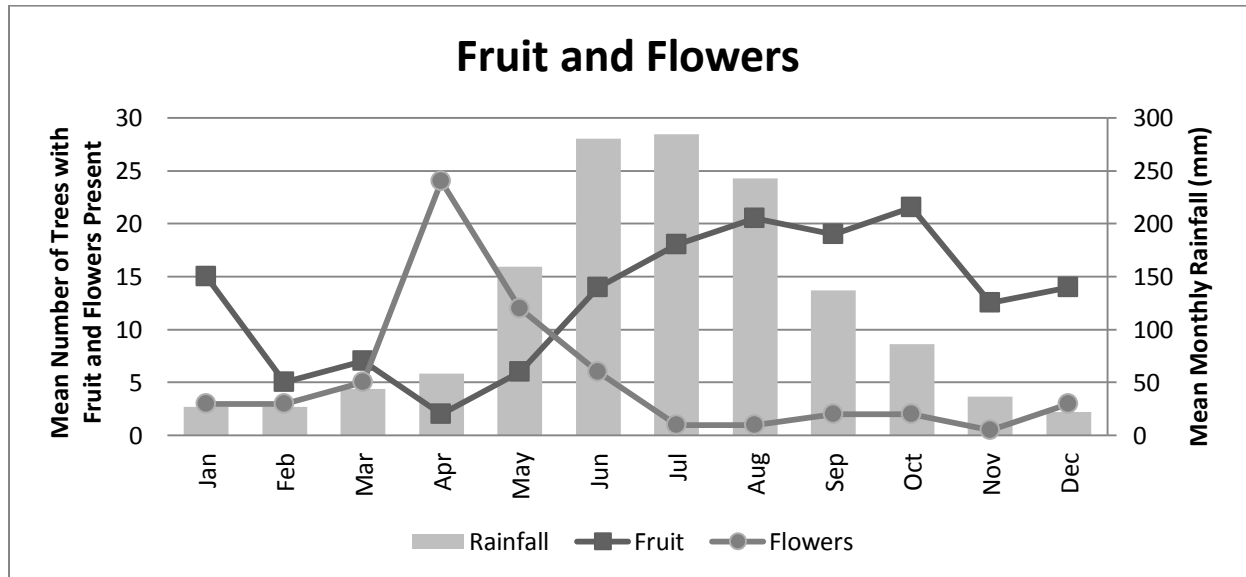
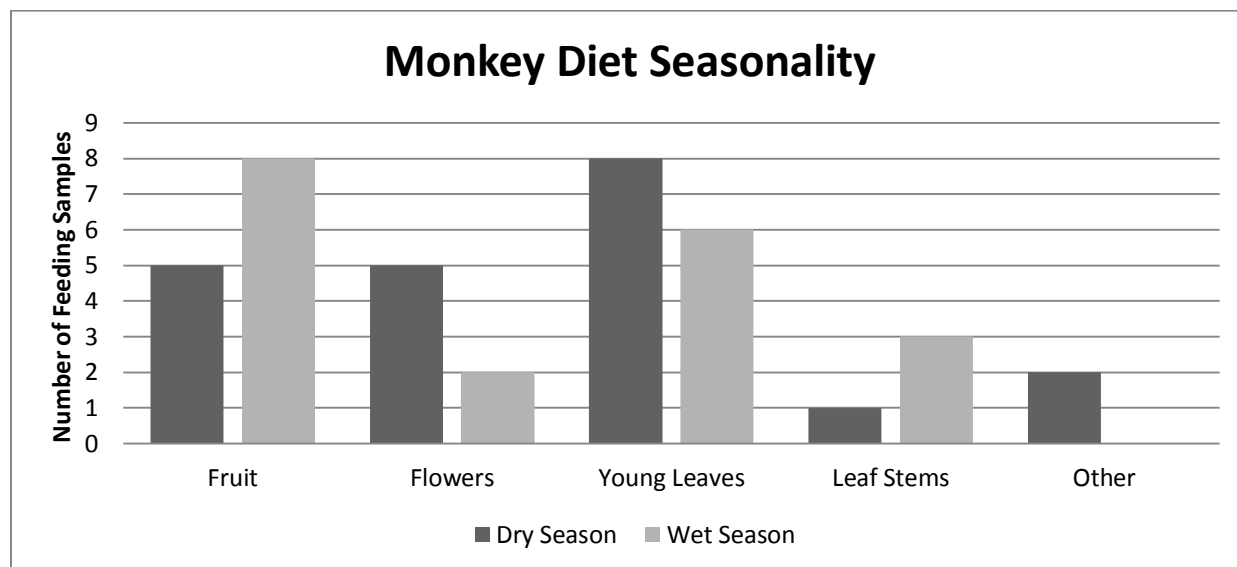


Figure 22. Comparison of mean monthly rainfall with fruit and flower availability in Khau Ca forest.



Tonkin Snub-Nosed Monkey Diet. From August 2011 through November 2012, 40 feeding samples were recorded during a total of nearly 50 observation hours with the monkeys. Young leaves (35%) and fruit (32.5%) formed the bulk of the observed *R. avunculus* dietary intake. Flowers (17.5%), leaf stems, or petioles (10%), and two unknown food items (5%) were also eaten. Although sample sizes were quite small, fruit and leaf stems were ingested more frequently in the wet season and conversely, TSNM consumed flowers – especially tree-borne orchids – and young leaves most often in the drier months [Figure 23]. For two of the three food items (young leaves and flowers), Spearman's correlation coefficients were not significant ($r_s = -0.049$, $p = 0.8800$ and $r_s = -0.154$, $p = 0.6338$); however, the monkeys did ingest fruit most commonly during months of high phenological availability ($r_s = 0.539$, $p = 0.0706$).

Figure 23. Comparison of food items ingested by Tonkin snub-nosed monkeys during the wet and dry seasons.



Evidence of Human Presence in Khau Ca. Although 20 cameras were originally deployed, one was lost due to theft and several either ceased to function temporarily (at times due to rapid fire photography filling memory cards within as little as one hour) or permanently. Overall, human traffic in Khau Ca was monitored for 3,498 trap-days, with between 9 and 16 cameras operating simultaneously. The number of operational trap-days was similar for wet and dry seasons (1688 and 1810 days, respectively), ranging from 217 days in September to 407 days in February. Trapping effort along each of the four transects monitored was relatively consistent among seasons, and monthly data are summarized in Table 12.

Seven of the camera traps captured 48 independent events of human activity within Khau Ca. By far, the camera recording the most frequent human foot traffic was one placed along a well-known entry point into the forest; 36 photos showing human

Table 12. Camera trap sampling effort summary (trap days by season and by location).

Trap Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total Days
Transect A	75	84	87	90	62	73	93	94	90	67	54	83	952
Transect B	121	114	96	90	93	53	62	58	48	59	42	72	908
Transect C	62	41	27	30	31	30	57	58	15	37	60	33	481
Transect D	73	84	24	0	0	24	62	56	47	54	48	33	505
Other	57	84	65	75	93	84	62	41	17	13	30	31	652
Total Days	338	407	299	285	279	264	336	307	217	230	234	252	3498

activity were recorded here. Seven of the remaining twelve events were captured on a second camera located along an interior trail not far from the first [Figure 18a]. In other words, 90% of all human traffic recorded via camera traps took place along the southwestern border of the protected area.

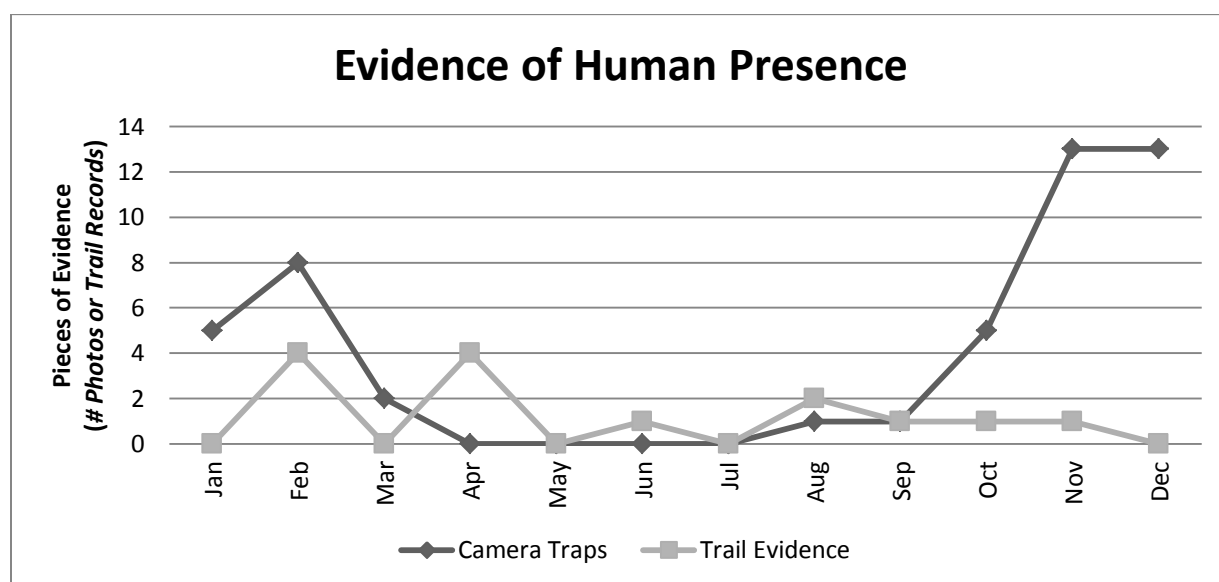
Researchers spent 96 days traversing transects and trails within Khau Ca, recording any new evidence of human presence, including direct encounters with local people. Nineteen pieces of evidence were found throughout Khau Ca using this method of direct observation of human traffic, the majority of which (58%) were sightings of recently cut trees located along the northwest portion of the forest.

Whether recorded via camera trap or by noting evidence of human presence along forest trails, human traffic within Khau Ca occurred primarily in the driest months ($r_s = -0.843$, $p = 0.0006$). Of the 67 recorded human activity events, 92% percent took place between October and February [Figure 24]. This highly seasonal human traffic pattern coincided with qualitative interview data. A large number (over 30%) of respondent households described a preference for forest excursions during the dry season, primarily because it was considered “free time.”

Focusing in on the specific types of human activity occurring each month within the TSNM SHCA [Figure 25], peak times for timber harvesting and the procurement of

non-timber forest products (NTFP's) overlapped significantly ($r_s = 0.852$, $p = 0.0004$). Besides timber and NTFP collection, two terrestrial small mammal traps were found at different locales, one in August 2011 and the other in August 2012. The other two pieces of evidence recorded during this study were the remains of a recent fire and some garbage left behind by human visitors.

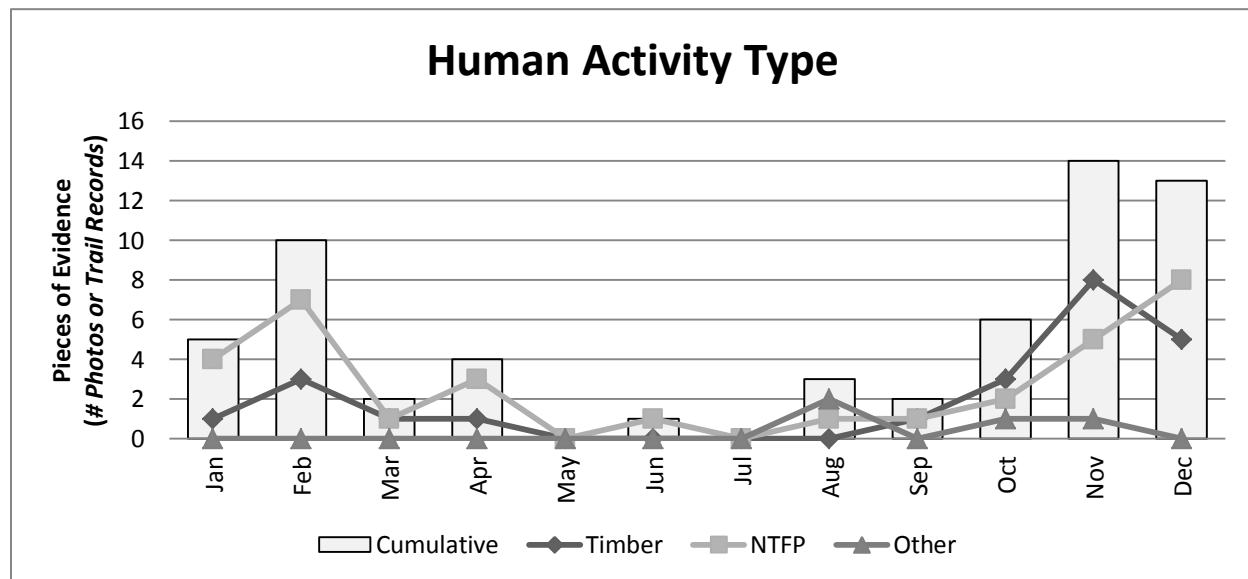
Figure 24. Seasonal pattern of direct observations of human traffic in Khau Ca forest, demonstrated by both camera trap and trail evidence.



Human and Non-human Primate Forest Use. While local people entered the forest significantly more often in cooler, drier months (October through February), Tonkin snub-nosed monkeys were present in the isolated Khau Ca forest year-round. Spatial overlap between the two species was high; minimum convex polygons for both were similar in size and shape (88.5% overlap). That said, there were also some clear core areas of human and monkey activity. Throughout the year, evidence of human presence was most commonly recorded along the southwestern border of the protected

area, with a secondary hub of activity just over the limestone karst ridge in the north central region of Khau Ca. Monkey activity, on the other hand, was concentrated quite near the center of the forest [Figure 26].

Figure 25. Seasonal pattern of the type of human activity within Khau Ca forest.



In comparing wet and dry-season forest use for both species, a similar pattern emerged. Wet season minimum convex polygons for monkeys and humans were quite similar, exhibiting 68% overlap [Figure 27]. In the dry season human-TSNM polygon overlap was lower - 57% [Figure 28]. During the dryer months, evidence of human presence was often recorded further north and south than monkey locations (closer to northern and southern forest boundaries), and TSNM more commonly ventured further east. While humans shifted their forest use to the west during the dry season, the shape and size of the TSNM polygon narrowed by 44% in the wet season.

Figure 26. Human (left) and Tonkin snub-nosed monkey (right) core areas of forest use (measured as kernel density, with the highest density taking on the lightest shade of gray).

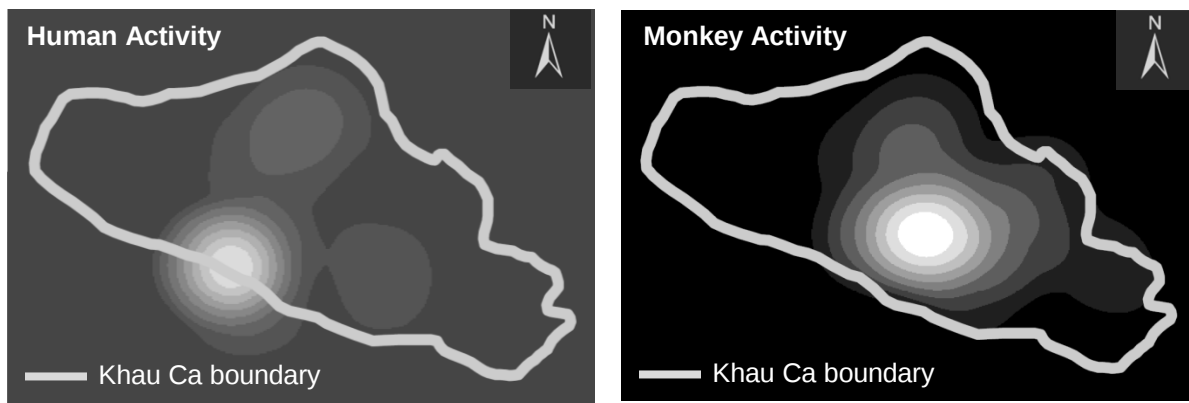


Figure 27. Wet season habitat use for humans and Tonkin snub-nosed monkeys, compared using the minimum convex polygon method.

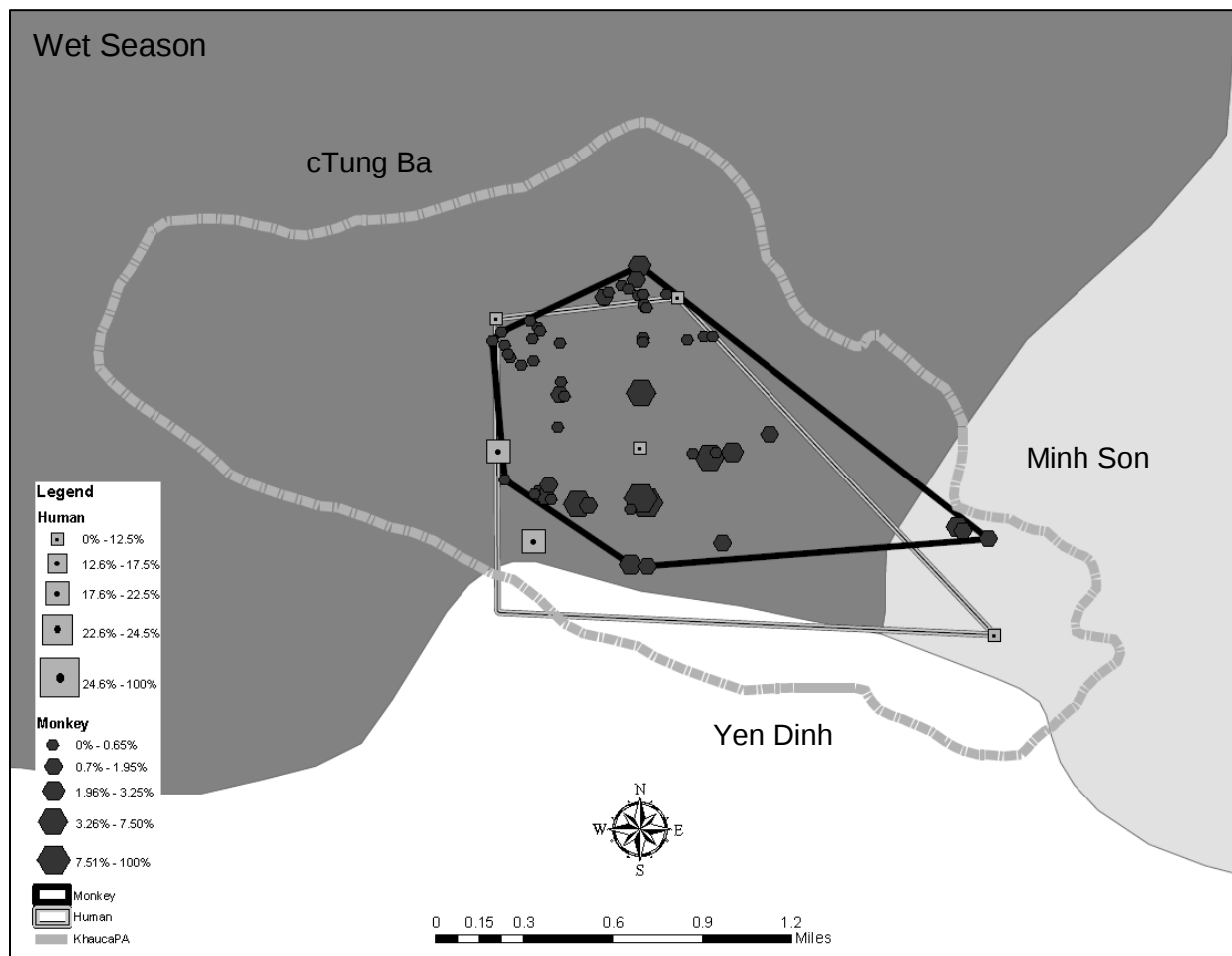
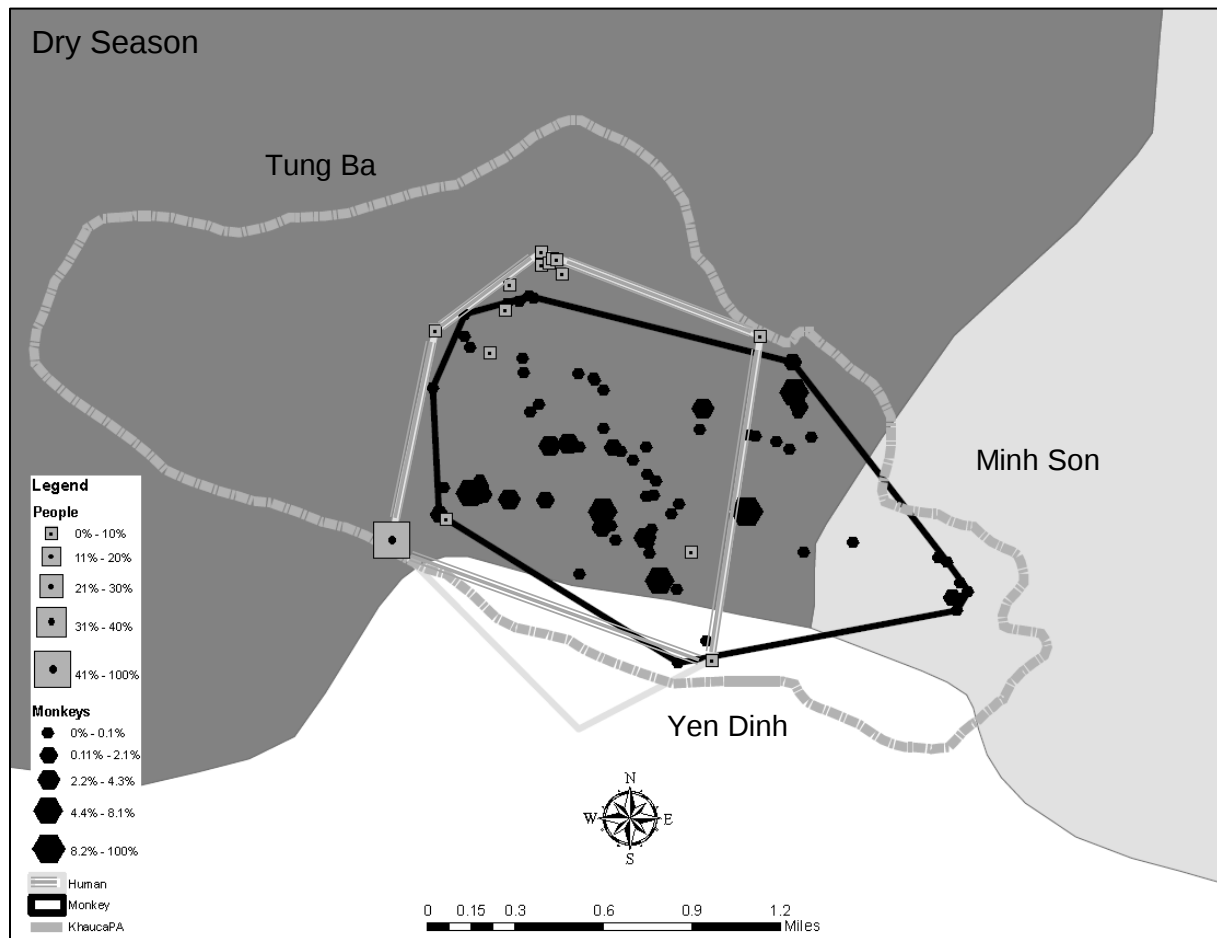


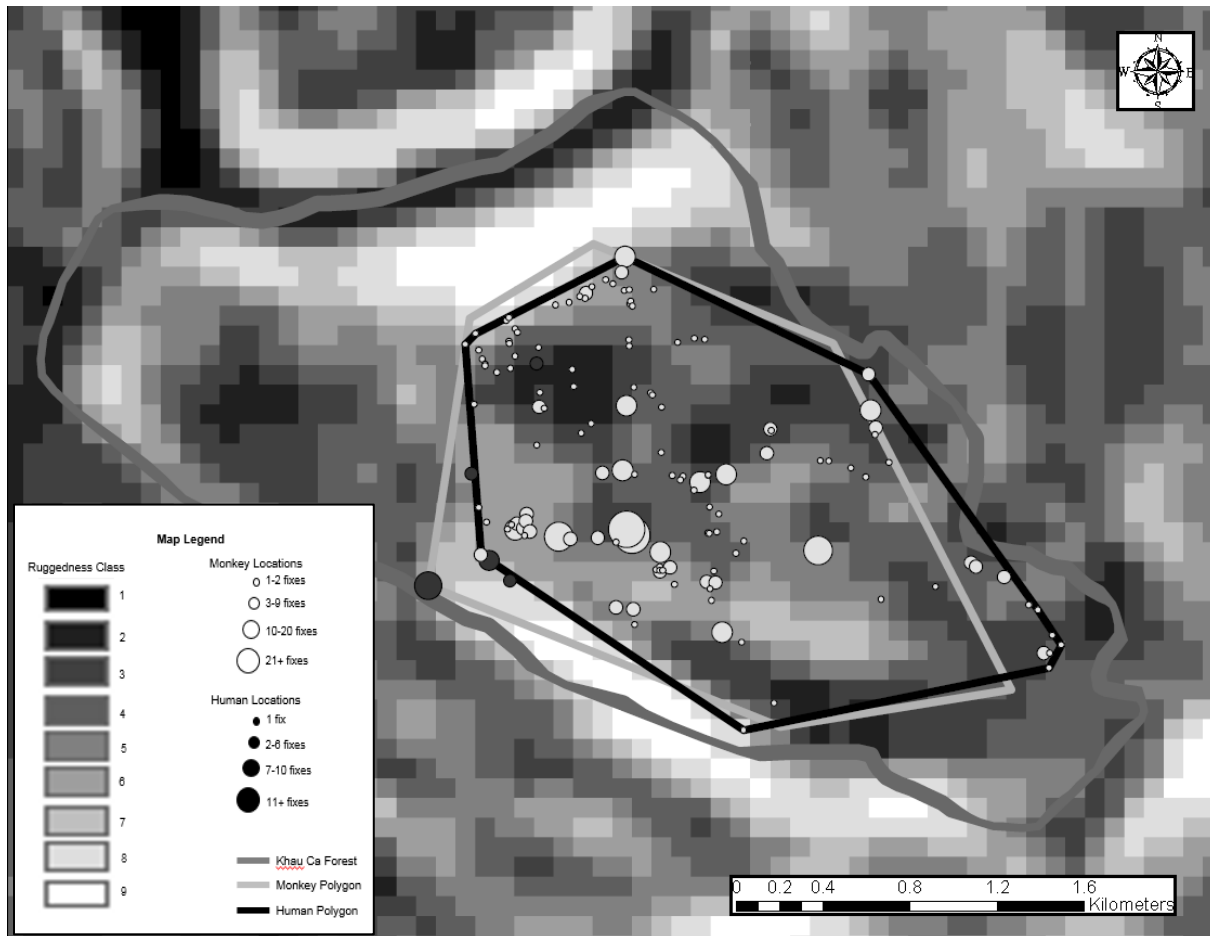
Figure 28. Dry season habitat use for humans and Tonkin snub-nosed monkeys in Khau Ca forest, compared using the minimum convex polygon method.



8.3.2 Ruggedness

Khau Ca forest is remarkably rugged. Of the approximately 1,000 hectares within the protected area, 20% were dominated by terrain falling into the least rugged SARI index classes 1-3 [Figure 29]. The bulk of the forest quadrats (58%) were ascribed to moderately rugged classes 4, 5, or 6, and the remaining terrain (22%) was classified into the most rugged classes, 7 through 9. Almost all of Khau Ca is moderately to extremely steep and topographically diverse. In addition, the forest is largely surrounded by incredibly

Figure 29. Locations of human (black) and Tonkin snub-nosed monkey (gray) activity in relation to forest ruggedness class (most rugged = lightest cells, least rugged = darkest cells), and including minimum convex polygons for all within-forest GPS points recorded for both species throughout the study period.

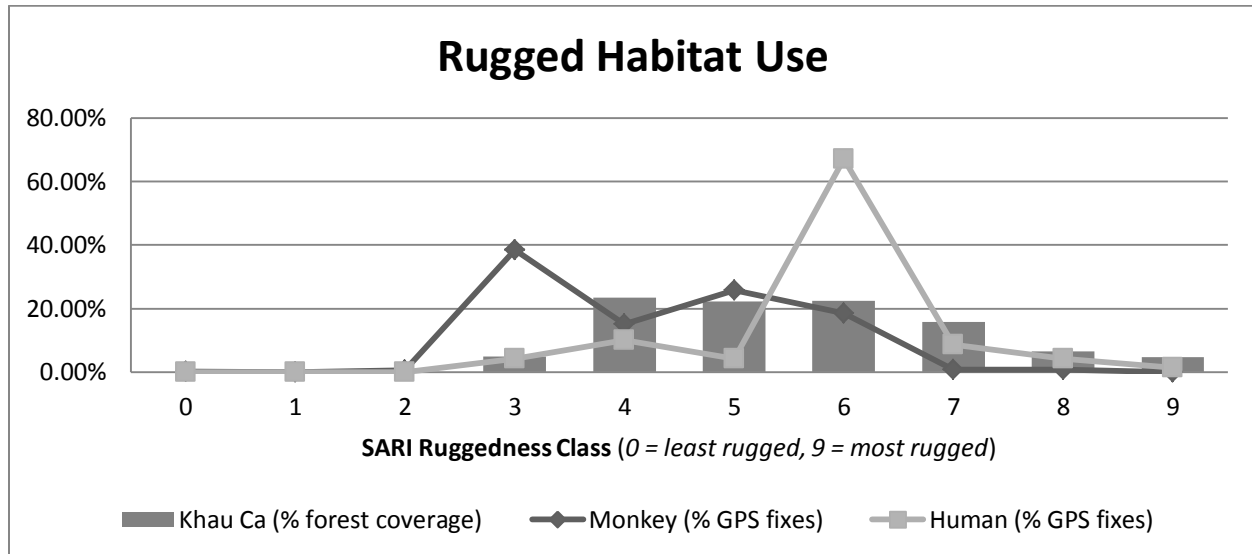


irregular limestone karst; over half of the cells immediately adjacent to the forest boundary are classified as some of the most rugged terrain in the region (SARI classes 8 and 9).

A Wilcoxon rank-sum test indicated that human and monkey use of ruggedness classes differed significantly ($T = 6.0$, $p = 0.0547$). Nearly all monkey GPS fixes were recorded in low to moderately rugged terrain (classes 3-6). Almost 40% of monkey

observations took place in class 3 cells, but human activity was most commonly recorded in comparatively steep and irregular locales [Figure 30]. Forty-seven of 70 human fixes fell within SARI classes of 6. Even when the 36 fixes from a single camera trap placed at a class 6 location were removed from consideration, this highly rugged SARI class remained the most frequently utilized by humans. In other words, these data suggest humans tended to use rugged terrain more frequently than did TSNM.

Figure 30. Comparison of human and Tonkin snub-nosed monkey rugged class use in Khau Ca forest.



8.3.3 Culture

Of the 75 interviews conducted, 24 took place in Minh Son, 25 in Yen Dinh and 26 in Tung Ba commune. The majority of household respondents (96%) lived within 8 km of the Khau Ca forest boundary and ten homesteads were within 1.5 km of the protected area limits. Just over half (56%) of households interviewed were Tay people, 26% belonged to the Dao ethnic group, and 16% self-ascribed as Hmong.

In addition to household respondents frequently citing “free time” in explaining their temporal use of forest resources, other themes emerged from the interviews, as well. Certainly not surprising was the fact that a vast majority of interviewees related food and fodder harvest times that coincided temporally with phenological availability. Focusing in on timber products more specifically, several household respondents explained that collection of timber occurred during the cold, dry months because of high winds that frequently knocked down leaves and branches, making wood easier to collect and carry. Still others said trees were drier and burned better when procured during the dry season, that it was a traditional time to collect timber, that the wood was easier to cut and carry at that time, and/or that it was less difficult to climb the mountain to access the forest at this time of year. Additionally, 13% of households shared that to minimize the presence of termites in wood, the best time within the dry season to harvest timber products was at the end of each lunar month, well after the full moon.

Another trend in the qualitative interview data was noted in relation to the most important holiday of the year – *Tet*, the Vietnamese Lunar New Year. One household respondent expressed that their primary rationale for extracting timber in December and January was a need for extra fuelwood during the celebrations of the *Tet* holiday. In addition, a traditional *Tet* food item, a stuffed sticky rice cake called *banh chung*, requires leaves from the wild *Phrynium* sp. plant [Figure 31]. These large *Dong* leaves are also harvested in December and January, and are used to wrap the square rice cakes, which are given to friends and family during the week to ten-day long Lunar New Year celebration.

Figure 31. Photos of non-timber forest product procurement (left) and of a Dong leaf, *Phrynium* sp., (right).



8.4 Discussion

The primary goal of this study was to compare spatial and temporal forest use patterns for human and Tonkin snub-nosed monkey groups at a 1,000 ha study site in northern Vietnam. Important to this type of research is a clear understanding of the ephemeral nature of food availability in a sub-tropical forest landscape. The phenological pattern that emerged here – with young leaf and flower presence cresting in April, followed by high fruit availability from July through October – closely mirrored previous findings from the same study site. Le Khac Quyet (2014) reported on monthly phenology monitoring that took place in 2010, which indicated peak flowering from March through May, and high fruit availability from June to September. The same study also indicated young leaves were most often present between April and June 2010, so the data from 2011-2012 presented here showed a slightly shorter cycle of young leaf availability, which was high in April and May but low in June. The differences observed between the two studies undertaken at Khau Ca may be the result of annual variations,

differential sample size (the current study included a smaller number of feeding samples than the 2010 study), or the likelihood that dietary investigations conducted to date are still early with respect to a species accumulation curve – with additional studies focused on TSNM feeding ecology in the future, we could see a significant rise in the dietary niche breadth. Regardless, given the high flower and young leaf availability in April during both investigations discussed above, it is not surprising that the most recent observation of TSNM groups gathering into one, large, multi-level super-troop took place in April 2015 (Schwitzer et al., 2016). It is possible *R. avunculus* coalesce when food availability is high, much like has been observed for other multi-level primate societies (Grueter et al., 2012).

8.4.1 Spatial and Temporal Use of the Forest

Timber and NTFP collection were the most commonly recorded human activities within Khau Ca forest throughout the study. Timber was likely harvested both for construction (especially in the case of felling large *E. tonkinense* trees) and fuelwood purposes (many camera trap photos showed people removing dead wood from the forest). Interview data suggests that NTFP were most likely procured for the purpose of livestock fodder, human food, rice wine distillation, and medicinal use, but some may have been collected for sale at local markets, as well. Both timber and NTFP harvest patterns were highly seasonal, occurring most often in the cooler, drier months.

On the other hand, monkey diets – which included young leaves, fruit, flowers, and leaf stems – did not vary significantly by season, but this may be a relic of small feeding sample size rather than reflecting true absence of seasonal TSNM feeding

patterns. Nonetheless, evidence from this investigation does not support a pattern of seasonal dietary shifting for Tonkin snub-nosed monkeys; there was only a minimal relationship between phenological scores and food item intake rates observed, and no evidence of variable ingestion of different plant parts by season. In contrast, Le Khac Quyet et al. (2007) hypothesized that TSNM may exhibit seasonally different dietary intake patterns given differences between his and a previous *R. avunculus* study. Thus, due to variable reports, as well as the preliminary nature and small sample size of both current and previous studies, it will be important to evaluate this finding further to more clearly determine whether TSNM exhibit feeding dynamics consistent with seasonal dietary shifting.

In regards to spatial use of Khau Ca forest, both humans and TSNM demonstrated core areas of activity, as well as some seasonal shifting. Human activity was concentrated along the southwestern portion of the protected area, with a node of secondary activity – largely small-scale timber extraction – occurring in the northwestern part of the forest. Whereas the southwestern core area of human use was likely accessed by inhabitants of both Tung Ba and Yen Dinh communes, the human activity taking place in the northwest was almost certainly undertaken by Tung Ba residents. Spatio-temporally, humans not only accessed the forest far less in the wet season overall, they also shifted their forest use to the west in the dry season, rarely utilizing the far east section of the protected area (the area in closest proximity to Minh Son commune) between April and September.

Not surprisingly, Tonkin snub-nosed monkeys focused their activity towards the center of the Khau Ca protected area, regardless of season. Typical TSNM home

range size has been difficult to discern because the majority of studies have either been short-term, have taken place in highly difficult terrain, and/or have occurred within forest fragments that may limit range size. And while we did not attempt to calculate home range size given these and other limiting factors, the data presented here suggest that Khau Ca's TSNM groups both shrink (in terms of overall area) and narrow (from north to south) their ranging patterns in wet, compared to dry, seasons. This is the opposite of what has been observed in both previous *R. avunculus* (Le Khac Quyet, 2014) and *R. roxellana* (Tan et al., 2007) studies, where data suggest these species tend to limit their range and activity in cool, rather than warm, months. Therefore, although TSNM habitat use during this investigation was not indicative of what might be considered a seasonal pattern of habitat shifting, further research is required to determine whether the habitat use pattern of this species truly exhibits increased or reduced time spent traveling during periods of high food availability. Indeed, although ecological examinations conducted by Le Khac Quyet are somewhat larger than the sample presented here, both should be considered preliminary, largely due to an incredibly complex topography that significantly limits sampling regimes.

In examining comparative occupancy dynamics of terrain ruggedness, the results revealed here were unexpected. Whereas it may make some logical sense for highly rugged landscapes to act as a sort of anti-predator refuge for arboreal mammals like Tonkin snub-nosed monkeys – especially from terrestrial predators like humans – the data presented here suggest otherwise. The majority of Khau Ca's terrain is moderately to extremely rugged, and human activity was commonly recorded in more rugged terrain compared to monkey activity. While TSNM seemed to prefer locales with low

ruggedness scores (SARI index class 3), 67% of human GPS fixes were recorded in moderately rugged areas (SARI index class 6). This is the opposite of what would be expected if monkeys were actively avoiding humans by escaping to rugged terrain as a refuge from potential human predators. There are several potential explanations for this unpredicted differential use of rugged terrain. First, preferred TSNM plant resources (for feeding, traveling, and other activities) may occur in less-rugged landscapes, especially since the ruggedness of an area can influence temperature, water flow, and vegetation type, all of which are also important factors in habitat selection. Second, it is possible that camera trap locations were biased to particularly rugged terrain, inadvertently skewing human activity towards steeper, more topographically variable landscapes. Third, TSNM may have chosen these less-rugged areas in order to maximize protection from climactic extremes, including high winds and sun exposure. Fourth, it is possible that the monkeys were easier to observe in less rugged terrain. And a final alternative explanation is that because over half of the protected area is surrounded by incredibly rugged terrain (SARI index class 8-9), humans must surmount these craggy, sharp, and uneven mountaintops (especially when coming from northwestern villages) to access Khau Ca forest, and not only does this demonstrate that ruggedness is not a limiting factor for these terrestrial bipeds, it is necessary to consider that human activity in these zones may be more visible than that taking place in less rugged areas. Further research is necessary to elucidate which of the above propositions may best explain observed behavior of humans and TSNM at this site in northern Vietnam.

An additional component of spatial habitat partitioning that was not evaluated here, but may be significant and an interesting avenue for future investigation, is that of vertical stratification of the forest and its resources. TSNM are almost exclusively arboreal primates and extant humans are highly terrestrial. While this type of spatial differentiation is important to consider, it is also valuable to keep in mind at least three factors: 1) when procuring forest resources, humans often harvest the entire plant – including felling whole trees – and thus may supersede any vertical stratification barrier, 2) the use of tools may aid humans in obtaining resources high in the canopy that would otherwise be inaccessible, and 3) local people at this site very often and without difficulty scale tree boles to procure floral resources from the highest canopy levels, including but not limited to gathering plant samples for the current investigation. Nonetheless, the exclusion of this type of vertically stratified resource partitioning in this study certainly limits interpretation of results presented here.

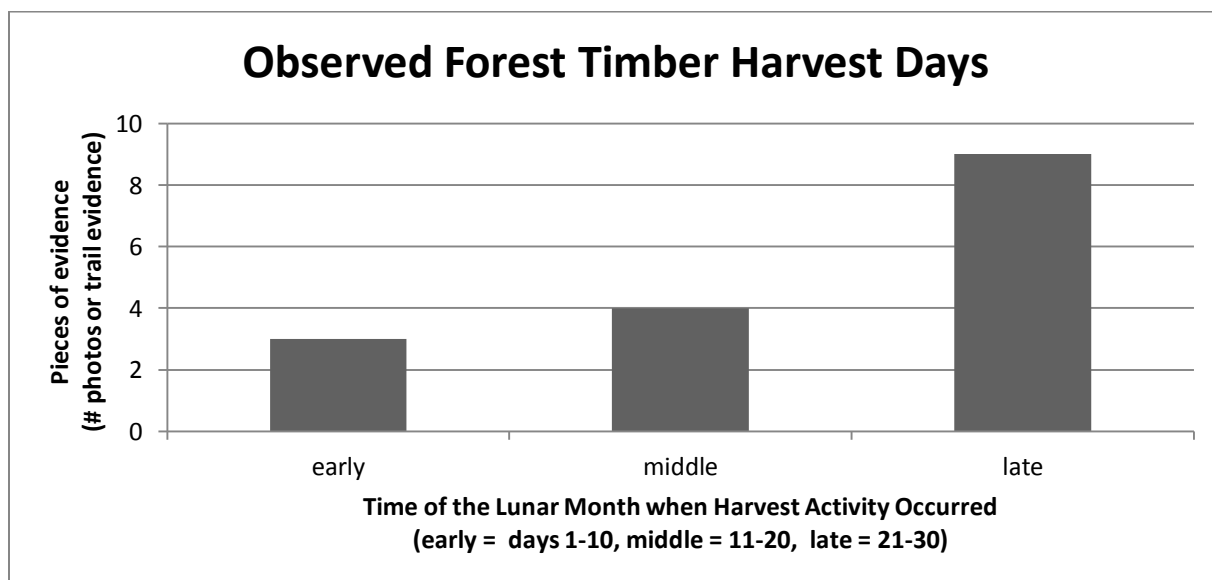
Perhaps the most striking aspect differentiating human and *R. avunculus* use of Khau Ca forest in space and time is the strong tendency for local people to access the protected area during the cool, dry season and towards the end of each month. The majority of human activity was recorded from October through February, with a peak in November and December. Harvesting of both timber and NTFP's occurred most frequently in the dry season months, and human presence in Khau Ca was significantly higher at this time of year compared to the wet season.

This direct evidence of the highly seasonal timing of human presence in the protected area correlated highly with qualitative results, as well. Almost one third of household respondents explained that they most often collected forest resources during

what they consider their free time, the cooler time of year when they are not as busy with agricultural responsibilities, such as tending rice fields and home gardens. Not only is timber purportedly dryer and simpler to access and carry in the dry season, it is also easier to collect and use because it weighs less and is generally not infested with termites at this time of year.

Termite presence in timber may also play an important role in the timing of tree procurement each month, or lunar cycle. Many households reported that they preferred to harvest timber towards the end of each lunar month, when the full moon had acquiesced. A *post-hoc* Wilcoxon rank-sum test examining of the days of each lunar month when direct evidence of timber collection occurred within Khau Ca demonstrated that the majority of timber harvest events took place towards the end of each lunar month ($T = 496$, $p < 0.0001$), when moonlight was relatively low [Figure 32].

Figure 32. Days of the month when forest timber was harvested from Khau Ca forest.



The fact that seasonal and lunar-dependent termite presence or variable wood characteristics may have a significant influence on timber collection regimes in northern Vietnam is not unusual. Jetz et al. (2003) found that in the Ivory Coast, termite presence in wood was limited to the wet season. Zurcher (2001) reported that in France, wood intended for use in construction was best harvested as the full moon wanes, when the wood was considered hard. After quantitatively evaluating wood weight, density, and hardness, this author explained that during the full moon – at least for the Norway spruce trees evaluated in the study – waxing moon wood was softer and lighter, compared to heavier, denser waning moon wood, which was more suitable for construction. This author also suggested that lighter waxing moon wood was less flammable and less resistant to decay, in contrast to denser new moon wood. According to Cole and Balick (2010), this lunar-dependent timber quality pattern has been woven into human harvesting traditions for thousands of years, since at least the time of Pliny the Elder (23-79 AD), who recommended that the best time to procure trees was during a waning moon.

In addition to wood hardness, plant chemistry is also hypothesized to vary in accordance with lunar cycles and herbivorous insect presence. Such variations may be closely related to insect activity, especially given the strong relationship between physiological plant defense mechanisms and herbivore feeding regimes, including that of insects (Vogt et al., 2002). In other words, plant secondary compounds, such as tannins and phenolics, likely vary according to lunar cycles and that variability may also influence activity levels of termites and other insects.

The time of year when human activity in Khau Ca was at its peak during this investigation not only co-occurred with times that may represent low termite activity, it also coincided with preparing for the most significant annual holiday for local people – *Tet*, the Vietnamese Lunar New Year. Ten days of *Tet* celebration before and after the New Year, taking the form of frequent, large gatherings of family and friends, occurs annually in late January or early February. Especially important at this time of year is the preparation of *banh chung*, a traditional *Tet* holiday rice cake that is wrapped in wild *Phrynium* sp. leaves. Forays into the forest to gather firewood, rice-wine distillation ingredients, and food items, including *Phrynium* leaves for associated holiday feasts were common during this study not only via direct observation but also in reviewing qualitative interview data. These *Dong* leaves, beautifully wrapped around square-shaped stuffed rice, are an indispensable part of the holiday celebration, and the story behind the importance of *banh chung* cakes is noble, indeed. According to authors of the website, “Vietnam Online” (2016), an old Hung king set out to determine which of his 21 sons would inherit the throne. He decided to hold a cooking contest. While the other princes tried to find rare and delicious foods, the eighteenth boy – who was poor and could not afford luxurious foods – created the square-shaped *banh chung*, to represent both the shape of a rice patty field and the importance of staple food items such as rice, pork, and wild edibles. The king not only found this dish to be delicious and respectful of the family’s ancestors, it was also a symbol of the Earth. From then on, *banh chung*, wrapped in *Dong* leaves, became a traditional and essential *Tet* food item. This story only serves to solidify the strong evidence presented here, supporting the idea that

human culture and traditions work together with more quantifiable ecological variables in shaping the dynamics of human use of Khau Ca forest.

8.4.2 Conservation Implications

With this clarified understanding of factors affecting spatio-temporal human and TSNM forest use dynamics, it will be possible to enhance TSNM conservation activities in this part of northern Vietnam. From a spatial perspective, future conservation efforts should focus on protecting vital TSNM habitat, especially food-bearing trees in the central region of Khau Ca forest. Boundary demarcation should be fortified in the southwest and northwest regions of the protected area, where human activity is most commonly observed. In addition, forest patrols could be focused on zones of frequent human activity, including the primary and secondary core areas near the Tung Ba and Yen Dinh residents' most common access points.

Additional, temporally concentrated conservation interventions should also be implemented. Knowing that resources, including forest patrol capabilities, are typically limited, the impact of patrols could be maximized by increasing patrol intensity between October and April, to not only include times of frequent human presence, but also to incorporate an important time of food availability for TSNM. Timing forest patrols to especially coincide with waning lunar cycles during the dry season may also result in significant mitigation of human timber resource harvesting activities. Because *Tet* holiday preparations occur towards the end of the dry season, it may be beneficial to determine if locally harvested *Dong* leaves, and any other seasonally relevant forest products, could be grown in home gardens, rather than being an additional draw to

enter the forest at this time of year. At least one variety of the *Dong* plant is already being successfully cultivated in other parts of Vietnam: *Phrynium placentarium* (Hong Truong Luu, personal communication).

Unlike wild *Phrynium* leaves, forest timber is most commonly harvested for the purposes of home construction and fuelwood. Therefore, conservation interventions focused on timber demand reduction would also be extremely beneficial in this part of the world. During the course of preparing this manuscript, researchers have been piloting a fuel-efficient stove project, wherein local authorities have been trained and incentivized to build highly efficient wood-burning stoves and act as stove ambassadors within their communities. Nearly 50 stoves have been built thus far, and the team is monitoring fuelwood consumption in households with and without these stoves, in hopes that stove presence will decrease timber demand. But reducing fuelwood demand is not enough.

Harvesting timber for use in the construction of traditional wooden stilt homes has proven to be a more difficult conservation challenge. More modern, concrete homes are becoming more common in the region, but encouragement of alternative concrete home construction could result in increased limestone mining activity. Limestone mining is currently occurring just outside of Khau Ca forest, and an increase in this anthropogenic activity could not only contribute to habitat loss, it could also cause significant erosion and landslides – a phenomenon that is already a frightening reality, especially in Minh Son commune. Further investigation into alternative home construction materials, as well as that of home gardening possibilities, would likely

serve to enhance the already successful Tonkin snub-nosed monkey conservation interventions taking place at Khau Ca forest in Ha Giang Province, Vietnam.

CHAPTER IX

CONCLUSIONS, FUTURE DIRECTIONS, AND CONSERVATION IMPLICATIONS

This research set out to clarify the various ways and extent to which Tonkin snub-nosed monkeys share forest resources with local people. By applying an ethnoprimate lens – a perspective that negates the idea that humans exist outside of natural systems and should, rather, be considered integral components of even the most pristine ecosystems – this research has unveiled new insights into the human and nonhuman primate community that has co-existed in northern Vietnam for thousands of years. Using a mixed investigative toolkit embracing both quantitative and qualitative methodologies, human and nonhuman forest use dynamics were evaluated simultaneously. Results of this study not only contribute to a growing body of work examining the human-nonhuman primate interface, they will also allow conservation practitioners to focus and enhance conservation interventions designed to preserve the single remaining viable population of critically endangered Tonkin snub-nosed monkeys at Khau Ca forest in northern Vietnam.

9.1 Major Findings and Future Research

This study has provided the first in-depth analysis of human-nonhuman primate forest use overlap in Vietnam. Major findings, presented in chapters six through eight,

can be ascribed to three main ideas. First, socio-economic variables of households surrounding Khau Ca explain a substantial amount of variation in human knowledge of forest resources. Second, over half of the plants used by the TSNM of Khau Ca are also important for human use. More importantly, however, there are some – and especially one – tree taxa that are frequently used by local people, but are truly essential to *R. avunculus* survival. And last, while there is minimal evidence for human-TSNM spatial segregation of Khau Ca forest and there is also little support for seasonal dietary or habitat shifting for the monkeys, the local people consistently access forest resources at very specific times. Further detail regarding the most significant research outcomes is provided below.

9.1.1 Socioeconomic Variables

In Chapter 6, a total assets index was developed and verified as an accurate yet rapid SES proxy measure for the largely subsistence-based economy of communities surrounding Khau Ca forest. This proxy, along with other socio-economic variables, such as self-ascribed ethnicity, household location, education level, and off-farm employment, were significantly correlated with human knowledge of forest plant resources. Such knowledge is often used to reflect resource importance, as well as use frequency (Quinlan, 2005). In this study, one ethnic group in particular, the Tay people, demonstrated extensive knowledge of timber taxa used for construction and fuelwood. They were also the ethnicity best known for their beautiful wooden stilt homes, which local residents have constructed and maintained themselves from tree resources in nearby forests since before written records. Thus, people of the Tay ethnicity will be

important to target when aiming to reduce forest timber harvesting activities for both construction and fuel.

Households located in Tung Ba Commune, which holds significant tenure within and around Khau Ca forest, were similarly well-versed in construction resources, but were also highly knowledgeable about wild plants used for distillation. People from Tung Ba had notably longer freelist lengths of forest resources used in construction, especially compared to residents of Yen Dinh. They also could be considered the local experts with respect to forest plants essential for rice wine, or *ruou*, distillation. This outcome is not surprising, as anecdotal observations during this 20-month study suggest *ruou* distillation (in English, best pronounced phonetically as, 'zil') is more common in Tung Ba than in the other two communes. So, in addition to Tay people, Tung Ba residents will be a key audience to engage in any construction and wine-production focused conservation interventions going forward.

Another demographic that was well-informed about forest plants useful for distillation was those who were most highly educated. Households with a high combined level of education also produced significantly longer lists when it came to (human) food items harvested from the forest. It is possible that individuals who spent a longer time in the Vietnamese education system, which focuses heavily on rote memorization, may simply be able to recall the names of more items – much as they would have done in preparing for a school exam. However, additional research regarding the relationship between education level and freelist length would be required to fully understand this statistically significant relationship.

Although people from all education levels, locations, and ethnicities listed a few forest products often found at local markets, it was households involved in a large percentage of off-farm employment that stood out as the experts in trade products. It was not surprising that families where adults spent more time working to earn cash would be most knowledgeable about forest products that are frequently present during local market days. These households would likely have more expendable income to spend on trade items than other local residents. Alternatively, some of these families that claim high off-farm employment levels may be involved in gathering forest products for sale at local markets. Either way, it will be essential to work closely with households that frequently work off-farm in developing conservation actions that minimize trade of timber and non-timber forest products.

Perhaps the most significant outcomes relating to the socio-economic aspects of this research were two strong correlations between the validated SES index and forest resource use knowledge. Whereas households with low SES scores knew much more about forest plants useful as livestock fodder, it was those with high SES scores who were significantly better versed in construction timber taxa. It is not unexpected that low-SES households frequently supplement home-grown fodder with wild forest plants, given they often have smaller home gardens which may not be productive enough to provide for both humans and livestock. In contrast, those with high SES scores typically dwell upon sizeable properties and also make their success known by building larger, more ornate wooden stilt homes. Indeed, interviews conducted during this investigation revealed that the size of a home is considered to be a clear indication of wealth in this part of the world. Therefore, while low-SES households will be important audiences to

target as NTFP-collection is addressed in the region, those with high SES and larger homes (who may often be of Tay ethnicity and live in Tung Ba commune) will be the key group to involve while exploring alternative home construction materials in the future.

9.1.2 Forest Resource Use Overlap

The second results chapter (Chapter 7) examined Khau Ca forest plant taxa use patterns for humans and TSNM, in an effort to better understand the degree to which resource overlap may or may not exist between these two primate species. This research confirmed earlier work conducted by Le Khac Quyet et al. (2007) that suggested fruit is the principal dietary component for *R. avunculus*. However, rather than leaf stems (petioles) being a secondary element of TSNM diets, in the current study, it was young leaves and flowers that ranked second and third in terms of dietary importance. Observed differences may be the result of small sample sizes and the preliminary nature of both studies. In addition, the TSNM visited several trees that are known food taxa, but were not observed eating from within. This may be evidence that, like many other nonhuman primates, these monkeys actively monitor the location, size, and quality of potential food resources (DiFiore and Suarez, 2007; Cunningham and Janson, 2007). Additional research would be required to confirm this proposition, however.

In turning to resource overlap, one method for determining degree of similarity is comparative niche breadth, or the relative number of plants utilized by co-existing species. While methods used to determine niche breadth for TSNM and the local people differed and thus could not be compared using standard statistical models, this

research demonstrated that both primates have what would be considered a narrow and selective dietary niche, as it pertains specifically to forest plants ingested. Food items were only one of several plant-use categories investigated for both species, however. Whereas the monkeys used only 22% of available flora for feeding, resting, traveling, and other behaviors, local people reported using approximately 67% of forest taxa for necessities including food, livestock fodder, construction materials, fuelwood, items to sell in local markets, distillation ingredients, and traditional medicine. This broader approach illustrates that TSNM have a much narrower forest resource niche breadth than do humans. Thus, in the construction of *R. avunculus* conservation action plans at Khau Ca it will be important to keep in mind that whereas local people appear to be able to use a wide variety of plants for each specific use-category, Tonkin snub-nosed monkeys seem to have a limited number of forest plants that are heavily relied upon for all of their daily activities. Investigating the degree to which the human study subjects conform to resource use dynamics of other generalist species, and conversely, the possibility of TSNM presenting with resource use patterns consistent with being a specialist, would be an intriguing next step for future research.

A second, basic method for comparing resource overlap is to count the number of plant taxa shared by the primates in question. Because this technique can distort the true degree of overlap, deeper investigation was also required. Over half (10 of 18 or 56%) of all plants used by TSNM for feeding, resting, and traveling were also reportedly useful for local people. Conversely, only 10% (18 of 180) plants utilized by people were also used by the monkeys. Further investigation demonstrated that each of the 10 forest plant taxa used by both people and monkeys ranked in the top quarter

of all human salience ranks. Human reliance on these overlapping forest resources for construction, food, fuelwood, distillation, and fodder was considerable. Results also showed that the most important tree genera for humans (*Lithocarpus* sp.), was never identified as one used by the monkeys during this study. However, the tree most essential for TSNM survival, *Excentrodendron tonkinense*, presented with a high human salience rank (it was the 5th most important plant), indicating this plant was also highly valued by local people. *E. tonkinense* ranked first for *R. avunculus* rest and travel behaviors, and was one of the two most important food plants during this research. Although this tree was a key resource for both people and TSNM, also significant is the fact that at least two additional monkey food items (*Schefflera* petioles and Orchidaceae flowers) often grow upon the boughs of *E. tonkinense*. Thus, loss of even a few giant *E. tonkinense* trees could have devastating effects for the future preservation of Tonkin snub-nosed monkeys living in Khau Ca forest.

Aside from the high degree of overlap between humans and TSNM as it pertains to *E. tonkinense* trees, the extent to which these two primates shared specific forest resources was otherwise relatively low. Along with this tree that is clearly vital for *R. avunculus*, three other trees used by the monkeys were also important for local people: *Phoebe*, *Pometia*, and *Garcinia* trees. In contrast, the top four most important plants for local people were not observed to be utilized by the monkeys at all. And although overall, the importance scores for the 10 plants used by both people and TSNM were positively associated, this correlation was not significant. The evidence outlined here suggests that, notwithstanding the shared use of *E. tonkinense* trees, human and nonhuman primate study subjects show a low to moderate degree of resource overlap.

Therefore, some degree of historical resource partitioning may have been at play between people and monkeys at this particular site in northern Vietnam.

9.1.3 Spatio-Temporal Forest Use

Rather than looking at plant taxa aspects of niche overlap, outcomes presented in Chapter 8 were focused on clarifying differential spatial and temporal forest use patterns of the two co-occurring primates that are the subjects of this research. Since the availability of resources is at the heart of spatio-temporal forest use dynamics, it was important to first assess seasonal phenology. Data from the current investigation confirmed monthly food abundance reports from Le Khac Quyet (2014). Flowering peaked in April in both studies, and fruit was most plentiful between July and October. Young leaf availability was highest during April and May in this study, a slightly shorter period of abundance than was noted in the previous report for the same field site. It is, therefore, not surprising that the most recent sighting of TSNM one-male units (OMU's) coalescing at Khau Ca occurred in April 2015 (Schwitzer et al., 2016). Indeed, the fact that this extremely large super-troop of at least 125 monkeys – the largest super-troop size reported for the species to date – synchronized with peak availability of flowers and young leaves, is not unlike observations of other multi-level primate societies. In these multi-level primate super-troops, congregations of OMU's are often observed in association with periods of high food availability (Grueter et al., 2012).

Regardless of season, within-forest spatial overlap of human and nonhuman study subjects was high throughout the investigation. Using the minimum convex polygon method to compare utilized and non-utilized areas, it became evident that a

large majority (88.5%) of habitat cells used by TSNM were also used by local people. Kernel density maps, outlining core areas of activity for both species, similarly indicated overlapping activity hot spots. Human presence was heavily concentrated at an entry point along the southwest forest boundary, near where Tung Ba and Yen Dinh communes meet. There was also a secondary node of significant human presence along the northern side of Khau Ca, where the most common activity was timber harvesting. Monkey locations converged in just one core area, positioned almost dead center in the middle of the forest. Such high levels of spatial overlap between people and TSNM do not support the idea that *R. avunculus* actively avoid areas of high rates of human occupancy at this site. Important to note, is that a gun confiscation program, initiated in 2005 and closely monitored thereafter, has significantly reduced gun-hunting incidents within Khau Ca. Only a handful of gunshots have been heard within the forest since that time. Therefore, it would be incredibly interesting to compare the results found at this site with human and monkey ranging patterns in other locations, such as the Na Hang Nature Reserve in neighboring Tuyen Quang Province, where human hunting of TSNM is currently thought to be much more common.

Given the high proportion of steep and irregular topography present in Khau Ca forest, terrain ruggedness was also evaluated as a potential habitat feature that may differ between humans and *R. avunculus*. TSNM are highly arboreal and are, thus, likely immune to the treacherous nature of the forest floor at this site. Bipedal humans, on the other hand, may consider this extremely rugged terrain a barrier to successful, safe, regular use. For this reason, and because many other primates reportedly utilize inaccessible refuge sites to minimize predation risk (Treves, 2002), it was hypothesized

here that TSNM may seek refuge from potential human predators in especially rugged habitat zones. Results, however, demonstrated the opposite to be true. Whereas local people were most often recorded as being present within moderately rugged parts, TSNM spent the majority of their time in some of the least rugged terrain within the protected area. This would be another fascinating aspect to consider in a future study of *R. avunculus* groups still under pressure from human hunting. It would also be especially interesting to determine if plants used by monkeys during feeding, resting and/or traveling are found in relatively non-rugged areas.

Although there was minimal evidence to support the idea of spatial segregation of humans and TSNM during this investigation (with the exception that humans appear to use slightly more rugged terrain than the monkeys), some significantly distinct temporal patterns did emerge. *R. avunculus* ingested fruit more commonly in the wet season, in accordance with the timing of fruit abundance. However, the consumption of young leaves and flowers did not correlate with local availability, suggesting that these primates may not shift dietary plant part components according to season. And while TSNM narrowed the expanse of their movement patterns in the wet season, there was no strong evidence of habitat shifting. This seasonal tapering of overall habitat size may be indicative of another common inclination observed within the Primate order: the tendency to reduce travel during times of high food availability, a pattern often observed in primates that do not exhibit significant territorial defense behaviors (Mitani and Rodman, 1979). Because other research regarding *Rhinopithecus* monkeys suggests otherwise, however, further investigation into this topic is also required.

Humans, on the other hand, demonstrated a highly distinct seasonal pattern of forest use. Timber and NTFP collection (by far the most common human activities that were directly observed within Khau Ca) occurred significantly more often in the dry season. Conversely, traps designed to capture terrestrial small mammals were only encountered – and removed – in August (both in August 2011 and August 2012). Local people also shifted their activities to the western side of the forest during the wet season, a time of year when human presence in Khau Ca was overall, very low. In fact, only 8% of the recorded evidence of human presence occurred during the wet season. Local people clearly preferred to access the forest in the dry season, a time many respondents referred to as free time.

The Vietnamese Lunar New Year, called *Tet*, also had some bearing on the timing of forest resource procurement. The *Tet* holiday occurs in the late dry season (January or February) each year, and household respondents reported that preparations for this annual celebration necessitated the collection of wild forest plants. Timber for fuel and a variety of NTFP's – especially a large, wild leaf called *Dong* – are collected in earnest prior to *Tet*, in anticipation of 10 days of family, friends, fires, fun, and feasts that surround the most important holiday of the year.

In addition to focusing timber and NTFP harvesting efforts in the dry season, and especially around *Tet*, local people also reported a preference for timber procurement at the end of each lunar month – the time of the waning moon. Household respondents often shared that it was traditional to collect timber at this time because the wood was dryer, easier to collect and carry, and had fewer termites. Not only did the quantitative data support these claims (people were found to venture into the forest significantly

more often during the waning moon), a *post-hoc* literature review provided supporting evidence, as well. It turns out that the tradition of harvesting wood according to lunar cycles is common around the world, and has been in existence for at least two thousand years (Cole and Balick, 2010). In addition, experiments have demonstrated that at least some timber products produce wood that is better for construction (drier and denser) and more flammable towards the end of each lunar month (Zurcher, 2001). And the relationship between lunar cycles, plant chemical defenses, and invertebrate activity has also been examined elsewhere, indicating that there may indeed be less termite activity at certain times each month, possibly as a result of changes in plant secondary compounds (Vogt et al., 2002). Further investigation into the relationship between lunar cycles and forest plant harvesting traditions at this particular study site could confirm whether the physical and/or chemical properties of timber collected from Khau Ca forest during waning moons are statistically different from those harvested at other times. Many nonhuman primate studies have already focused on physical and chemical properties of dietary components; it would be quite fascinating to undertake a study examining the nuances of these plant characteristics in relation to lunar cycles, as well.

9.2 Conservation Implications

The Tonkin Snub-Nosed Monkey Species and Habitat Conservation Area, commonly known as Khau Ca forest, was an ideal location for this type of investigation. The antiquity of human-nonhuman sympatry in this region is well-documented (see Chapter 5), and the local people living in Ha Giang Province today are, for the most part, a subsistence- based society relying heavily on forest products for survival. This

location also houses the single known viable population of one of the world's most critically endangered wildlife species, and one of the top 25 most endangered primates for the past 16 years (Baillie and Butcher, 2012; Schwitzer et al., 2016). Current estimates suggest there are no more than 250 *R. avunculus* alive today, half of which dwell in the rugged limestone karst forest of Khau Ca. Carefully planned, executed, evaluated, and adapted conservation interventions will be essential if Tonkin snub-nosed monkeys are to persist into future generations.

In 2011, the author of this thesis developed a conceptual model for TSNM conservation at Khau Ca forest, following procedures outlined in a toolkit known as the Open Standards for the Practice of Conservation (CMP, 2007). At that time, it became evident that while much research was already complete or underway documenting the status of the two biodiversity targets – TSNM and the Khau Ca forest – less was known about the dynamics of their direct and indirect threats. Even though a baseline understanding of these threats was not in place, several interventions had been, and were being successfully undertaken by local and international conservationists. While many of the strategies being applied have had positive effects on the intended biodiversity targets (for example, the gun 2005 gun confiscation program and the establishment of Khau Ca as a Species and Habitat Conservation Area in 2009, evidenced by consistent annual growth in the TSNM population size), it is difficult to measure success of other interventions without a clear understanding of current threat status. The research presented here not only aimed to investigate human-nonhuman primate resource overlap from a theoretical perspective, it was also designed to provide

much-needed information regarding the status of within-forest threats to Khau Ca and Tonkin snub-nosed monkey biodiversity targets [Figure 33].

The present investigation was not only focused on within-forest threats to TSNM, it was more specifically intended to evaluate the differential ways in which human and nonhuman primates access the forest and its plant resources in space and time. Therefore, some within-forest threats, such as hunting of monkeys and birds, forest regeneration, forest fires, and erosion, were not included here as primary topics of study. Instead, this research concentrated most heavily on how human timber and NTFP procurement may impact the TSNM population of Khau Ca. The modified Open Standards conceptual model presented in Figure 34 outlines these threats more specifically.

In addition to focusing on the particular aspects of timber and NTFP harvest, the current study clearly indicated that various indirect factors were acting upon different plant use-categories. Therefore, the model in Figure 34 not only shows primarily plant-based threats, it also parses out the collection of timber versus NTFP's, as well as further distinguishing among various NTFP uses. As well, indirect threats were modified according to results of this investigation. For example, it is now evident that several distinct factors impact the threat of small-scale timber extraction. Commune of residence, ethnicity, and SES status have been clearly linked to timber harvest patterns, and that harvest occurs most often at specific times and places within Khau Ca. Indeed, the most significant within-forest direct threat to both Khau Ca forest and its TSNM inhabitants is harvesting of timber for construction and fuelwood purposes. Because most conservation organizations have limited financial, temporal, and human

resources, it is often important to focus strategies and interventions on one or two chief biodiversity threats. Thus, the third, further simplified model [Figure 35] outlines a conservation action plan focused specifically on the significant threat of timber harvesting within Khau Ca. And, if additional refinement is necessary due to resource limitations, the best approach to eliminating potential strategies and/or interventions, would be to implement activities expected to deliver the highest impact with the least amount of effort and resource expenditure. Results of the current research can further aid in identifying this impact/effort ratio for several of the indirect threats listed here.

The next step in applying Open Standards for the Practice of Conservation to this specific context in northern Vietnam, is to identify indicators of success and outline methods for measuring those indicators. In doing so, it will be important to keep in mind that success can not only be evaluated via biodiversity target indicators, evidence of threat (or indirect threat) mitigation, is also important to gauge along the way. Ideally, the baseline status of each of these steps in the model would be assessed prior to implementing interventions; nonetheless, pre-implementation measurements of success indicators will be essential to clearly determine the level of impact any giving intervention may have.

The definition of measures and indicators, as well as the implementation of the specific strategies and interventions presented in the diagrams above, are outside the scope of the current investigation. However, the application of results reported in this thesis, combined with this type of quantitative and iterative evaluation of conservation actions, may hold the key to continued Tonkin snub-nosed monkey conservation success in Khau Ca forest.

Figure 33. Open Standards conceptual model for Tonkin snub-nosed monkey conservation, focused on within-forest threats to conservation success.

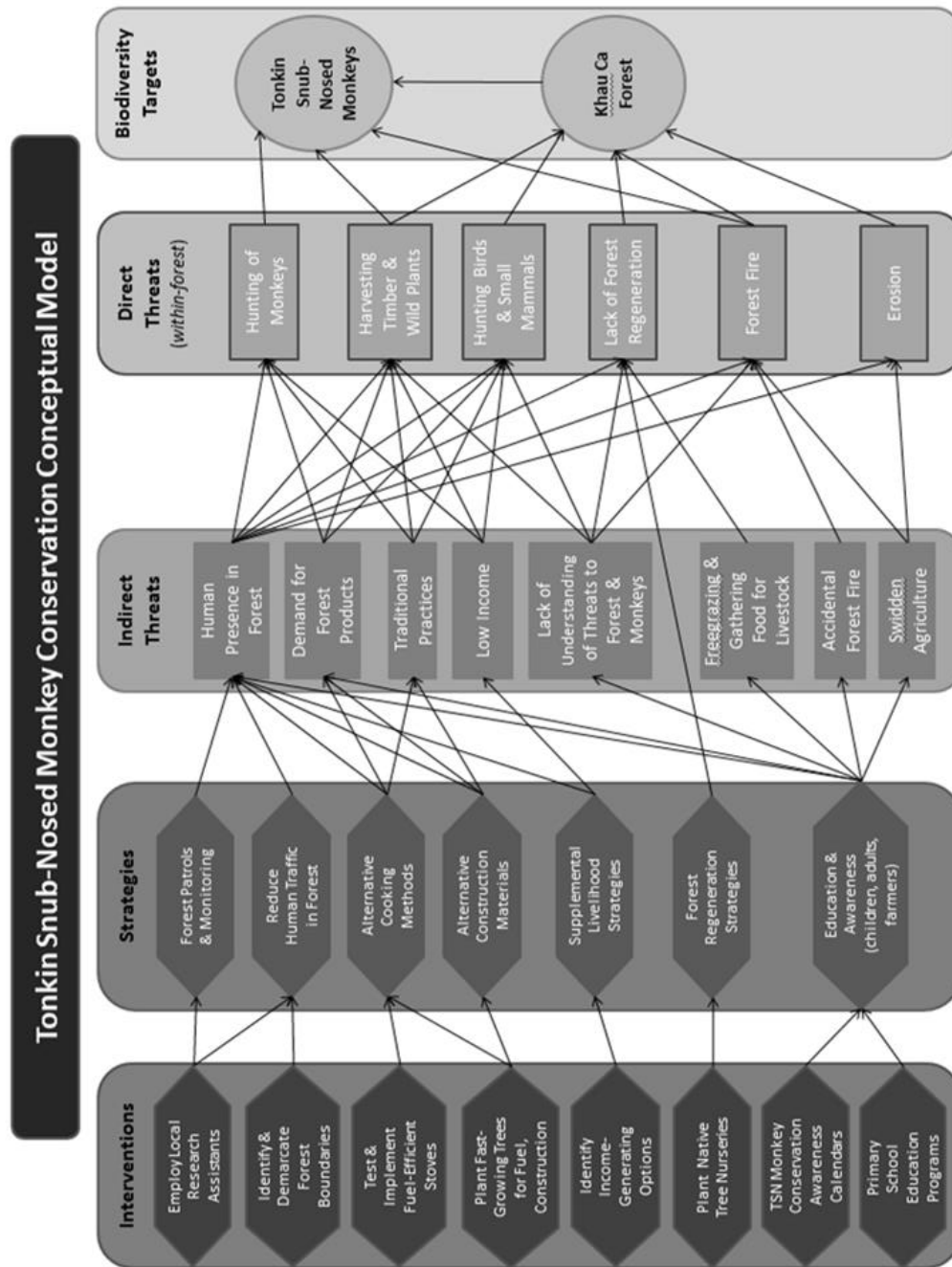


Figure 34. Modified Tonkin snub-nosed monkey conservation conceptual model, based on results of the current investigation.

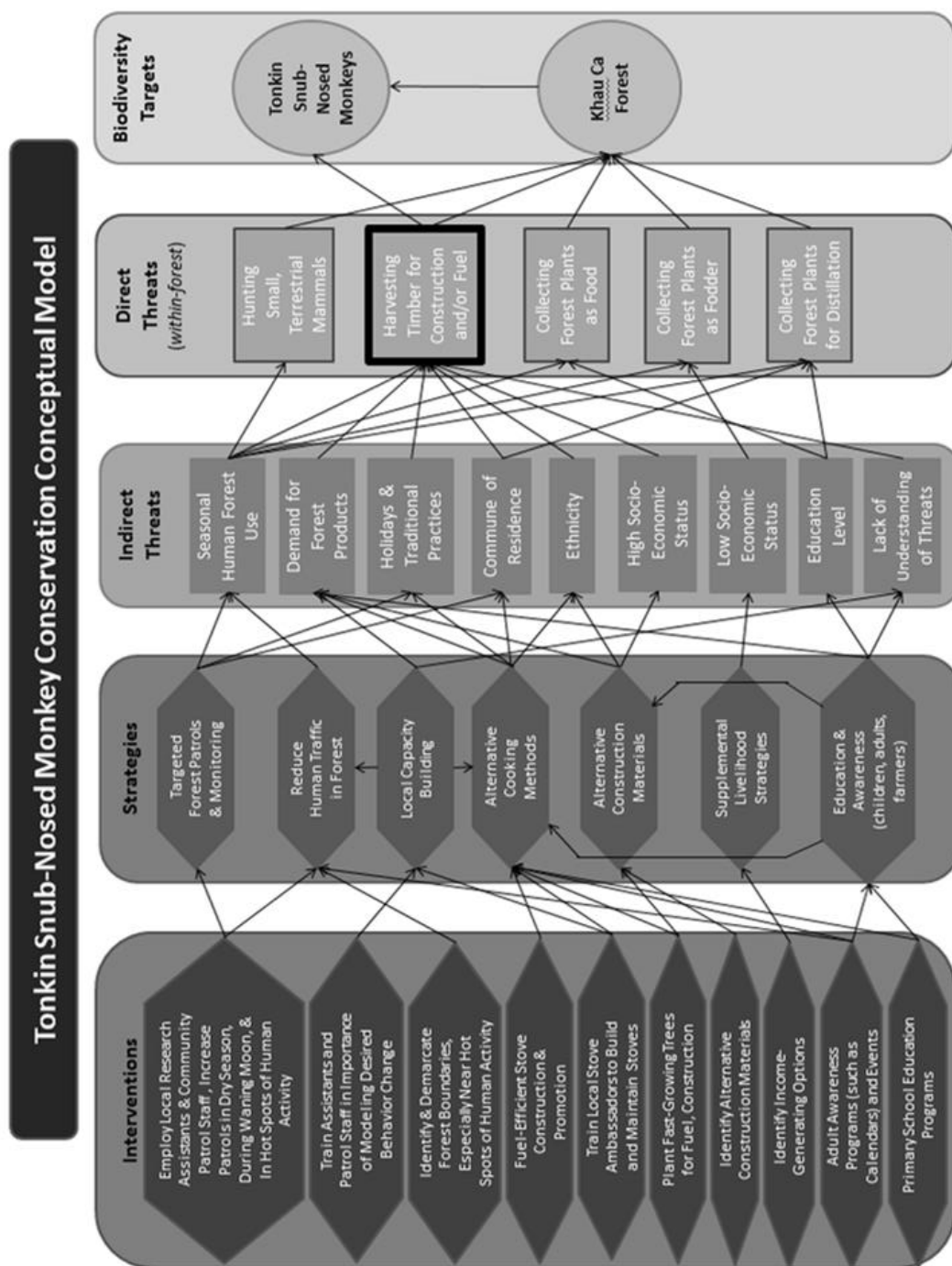
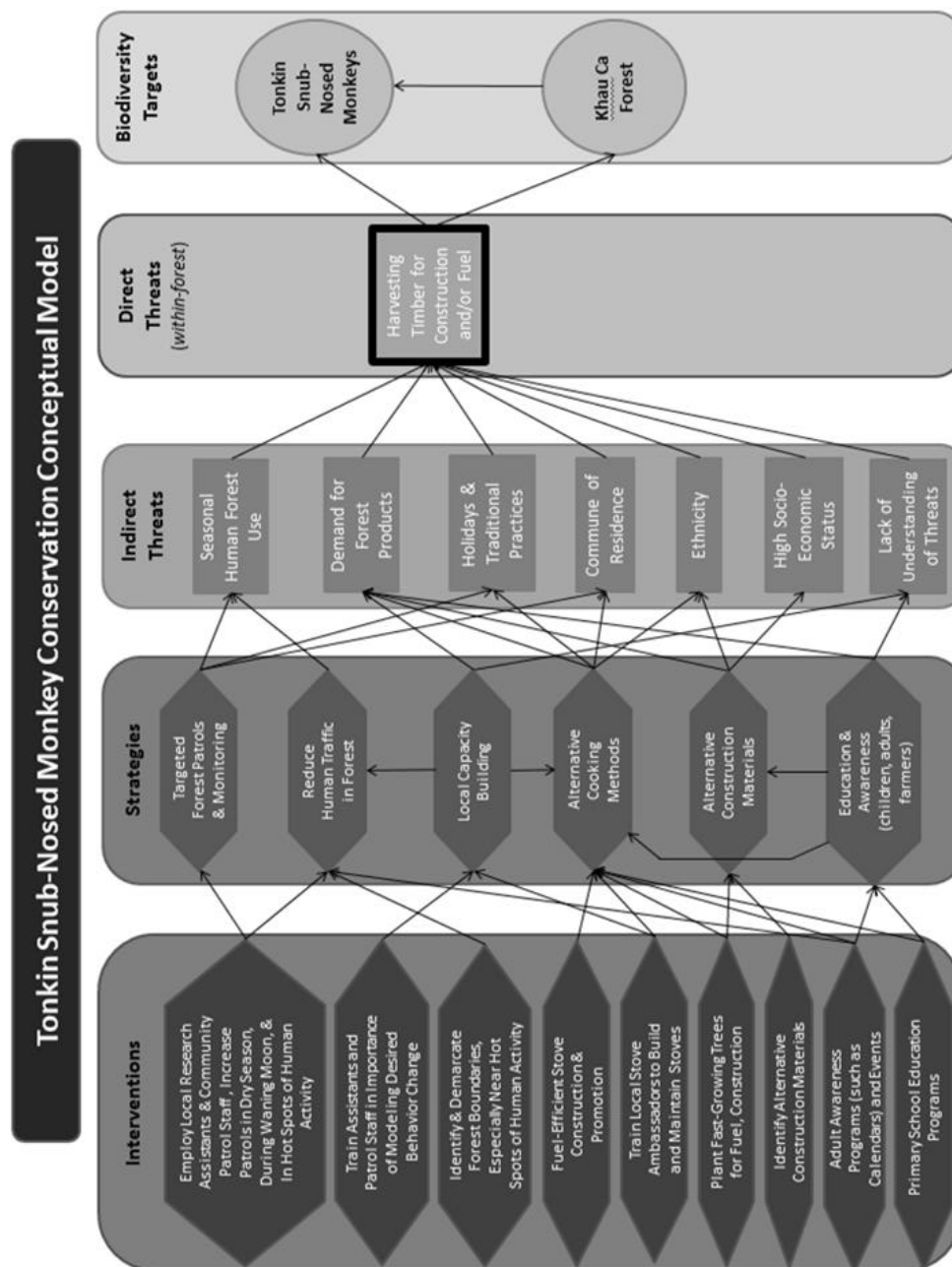


Figure 35. Conservation conceptual model focused specifically on the most significant threat to TSNM: timber harvesting activities within Khau Ca.



9.3 Recommended Conservation Actions

The following list summarizes interventions and strategies that, based on outcomes of this research, are expected to enhance conservation efforts already underway at the Tonkin Snub-Nosed Monkey Species and Habitat Conservation Area in Ha Giang Province, Vietnam:

- Establish clear goals along with measurable, replicable success indicators for TSNM and Khau Ca forest biodiversity targets; regularly measure status
- Establish clear objectives and measurable, replicable indicators for successful abatement of direct and indirect threats; measure status before and after implementing priority interventions
- Prioritize strategies and interventions that maximize impact while minimizing effort; consider focusing the majority of future conservation actions on the direct threat of timber harvesting
- Ensure implemented strategies and interventions intentionally address direct and indirect threats, for example:
 - Increase forest patrol intensity and research assistant presence
 - In the dry season
 - At the end of each lunar month
 - In hotspots of human activity
 - Build local capacity in efficient fuelwood stove construction and maintenance, as well as in the importance of local conservation leaders (research assistants, patrol staff, and ambassadors) modeling desired behaviors

- Clearly identify and demarcate forest boundaries, especially near hotspots of human activity
- Encourage local households to plant fast growing trees that are already common alternatives for use in construction and as fuelwood
- Work with local communities to identify potential, accessible alternatives for traditional construction materials
- Re-design education and awareness programs, and implement new programs, which focus more clearly on mitigating indirect threats that impact timber harvesting; ensure education and awareness programs engage newly identified key target audiences

BIBLIOGRAPHY

- Abwe, E.E. and Morgan, B.J. (2008). The Ebo forest: Four years of preliminary research and conservation of the Nigeria-Cameroon chimpanzee (*Pan troglodytes vellerosus*). *Pan Africa News* 15(2): 26-29.
- Adhikari, B., Di Falco, S., and Lovett, J.C. (2004). Household characteristics and forest dependency: Evidence from common property forest management in Nepal. *Ecological Economics* 48(2): 245-257. doi:10.1016/j.ecolecon.2003.08.008.
- Ahmad, R., Mishra, C., Singh, N.J., Kaul, R., and Bhatnagar, Y.V. (2016). Forage and security trade-offs by markhor *Capra falconeri* mothers. *Current Science* 110(8): 1559-1564.
- Albert, A., Savini, T., and Huynen, M. (2011). Sleeping site selection and presleep behavior in wild pigtailed macaques. *American Journal of Primatology* 73: 1-9.
- Altmann, J. (1974). Observational study of behavior: Sampling methods. *Behaviour* 49: 227-269.
- Appiah, M., Blay, D., Damnyag, L., Dwomoh, F.K., Pappinen, A., and Luukkanen, O. (2009). Dependence on forest resources and tropical deforestation in Ghana. *Environmental Development and Sustainability* 11: 471-487.
- Arletazz, R., Perrin, N., and Hausser, J. (1997). Trophic resource partitioning and competition between two sibling bat species *Myotis myotis* and *Myotis blythii*. *Journal of Animal Ecology* 66: 897-911.
- Arletazz, R. (1999). Habitat selection as a major resource partitioning mechanism between the two sympatric sibling bat species *Myotis myotis* and *Myotis blythii*. *Journal of Animal Ecology* 68: 460-471.
- Baillie, J.E.M. and Butcher, E.R. (2012). Priceless or Worthless? The world's most threatened species. Zoological Society of London, United Kingdom.
- Baral, N. and Heinen, J.T. (2007). Resource use, conservation attitudes, management intervention, and park-people relations in the Western Terai landscape of Nepal. *Environmental Conservation* 34(1): 64-72. doi:10.1017/S0376892907003670.
- Barrera-Bassols, N. and Toledo V.M. (2005). Ethnoecology of the Yucatec Maya: Symbolism, knowledge and management of natural resources. *Journal of Latin American Geography* 4(1): 9-41.
- Bartlett, T. Q. (2007). The Hylobatidae: Small apes of Asia. In: *Primates in Perspective*. Campbell, C.J., Fuentes, A., MacKinnon, K.C., Panger, M., and Bearder, S.K., (eds.). New York: Oxford University Press, pp. 274-289.

- Baoguo Li and Dapeng Zhao (2007). Copulation behavior within one-male groups of wild *Rhinopithecus roxellana* in the Qinling Mountains of China. *Primates* 48:190-196.
- Baoping Ren, Ming Li, Yongcheng Long, Gruter, C.C., and Fuwen Wei (1998). Measuring daily ranging distances of *Rhinopithecus bieti* via Global Positioning System collar at Jinsichang, China: A methodological consideration. *International Journal of Primatology* 29: 783-794.
- Berkes, F. 1993. Traditional Ecological Knowledge in Perspective. *In: Traditional Ecological Knowledge: Concepts and Cases*. Inglis, J.T. (ed.). Ottawa, Canada: International Development Research Center, pp. 1-10.
- Bernard, H.R. (2006). *Research Methods in Anthropology: Qualitative and Quantitative Approaches*, Fourth Edition. Lanham, Maryland: AltaMira Press.
- Bernard, H., Matsuda, I., Hanya, G., and Ahmad, A.H. (2011). Characteristics of night sleeping trees of proboscis monkeys (*Nasalis larvatus*) in Sabah, Malaysia. *International Journal of Primatology* 32: 259-267.
- Bird, R.B. and Bird, D.W. (2005). Human hunting seasonality. *In: Seasonality in Primates: Studies of Living and Extinct Human and Nonhuman Primates*, Brockman, D.K. and van Schaik, C.P. (eds.). Cambridge: Cambridge University Press, pp. 243-266.
- Blair, M.E., Sterling, E., and Hurley, M. (2011). Taxonomy and conservation of Vietnam's primates: A review. *American Journal of Primatology* 73: 1093-1106.
- Blankston, C. (2007). Hmong Americans. *Countries and Their Cultures*. Retrieved February 12, 2016: <http://www.everyculture.com/multi/Ha-La/Hmong-Americans.html>.
- Bleisch, W.V., Ao Song Cheng, Xiao Dong Ren, and Jia Hua Xie (1993). Preliminary results from a field study of wild Guizhou snub-nosed monkeys (*Rhinopithecus brelichii*). *Folia Primatologica* 60: 72-82.
- Bleisch, W.V. and Jia Hua Xie. (1998). Ecology and behavior of the Guizhou snub-nosed langur (*Rhinopithecus [Rhinopithecus] brelichii*), with a discussion of socioecology in the genus. *In: The Natural History of the Doucs and Snub-Nosed Monkeys*. Jablonski, N. (ed.). Singapore: World Scientific Publishing Co. Pte. Ltd., pp. 241-254.
- Boonratana, R. (2000). Ranging behavior of proboscis monkeys (*Nasalis larvatus*) in the Lower Kinabatangan, northern Borneo. *International Journal of Primatology* 21(3): 497-518.
- Boonratana, R. and Le Xuan Canh (1998a). Conservation of Tonkin snub-nosed monkeys (*Rhinopithecus [Presbytiscus] avunculus*) in Vietnam. *In: The Natural History of the Doucs and Snub-nosed Monkeys*. Jablonski, N. (ed.). Singapore: World Scientific Publishing Co. Pte. Ltd., pp. 315-322.

- Boonratana, R. and Le Xuan Canh (1998b). Preliminary observations of the ecology and behavior of the Tonkin snub-nosed monkey (*Rhinopithecus [Presbytiscus] avunculus*) in Northern Vietnam. *In: The Natural History of the Doucs and Snub-nosed Monkeys*. Singapore: World Scientific Publishing Co. Pte. Ltd., pp. 207-216.
- Boonratana, R. and Le Xuan Canh (2013). Coping with fragmented forests: The critically endangered Tonkin snub-nosed monkeys (*Rhinopithecus avunculus*) in Viet Nam. *In: Primates in Fragments: Complexity and Resilience*. Marsh, L.M. and Chapman, C.A. (eds.). New York: Springer Science, pp. 313-327.
- Borgatti, S. (2002). Cultural Domain Analysis (CDA). Boston College Presentation. ABT Associates, January 8, 2002. Retrieved March 6, 2012: <http://www.analytictech.com>.
- Borgerhoff Mulder, M. and Coppolillo, P. (2005). Conservation: Linking Ecology, Economics, and Culture. Princeton, NJ: Princeton University Press.
- Bragin, N., Singh, N.J., and Reading, R.P. (2013). Creating a ruggedness layer for use in habitat suitability modeling for Ikh Nart Nature Reserve, Mongolia. *Mongolian Journal of Biological Sciences* 11: 19-23.
- Buzzard, P.J. (2006). Ecological partitioning of *Cercopithecus campbelli*, *C. petaurista*, and *C. diana* in the Tai Forest. *International Journal of Primatology* 27(2): 529-558.
- Byron, C.D. and Covert, H.H. (2004). Unexpected locomotor behaviour: Brachiation by an Old World monkey (*Pygathrix nemaeus*) from Vietnam. *Journal of Zoology* 263(1): 101–6. doi:10.1017/S0952836904004935.
- Cachelin, A., Norvell, R., and Darling, A. (2010). Language fouts in teaching ecology: Why traditional metaphors undermine conservation literacy. *Conservation Biology* 24(3): 669-674.
- Campbell-Smith, G., Simanjorang, H.V.P., Leader-Williams, N., and Linkie, M. (2010). Local attitudes and perceptions toward crop-raiding by orangutans (*Pongo abelii*) and other nonhuman primates in northern Sumatra, Indonesia. *American Journal of Primatology* 72(10): 866–76. doi:10.1002/ajp.20822.
- Campbell, C.J., Crofoot, M., MacKinnon, K.C., and Stumpf, R.M. (2011). Behavioral data collection in primate field studies. *In: Primates in Perspective*. Campbell, C.J., Fuentes, A., MacKinnon, K.C., Bearder, S.K., and Stumpf, R.M. (eds.). New York: Oxford University Press, pp. 358-367.
- Cashdan, E. (1983). Territoriality among human foragers: Ecological models and an application to four bushman groups. *Current Anthropology* 24(1): 47-66.
- Castaneda, H. and Stepp, J.R. (2007). Ethnoecological importance value (EIV) methodology: Assessing the cultural importance of ecosystems as sources of useful

plants for the Guaymi people of Costa Rica. *Ethnobotany Research and Applications* 5: 249-257.

Chapman, C. (1987). Flexibility in diets of three species of Costa Rican primates. *Folia Primatologica* 49(2): 90-105.

Chapman, C. (1988). Patterns of foraging and range use by three species of Neotropical primates. *Primates* 29(2): 177-194.

Chapman, C. and Fedigan, L. (1990). Dietary differences between neighboring *Cebus capucinus* groups: Local traditions, food availability, or responses to food profitability? *Folia Primatologica* 54: 177-186.

Chapman, C.A., Balcomb, S.R., Gillespie, T.R., Skorupka, J.P., and Strusaker, T.T. (2000). Long-term effects of logging on African primate communities: A 28-year comparison from Kibale National Park, Uganda. *Conservation Biology* 14(1):207-217.

Cheney, D.L. and Wrangham, R.W. (1987). Predation. *In: Primate Societies*. Smuts, B.B., Cheney, D.L., Seyfarth, R.M., and Wrangham, R.W. (eds.). Chicago: University of Chicago Press, pp. 227-239.

Chivers, D.J. (1994). Functional anatomy of the gastrointestinal tract. *In: Colobine Monkeys: Their Ecology, Behaviour and Evolution*. Davies, A.G. and Oates, J.F. (eds.). Cambridge: Cambridge University Press, pp. 205-227.

CIA [Central Intelligence Agency] (2016). The World Factbook: Vietnam. Retrieved May 21, 2016: <https://www.cia.gov/library/publications/the-world-factbook/geos/vm.html>.

Ciuti, S., Northrup, J.M., Muhly, T.B., Simi, S., Musiani, M., Pitt, J.A., and Boyce, M.S. (2012). Effects of humans on behavior of wildlife exceed those of natural predators in a landscape of fear. *PLoS ONE* 7(11): 1-13. doi:10.1371/journal.pone.0050611.

Clutton-Brock, T.H. and Harvey, P.H. (1977). Primate ecology and social organization. *Journal of Zoology* 183: 1-39.

Clutton-Brock, T.H. and Harvey, P.H. (1979). Comparison and adaptation. *Proceedings of the Royal Society of London* 205: 547-565.

CMP [Conservation Measures Partnership] (2007). The Open Standards for the Practice of Conservation. Washington, D.C.: CMP. Retrieved October 20, 2010: www.conservationmeasures.org.

Cole, I.B. and Balick, M.J. (2010). Lunar influence: Understanding chemical variation and seasonal impacts on botanicals. *Journal of the American Botanical Council* 85: 50-56.

Colwell, R.K. and Futuyma, D.J. (1971). On the measurement of niche breadth and overlap. *Ecology* 52(4): 567-576.

- Corfield, J. (2008). *The History of Vietnam*. Westport, Connecticut: Greenwood Press.
- Cormier, L.A. (2002). Monkey as food, monkey as child: Guaja symbolic cannibalism. *In: Primates Face to Face: Conservation Implications of Human-Nonhuman Primate Interconnections*. Fuentes, A. and Wolfe, L.D. (eds.). New York: Cambridge University Press, pp. 63-84.
- Coughenour, M.B., Ellis, J.E., Swift, D.M., Coppock, D.L., Galvin, K., McCabe, J.T., and Hart, T.C. (1985). Energy extraction and use in a nomadic pastoral ecosystem. *Science* 230(4726): 619-625.
- Covert, H.H., Le Khac Quyet, and Harrison-Levine, A. (2011). Tonkin snub-nosed monkey (*Rhinopithecus avunculus*) conservation in Ha Giang Province, Vietnam. *American Journal of Primatology* 73(Suppl.1): 52.
- Covert, H.H., Le Khac Quyet, and Wright, B.W. (2006). A preliminary report of the positional behavior of the critically endangered Tonkin snub-nosed monkey (*Rhinopithecus avunculus*) at Du Ghai Nature Reserve, Ha Gaing Province, Vietnam. *International Journal of Primatology* 27(Suppl. 1): 306.
- Covert, H.H., Le Khac Quyet, and Wright, B.W. (2008). On the brink of extinction: Research for the conservation of the Tonkin snub-nosed monkey (*Rhinopithecus avunculus*). *In: Elwyn Simons: A Search for Origins*. Fleagle, J.G. and Gilbert, C.C. (eds.). New York: Springer Science and Business Media, LLC, pp. 409-427.
- Cowlshaw, G. (1997). Trade-offs between foraging and predation risk determine habitat use in a desert baboon population. *Animal Behaviour* 53(4): 667-686.
- Cowlshaw, G. and Dunbar, R.I.M. (2000). *Primate Conservation Biology*. Chicago: The University of Chicago Press.
- Cunningham, E.P. and Janson, C. (2007). Integrating information about location and value of resources by white-faced saki monkeys (*Pithecia pithecia*). *Animal Cognition* 10: 293-304.
- Da Silva, L.G., Ribeiro, M.C., Hasui, E., da Costa, C.A., and da Cunha, R.G.T. (2015). Patch size, functional isolation, visibility, and matrix permeability influences Neotropical primate occurrence within highly fragmented landscapes. *PLoS ONE* 10(2): 1-20. doi:10.1371/journal.pone.0114025.
- Davidar, P., Sahoo, S., Mammen, P.C., Acharya, P., Puyravaud, J-P., Arjunan, M., Garrigues, J.P., and Roessingh, K. (2010). Assessing the extent and causes of forest degradation in India: Where do we stand? *Biological Conservation* 143: 2937-2944.
- Defler, T.R. and Defler, S.B. (1996). Diet of a group of *Lagothrix lagothricha lagothricha* in southeastern Colombia. *International Journal of Primatology* 17(2): 161-190.

- Delson, E. (1994). Evolutionary history of the colobine monkeys in paleoenvironmental perspective. *In: Colobine Monkeys: Their Ecology, Behaviour and Evolution*. Davies, A.G. and Oates, J.F. (eds.). Cambridge: Cambridge University Press, pp. 11-43.
- DeSilva, J.M. (2009). Functional morphology of the ankle and the likelihood of climbing in early hominins. *Proceedings of the National Academy of Sciences* 106(16): 6567-6572.
- Dewalt, B.R. (1979). *Modernization in a Mexican Ejido: A Study in Economic Adaptation*. New York: Cambridge University Press.
- DiFiore, A. and Suarez, S. (2007). Route-based travel and shared routes in sympatric spider and woolly monkeys: Cognitive and evolutionary implications. *Animal Cognition* 10(3): 317-329.
- Dollman, G. (1912). A new snub-nosed monkey. *Proceedings of the Zoological Society of London* 106: 503-504.
- Dong Thanh Hai. (2008). Behavioral Ecology and Conservation of the *Rhinopithecus avunculus* in Vietnam. Report submitted to the School of Archaeology and Anthropology, Australian National University. Retrieved June 2, 2016: http://www.conservationleadershipprogramme.org/media/2014/11/001604_Vietnam_FR_Rhinopithecus_avunculus1.pdf.
- Driscoll, D.L., Appiah-Yeboah, A., Salib, P., and Rupert, D.J. (2007). Merging qualitative and quantitative data in mixed methods research: How to and why not. *Ecological and Environmental Anthropology* 3(1): 19-28.
- Dyson-Hudson, R. and Smith, E.A. (1978). Human territoriality: An ecological reassessment. *American Anthropologist* 80(1): 21-41.
- Eisenberg, J.F., Muckernhirn, N.A. and Rudran, R. (1972). The relation between ecology and social structure in primates. *Science* 176:863-874.
- Elden, S. (2010). Land, terrain, territory. *Progress in Human Geography*. 34(6): 799-817.
- Eudey, A.A. (1999). Asian primate conservation--My perspective. *In: The Nonhuman Primates*. Dolhinow, P. and Fuentes, A. (eds.). Mountain View, CA: Mayfield Publishing, pp. 151-158.
- Eudey, A.A. (2008). The crab-eating macaque (*Macaca fascicularis*): Widespread and rapidly declining. *Primate Conservation* 23(1): 129-132.
- Felton, A.M., Felton, A., Wood, J.T., and Lindenmayer, D.B. (2008). Diet and feeding ecology of *Ateles chamek* in a Bolivian semihumid forest: The importance of *Ficus* as a staple food resource. *International Journal of Primatology* 29: 379-403.

- Fleagle, J.G. (2013). *Primate Adaptation and Evolution*: 3rd Edition. San Diego, California: Academic Press.
- Fleagle, J.G. and Mittermeier, R.A. (1980). Locomotor behavior, body size, and comparative ecology of seven Surinam monkeys. *American Journal of Physical Anthropology* 52(3): 301-314.
- Fuentes, A. (2006). Human-nonhuman primate interconnections and their relevance to anthropology. *Ecological and Environmental Anthropology* 2(2):1-11.
- Fuentes, A. and Hockings, K.J. (2010). The ethnoprimate approach in primatology. *American Journal of Primatology* 72(10): 841–47. doi:10.1002/ajp.20844.
- Furuichi, T., Hashimoto, C., and Tashiro, Y. (2001). Fruit availability and habitat use by chimpanzees in the Kalinzu Forest, Uganda: Examination of fallback foods. *International Journal of Primatology* 22(6): 929-945.
- Futuyma, D.J. and Moreno, G. (1988). The evolution of ecological specialization. *Annual Review of Ecological Systematics* 19: 207-233.
- Ganzhorn, J.U. (1988). Food partitioning among Malagasy primates. *Oecologia* 75(3): 436-450.
- Ganzhorn, J.U. (1995). Low-level forest disturbance effects on primary production, leaf chemistry, and lemur populations. *Ecology* 76(7): 2084-2096.
- Garber, P.A. (1993). Seasonal patterns of diet and ranging in two species of tamarin monkeys: Stability versus variability. *International Journal of Primatology* 14(1): 145-166.
- Garber, P.A., Pruett, J.D., and Isaacson, J. (1993). Patterns of range use, range defense, and intergroup spacing in moustached tamarin monkeys. *Primates* 34(1): 11-25.
- Gautier-Hion, A., Emmons, L.H., and Dubost, G. (1980). A comparison of the diets of three major groups of primary consumers of Gabon (primates, squirrels, and ruminants). *Oecologia* 45: 182-189.
- Geissman, T., Ngwe Lwin, Saw Soe Aung, Thet Naing Aung, Zin Myo Aung, Tony Htin Hla, Grindley, M., and Momberg, F. (2010). A new species of snub-nosed monkey, genus *Rhinopithecus*, Milne-Edwards, 1872 (Primates, Colobinae), from north Kachin state, northeastern Myanmar. *American Journal of Primatology* 72:1-12.
- Ghorbani, A., Langenberger, G., and Sauerborn, J. (2012). A comparison of the wild food plant use knowledge of ethnic minorities in Naban River Watershed National Nature Reserve, Yunnan, SW China. *Journal of Ethnobiology and Ethnomedicine* 8: 17-25.

- Glander, K.E. (1981). Feeding patterns in mantled howling monkeys. *In: Foraging Behavior: Ecological, Ethological, and Psychological Approaches*. Kamil, A.C. and Sargent, T.D. (eds.). New York: Garland STPM Press, pp. 231-257.
- Godoy, R., Brokaw, N., and Wilkie, D. (1995). The effect of income on the extraction of non-timber tropical forest products: Model, hypotheses, and preliminary findings from the Sumu Indians of Nicaragua. *Human Ecology* 23(1): 29-52.
- Godoy, R. and Contreras, M. (2001). A comparative study of education and tropical deforestation among lowland Bolivian Amerindians: Forest values, environmental externality, and school subsidies. *Economic Development and Cultural Change* 49: 555–574.
- Gomiero, T., Paoletti, M. G., and Pimentel, D. (2010). Biofuels: Efficiency, ethics, and limits to human appropriation of ecosystem services. *Journal of Agricultural and Environmental Ethics* 23(5): 403–434. doi:10.1007/s10806-009-9218-x.
- Gould, S.J. and Lewontin, R.C. (1979). The spandrels of San Marco and the Panglossian paradigm: A critique of the adaptationist programme. *Proceedings of the Royal Society of London* 205: 581-598.
- Grant, P.R. and Grant, B.R. (2002). Adaptive radiation of Darwin's finches: Recent data help explain how this famous group of Galapagos birds evolved, although gaps in our understanding remain. *American Scientist* 90: 130-140.
- Griffiths, M. and van Schaik, C.P. (1993). The impact of human traffic on the abundance and activity periods of Sumatran rain forest wildlife. *Conservation Biology* 7(3): 623-626.
- Groves, C. P. (2007). Speciation and biogeography of Vietnam's primates. *Vietnamese Journal of Primatology* 1: 27-40.
- Grueter, C.C., Dayong Li, Baoping Ren, Fuwen Wei, Zuofu Xiang, and van Schaik, C.P. (2009). Fallback foods of temperate-living primates: A case study on snub-nosed monkeys. *American Journal of Physical Anthropology* 140: 700-715.
- Grueter, C.C., Chapais, B., and Zinner, D. (2012). Evolution of multilevel social systems in nonhuman primates and humans. *International Journal of Primatology* 33(5): 1002-1037.
- Greuter, C.C., Dayong Li, Baoping Ren, Zuofu Xiang, and Ming Li (2012). Food abundance is the main determinant of high-altitude range use in snub-nosed monkeys. *International Journal of Zoology*: 1-4. doi:10.1155/2012/739419.
- Ha Giang Forestry Protection Department (FPD), Fauna and Flora International Vietnam Conservation Support Programme, Kempinski, J., Hoang Van Tue, Hoang Van Lam, Le Khac Quyet, Covert, H., Wright, B., and Insua-Cao, P. (2008). Feasibility study for establishing the Tonkin Snub-nosed Monkey species conservation area – Ha

- Giang at Khau Ca Forest, March 2009. Hanoi, Vietnam, unpublished report, pp. 1-62.
- Hames, R.B. and Vickers, W.T. (1982). Optimal diet breadth theory as a model to explain variability in Amazonian hunting. *American Ethnologist* 9(2): 358-378.
- Hardin, G. (1960). The competitive exclusion principle. *Science New Series* 131(3409): 1292-1297.
- Harrison-Levine, A.L., Barnett, A.A., Covert, H.H., Norconk, M.A., Santos, R.R., and Fearnside, P. (*in review*). Dams: Primate responses to widespread anthropic flooding. *In: Primates in Flooded Habitats*. Barnett, A.A., Matsuda, I., and Nowack, K. (eds). Cambridge: Cambridge University Press.
- Hartwig, W. (2007). Primate evolution. *In: Primates in Perspective*. Campbell, C.J., Fuentes, A., MacKinnon, K.C., Panger, M., and Bearder, S.K., (eds.). New York: Oxford University Press, pp. 11-22.
- Haus, T., Vogt, M., Forster, B., Ngoc Thanh Vu, and Ziegler, T. (2009). Distribution and population densities of diurnal primates in the karst forests of Phong Nha – Ke Bang National Park, Quang Binh Province, Central Vietnam. *International Journal of Primatology* 30: 301-312.
- Harvey, P.H. and Purvis, A. (1991). Comparative methods for explaining adaptations. *Nature* 351: 619-624.
- Heimlich, J.E. (2010). Environmental education evaluation: Reinterpreting education as a strategy for meeting mission. *Evaluation and Program Planning* 33(2): 180-185.
- Hemingway, C.A. and Bynum, N. (2005). The influence of seasonality on primate diet and ranging. *In: Seasonality in Primates: Studies of Living and Extinct Human and Non-human Primates*. Brockman, D.K. and van Schaik, C.P. (eds.). Cambridge: Cambridge University Press, pp. 57-104.
- Her, V.K. (2005). Hmong cosmology: Proposed model, preliminary insights. *Hmong Studies Journal* 6: 1-25.
- Hockings, K.J. (2007). Human-chimpanzee coexistence at Boussou, the Republic of Guinea: A chimpanzee perspective. Dissertation submitted to the Department of Psychology at the University of Stirling.
- Hockings, K.J., Anderson, J.R., and Matsuzawa, T. (2009). Use of wild and cultivated foods by chimpanzees at Bossou, Republic of Guinea: Feeding dynamics in a human-influenced environment. *American Journal of Primatology* 71(8): 636–46. doi:10.1002/ajp.20698.

- Hockings, K. and Humle, T. (2009). Best Practice Guidelines for the Prevention and Mitigation of Conflict Between Humans and Great Apes. Gland, Switzerland: IUCN/SSC Primate Specialist Group (PSG).
- Hockings, K.J. and Sousa, C. (2013). Human-chimpanzee sympatry and interactions in Cantanhez National Park, Guinea-Bissau: Current research and future directions. *Primate Conservation* 26: 57-65.
- ICEM [International Centre for Environmental Management] and PADP [Protected Areas and Development Partnership] (2003). Vietnam: National Report on Protected Areas and Development. Queensland, Australia: Indooroopilly.
- Ingle, M. and Halimi S. (2007). Community-based environmental management in Vietnam: The challenge of sharing power in a politically guided society. *Public Administration and Development* 27(2): 95–109. doi:10.1002/pad.443.
- Insua-Cao, P. (2006). Implementation of a long-term conservation strategy to ensure the survival of the population of Tonkin snub-nosed monkeys in Ha Giang Province: 2005 Annual Progress report to DEFRA Flagship Species Fund. Hanoi, Vietnam: Fauna and Flora International, Vietnam, Conservation Support Programme, unpublished report.
- Isbell, L. A. (1994). Predation on primates: Ecological patterns and evolutionary consequences. *Evolutionary Anthropology: Issues, News, and Reviews* 3(2): 61-71.
- IUCN (2015). IUCN Red List of Threatened Species. Website accessed online November 22: <http://www.iucnredlist.org>.
- Jacobson, S.K. and Duff, M.D. (1998). Training idiot savants: The lack of human dimensions in conservation biology. *Conservation Biology* 12(2): 263-267.
- Janson, C.H. (1992). Evolutionary ecology of primate social structure. In: *Evolutionary Ecology and Human Behavior*. Smith, E.A. and Winterhalder, B. (eds.). New York: Aldine De Gruyter, pp. 97-130.
- Jenks, B., Vaughan, P.W., and Butler, P.J. (2010). The evolution of Rare Pride: Using evaluation to drive adaptive management in a biodiversity conservation organization. *Evaluation and Program Planning* 33: 186-190.
- Jetz, W., Steffen, J., and Linsenmair, K.E. (2003). Effects of light and prey availability on nocturnal, lunar, and seasonal activity of tropical nightjars. *Oikos* 103: 627-639.
- Johns, A.D. (1985). Behavioral responses of two Malaysian primates (*Hylobates lar* and *Presbytis melalophos*) to selective logging: Vocal behavior, territoriality, and nonemigration. *International Journal of Primatology* 6(4):423-433.
- Johns, A.D. and Skorupa, J.P. (1987). Responses of rain-forest primates to habitat disturbance: A review. *International Journal of Primatology* 8(2):157-191.

- Jorgenson, J.P. and Redford, K.H. (1993). Humans and big cats as predators in the Neotropics. *Symposium of the Zoological Society of London* 65: 367-390.
- Kawecki, T.J. and Ebert, D. (2004). Conceptual issues in local adaptation. *Ecology Letters* 7: 1225-1241.
- Kay, R.N.B., and Davies, A.G. (1994). Digestive physiology. *In: Colobine Monkeys: Their Ecology, Behaviour and Evolution*. Davies A.G. and Oates, J.F. (eds.). Cambridge: Cambridge University Press, pp. 229-249.
- Kinnaird, M.F. (1992). Competition for a forest palm: Use of *Phoenix* by human and nonhuman primates. *Conservation Biology* 6(1): 101-107.
- Kinzey, Warren G. (1997). *New World Primates: Ecology, Evolution, and Behavior*. New York: Adeline de Gruyter.
- Kirkpatrick, R.C. (1995). The natural history and conservation of the snub-nosed monkeys (Genus *Rhinopithecus*). *Biological Conservation* 72: 363-369.
- Kirkpatrick, R.C., Gu, H.J., and Zhou, X.P. (1999). A preliminary report on Sichuan snub-nosed monkeys (*Rhinopithecus roxellana*) at Baihe Nature Reserve. *Folia Primatologica* 70: 117-120.
- Kirkpatrick, R.C. (2007). The Asian colobines: Diversity among leaf-eating monkeys. *In: Primates in Perspective*. Campbell, C.J., Fuentes, A., MacKinnon, K.C., Panger, M., and Bearder, S.K., (eds.). New York: Oxford University Press, pp. 186-200.
- Kirkpatrick, R.C. and Greuter, C.C. (2010). Snub-nosed monkeys: Multilevel societies across varied environments. *Evolutionary Anthropology* 19: 98-113.
- Kirkpatrick, R.C. (2011). The Asian Colobines: Diversity among leaf-eating monkeys. *In: Primates in Perspective*. Campbell, C.J., Fuentes, A., MacKinnon, K.C., Bearder, S.K., and Stumpf, R.M. (eds.). New York: Oxford University Press, pp. 189-202.
- Koehler, G.M. and Hornocker, M.G. (1991). Seasonal resource use among mountain lions, bobcats, and coyotes. *Journal of Mammology* 72(2): 391-396.
- Kormondy, E.J. and Brown, D.E. (1998). *Fundamentals of Human Ecology*. Upper Saddle River, New Jersey: Prentice Hall.
- Kümpel, N.F., Milner-Gulland, E.J., Rowcliffe, J.R., and Cowlshaw, G. (2008). Impact of gun-hunting on diurnal primates in continental Equatorial Guinea. *International Journal of Primatology* 29(4): 1065–82. doi:10.1007/s10764-008-9254-9.
- Lan Vu, Bich Tran and Anh Le (2011). The use of total assets as a proxy for socioeconomic status in northern Vietnam. *Asia Pacific Journal of Public Health* 23: 996-1004.

- Le Khac Quyet (2014). Positional behavior and support use of the Tonkin snub-nosed monkeys (*Rhinopithecus avunculus*) in Khau Ca Forest, Ha Giang Province, Vietnam. Dissertation submitted to the Department of Anthropology, University of Colorado Boulder.
- Le Khac Quyet and Covert, H.H. (2010). Another population of the Tonkin snub-nosed monkey (*Rhinopithecus avunculus*) discovered in Ha Giang Province, Vietnam. *Vietnamese Journal of Primatology* 4: 19-25.
- Le Khac Quyet, Covert, H.H., and Wright, B.W. (2006). Status of the critically endangered Tonkin snub-nosed monkey (*Rhinopithecus avunculus*) at Du Ghai Nature Reserve, Ha Gaing Province, Vietnam. *International Journal of Primatology*, 27(Suppl. 1): 428.
- Le Khac Quyet, Nguyen Anh Duc, Vu Anh Tai, Wright, B.W., and Covert, H.H. (2007). Diet of the Tonkin snub-nosed monkey (*Rhinopithecus avunculus*) in the Khau Ka area, Ha Giang Province, Northeastern Vietnam. *Vietnamese Journal of Primatology* 1: 75-83.
- Le Khac Quyet, Dong Thahn Hai and Tilo Nadler (2016). Tonkin snub-nosed monkey *Rhinopithecus avunculus* (Dollman, 1912). In: *Primates in Peril: The World's 25 Most Endangered Primates 2014–2016*. Schwitzer, C., Mittermeier, R.A., Rylands, A.B., Chiozza, F., Williamson, E.A., Wallis, J., and Cotton, A. (eds.). Arlington, Virginia: IUCN SSC Primate Specialist Group (PSG), International Primatological Society (IPS), Conservation International (CI), and Bristol Zoological Society, pp. 20–22.
- Le Van Dung, Le Khac Quyet, and Levine, A. (2014). Range use of Tonkin snub-nosed monkey (*Rhinopithecus avunculus*) in the Khau Ca forest, Ha Giang Province, Vietnam. Hanoi, Vietnam: International Primatological Society XXV Congress.
- Le Xuan Canh, Le Khac Quyet, Dong Thanh Hai, and Boonratana, R. 2008. *Rhinopithecus avunculus*. The IUCN Red List of Threatened Species. Version 2014.3. Retrieved May 10, 2015: <http://www.iucnredlist.org>.
- Lee, P.C. (1991). Adaptations to environmental change: An evolutionary perspective. In: *Primate responses to environmental change*. Box, H.O. (ed). London: Chapman and Hall, pp. 39-56.
- Lee, Mai Na M. (1998). The thousand-year myth: Construction and characterization of Hmong. *Hmong Studies Journal* 2(2), pp. 1-23.
- Lee, T.P. and Pfeifer, M.E. (2006). *Building Bridges: Teaching about the Hmong in our Communities*. St. Paul, Minnesota: Hmong Cultural and Resource Center. Presentation retrieved March 18, 2015: <http://www.hmongstudies.org>.
- Lees, C., Rawson, B.M., Behie, A.M., Hendershott, R., and Leonard N. (2014). Preliminary population viability analysis of the critically endangered Cat Ba langur

(*Trachypithecus poliocephalus*). Hanoi, Vietnam: IUCN SSC Conservation Breeding Specialist Group, Fauna and Flora International.

- Lippold, L.K. and Vu Ngoc Thanh (1998). Primate conservation in Vietnam. *In: The Natural History of the Doucs and Snub-nosed Monkeys*. Jablonski, N. (ed). Singapore: World Scientific Publishing Co. Pte. Ltd., pp. 293-300.
- Lizarralde, M. (2002). Ethnoecology of monkey among the Bari of Venezuela: Perception, use and conservation. *In: Primates face to face: Conservation implications of human-nonhuman primate interconnections*. Fuentes, A. and Wolfe, L.D. (eds.). New York: Cambridge University Press, pp. 85-100.
- Lucas, P.W. and Teaford, M.F. (1994). Functional morphology of colobine teeth. *In: Colobine Monkeys: Their Ecology, Behaviour and Evolution*. Davies, A.G. and Oates, J.F. (eds.). Cambridge: Cambridge University Press, pp. 173-203.
- Ma Chi, Huang Zhi-Pang, Zhao Xiao-Fei, Zhang Li-Xiang, Sun Wen-Mo, Scott, M.B., Wang Xing-Wen, Cui Liang-Wei, and Xiao Wen (2014). Distribution and conservation status of *Rhinopithecus strykeri* in China. *Primates* 55: 377-382.
- Manfredo, M.J., Vaske, J.J., and Decker, D.J. (1995). Human dimensions of wildlife management: Basic concepts. *In: Wildlife and Recreationists: Coexistence Through Management and Research*. Knight, R.L. and Gutzwiller, K.J. (eds). Washington D.C.: Island Press, pp. 17-32.
- Margoluis, R., Stem, C., Salafsky, N., and Brown, M. (2009). Design alternatives for evaluating the impact of conservation projects. *New Directions for Evaluation* 122: 85-96.
- Marshall, A.J., Boyko, C.M., Feilen, K.L., Boyko, R.H., and Leighton, M. (2009). Defining fallback foods and assessing their importance in primate ecology and evolution. *American Journal of Physical Anthropology* 140: 603-614.
- Martin, P. and Bateson, F.R.S. (1993). *Measuring Behaviour: An Introductory Guide*, Second Edition. Cambridge: Cambridge University Press, Cambridge.
- Mazess, R.B. (1975). Biological adaptation: Aptitudes and acclimatization. *In: Biosocial Interrelations in Population Adaptation*. Watts, E.S., Johnston, F.E., and Lasker, G.W. (eds). The Hague: Mouton Publishers, pp. 9-18.
- McElwee, P.D. (2010). Resource use among rural agricultural households near protected areas in Vietnam: The social costs of conservation and implications for enforcement. *Environmental Management* 45: 113-131.
- McGraw, W.S. (1996). Cercopithecoid locomotion, support use, and support availability in the Tai Forest, Ivory Coast. *American Journal of Physical Anthropology* 100(4): 507-522.

- Meyers, N., Mittermeier, R.A., Mittermeier, C.G., da Fonseca, G.A.B., and Kent, J. (2000). Biodiversity hotspots for conservation priorities. *Nature* 403: 853-858.
- Miller, L.E. (2002). An introduction to predator sensitive foraging. *In: Eat or Be Eaten: Predator Sensitive Foraging Among Primates*. Miller, L.E. (ed.). New York: Cambridge University Press, pp. 1-17.
- Miller, L.E. and Treves, A. (2007). Predation on primates: Past studies, current challenges, and direction for the future. *In: Primates in Perspective*. Campbell, C.J., Fuentes, A., MacKinnon, K.C., Panger, M., and Bearder, S.K., (eds.). New York: Oxford University Press, pp. 525-543.
- Miller, L.E. and Treves, A. (2011). Predation on primates: Past studies, current challenges, and direction for the future. *In: Primates in Perspective*. Campbell, C.J., Fuentes, A., MacKinnon, K.C., Bearder, S.K., and Stumpf, R.M. (eds.). New York: Oxford University Press, pp. 535-547.
- Mitani, J.C. and Rodman, P.S. (1979). Territoriality: The relation of ranging pattern and home range size to defendability, with an analysis of territoriality among primate species. *Behavioral Ecology and Sociobiology* 5(3): 241-251.
- Mittermeier, R.A. (1987). Effects of hunting on rainforest primates. *In: Primate Conservation in the Tropical Rain Forest*. New York: Alan R. Liss, Inc., pp. 109-146.
- Mittermeier, R. and Cheney, D. (1987). Conservation of primates and their habitats. *In: Primate Societies*. Smuts, B.B., Cheyney, D.L., Seyfarth, R.M., Wrangham, R., and Struhsaker, T.T. (eds.). Chicago: University of Chicago Press, pp. 477-490.
- Mittermeier, R., Valladares-Padua, C., Rylands, A., Eudey, A., Butynski, T., Ganzhorn, J., Kormos, R., Aguiar, J., and Walker, S. (2006). Primates in peril: The world's 25 most endangered primates, 2004-2006. *Primate Conservation* 20: 1-28.
- Mittermeier, R.A., Wallis, J., Rylands, A.B., Ganzhorn, J.U., Oates, J.F., Williamson, E.A., Palacios, E., Heymann, E.W., Kierulff, M.C.M., Long, Y., Supriatna, J., Roos, C., Walker, S., Cortes-Ortiz, L., Schwitzer, C., and Nash, S.D. (2009). Primates in peril: The world's 25 most endangered primates 2008-2010. *Primate Conservation* 24: 1-57.
- Mouyu Yang, Sun, D.Y., Zinner, D., and Roos, C. (2009). Reproductive parameters in Guizhou snub-nosed monkeys (*Rhinopithecus brelichi*). *American Journal of Primatology* 71(1): 266-270.
- Nadler, T., Vu Ngoc Thanh, and Stricher, U. (2007). Conservation status of Vietnamese primates. *Vietnamese Journal of Primatology* 1: 7-26.
- Nekaris, K.A.I., Shepherd, C.R., Starr, C.R., and Nijman, V. (2010). Exploring cultural drivers for wildlife trade via an ethnoprimateological approach: A case study of

slender and slow lorises (*Loris* and *Nycticebus*) in South and Southeast Asia. *American Journal of Primatology* 72(10): 877–86. doi:10.1002/ajp.20842.

- Nekaris, K.A.I. and Bearder, S.K. (2011). The lorisiform primates of Asia and mainland Africa. . *In: Primates in Perspective*. Campbell, C.J., Fuentes, A., MacKinnon, K.C., Bearder, S.K., and Stumpf, R.M. (eds.). New York: Oxford University Press, pp. 34-54.
- Newton, P.N. and Dunbar, R.I.M. (1994). Colobine monkey society. *In: Colobine Monkeys: Their Ecology, Behaviour and Evolution*. Davies, A.G. and Oates, J.F. (eds.). Cambridge: Cambridge University Press, pp. 311-346.
- Nguyen Anh Duc, Vu Anh Tai, and Le Khac Quyet (2006). Plant diversity in Khau Ca forest, Ha Giang province, northeast Vietnam. *Vietnam National University Journal of Science (Natural Sciences and Technology)*. T.XXII(3C): 91-95.
- Nguyen Nghia Thin (2006). Vegetation and flora survey of Khau Ca area, Ha Giang Province. Hanoi, Vietnam: Report prepared for Fauna and Flora International and the Hanoi National University Botanical Museum.
- Nguyen Van Song (2008). Wildlife trading in Vietnam: Situation, causes, and solutions. *Journal of Environmental Development* 17: 145-165.
- Nguyen Vinh Quang and Noriko, S. (2008). Forest allocation policy and level of forest dependency of economic household groups: A case study in northern central Vietnam. *Small-Scale Forestry* 7: 49-66.
- Nobrega Alves, R.R. and Silva Souto, W.M. (2015). Ethnozoology: A brief introduction. *Ethnobiology and Conservation* 4(1): 1-13. doi:10.15451/ec2015-1-4.1-1-13.
- Novellino, D. (2000). Indigenous highlands in transition: The case of Ha Giang Province in northern Viet Nam. Vietnam: Land Reform Report, FAO Corporate Document Repository. Retrieved February 21, 2012: http://www.fao.org/DOCREP/003/X8050T/x8050t09.htm#P10_2222.
- Nowak, K. (2012). Mangrove and peat swamp forests: Refuge habitats for primates and felids. *Folia Primatologica* 83: 361-376.
- Oates, J.F. and Davies, A.G. (1994). What are the Colobines? *In: Colobine Monkeys: Their Ecology, Behaviour and Evolution*. Davies, A.G. and Oates, J.F. (eds.). Cambridge: Cambridge University Press, pp. 1-10.
- Olson, D.M., Dinerstein, E., Wikramanayake, E.D., Burgess, N.D., Powell, G.V.N., Underwood, E.C., D'Amico, J.A., Itoua, I., Strand, H.E., Morrison, J.C., Loucks, C.J., Allnutt, T.F., Ricketts, T.H., Kura, Y., Lamoureux, J.F., Wettengel, W.W., Hedao, P., and Kassem, K.R. (2001). Terrestrial ecoregions of the world: A new map of life on earth. *Bioscience* 51(11): 933-938.

- Olupot, W., Chapman, C.A., Waser, P.M., and Isabirye-Basuta, G. (1997). Mangabey (*Cercocebus albigena*) ranging patterns in relation to fruit availability and the risk of parasite infection in Kibale National Park, Uganda. *American Journal of Primatology* 43: 65-78.
- Olupot, W., Barigiyira, R., and Chapman, C.A. (2009). The status of anthropogenic threat at the people-park interface of Bwindi Impenetrable National Park, Uganda. *Environmental Conservation* 36(1): 41-50.
- Opalinski, A. (2010). What are key factors in Haitian and Hispanic children and obesity: Parent answers. *Journal of Nurse Practitioners* 6(4): 281-286.
- Parathian, H.E. and Maldonado, A.M. (2010). Human-nonhuman primate interactions amongst Tikuna people: Perceptions and local initiatives for resource management in Amacauacu in the Colombian Amazon. *American Journal of Primatology* 71: 1-11.
- Pavelka, M.M. (2002). Resistance to the cross-species perspective in anthropology. In: Primates face to face: Conservation implications of human-nonhuman primate interconnections. Fuentes, A. and Wolfe, L.D. (eds.). New York: Cambridge University Press, pp. 25-44.
- Peres, C.A. (1993). Structure and spatial organization of an Amazonian terra firme forest primate community. *Journal of Tropical Ecology* 9: 259-276.
- Peres, C.A. (1994). Primate responses to phenological changes in an Amazonian terra firme forest. *Biotropica* 26: 98-112.
- Peres, C.A. (1996). Food patch structure and plant resource partitioning in interspecific associations of Amazonian tamarins. *International Journal of Primatology* 17(5): 695-723.
- Peres, C.A. and Dolman, P.M. (2000). Density compensation in Neotropical primate communities: Evidence from 56 hunted and nonhunted Amazonian forests of varying productivity. *Oecologia* 122: 175-189.
- Phillips, K.A. (1995). Resource patch size and flexible foraging in white-faced capuchins (*Cebus capucinus*). *International Journal of Primatology* 16: 509-519.
- Phyala, A., Brown, K., and Adger, W.N. (2006). Implications of livelihood dependence on non-timber products in Peruvian Amazonia. *Ecosystems* 9: 1328-1341.
- Pontes, A.R.M. (1997). Habitat partitioning among primates in Maraca Island, Roraima, Northern Brazilian Amazon. *International Journal of Primatology* 18(2): 131-157.
- Porter, L.M. (2003). Forest use and activity patterns of *Callimico goeldii* in comparison to two sympatric tamarins, *Saguinus fuscicollis* and *Saguinus labiatus*. *American Journal of Physical Anthropology* 124(2): 139-153.

- Poulsen, J.R., Clark, C.J., Connor, E.F., and Smith T.B. (2002). Differential resource use by primates and hornbills: Implications for seed dispersal. *Ecology* 83(1): 228-240.
- Pruetz, J. (2002). Competition between savanna chimpanzees and humans in southeastern Senegal. *American Journal of Physical Anthropology* (Suppl 34): 128.
- Quang, N.V., and Noriko, S. (2008). Forest allocation policy and level of forest dependency of economic household groups: A case study in northern central Vietnam. *Small-scale Forestry* 7(1): 49-66.
- Quinlan, M. (2005). Considerations for collecting freelists in the field: Examples from ethnobotany. *Field Methods* 17(3): 1-16.
- Rambo, A.T. and Jameison, N.L. (2003). Upland areas, ethnic minorities, and Development. In: Postwar Vietnam: Dynamics of a transforming society. Hy V. Luong (ed.). Lanham, Maryland: Rowman and Littlefield Publishers, Inc., pp. 139-200.
- Rasmussen, D.R. (1979). Correlates of patterns of range use of a troop of yellow baboons (*Papio cynocephalus*): I. Sleeping sites, impregnable females, births, and male emigrations and immigrations. *Animal Behavior* 27: 1098-1112.
- Rawson, B.M., Insua-Cao, P., Nguyen Manh Ha, Van Ngoc Thinh, Hoang Minh Duc, Mahood, S., Geissmann, T., and Roos, C. (2011). The Conservation Status of Gibbons in Vietnam. Hanoi, Vietnam: Fauna and Flora International/Conservation International.
- Richard, A.F. and Dewar, R.E. (1991). Lemur ecology. *Annual Review of Ecology and Systematics* 22: 145-175.
- Riley, E.P. (2006). Ethnoprimatology: Toward reconciliation of biological and cultural anthropology. *Ecological and Environmental Anthropology* 2(2): 75-86.
- Riley, E.P. (2007). The human-macaque interface: Conservation implications of current and future overlap and conflict in Lore Lindu National Park, Sulawesi, Indonesia. *American Anthropologist* 109(3): 473-484.
- Riley, E.P. and Fuentes, A. (2011). Conserving social-ecological systems in Indonesia: Human-nonhuman primate interconnections in Bali and Sulawesi. *American Journal of Primatology* 73(1): 62–74. doi:10.1002/ajp.20834.
- Riley, S.J. (1999). A landscape analysis of cougar distribution and abundance in Montana, USA. *Environmental Management* 28(3): 317-323.
- Robbins, P., McSweeney, K., Chhangani, A.K., and Rice, J.L. (2009). Conservation as it is: Illicit resource use in a wildlife reserve in India. *Journal of Human Ecology* 37: 559-575.

- Robinson, J.G. (2006). Conservation biology and real-world conservation. *Conservation Biology* 20(3): 658-669.
- Roos, C., Boonratana, R., Supriatna, J., Fellowes, J.R., Rylands, A.B. and Mittermeier, R.A. (2013). An updated taxonomy of primates in Vietnam, Laos, Cambodia and China. *Vietnamese Journal of Primatology* 2(2): 13-26.
- Rose, A.L. (2002). Conservation must pursue human-nature biosynergy in the era of social chaos and bushmeat commerce. *In: Primates face to face: Conservation implications of human-nonhuman primate interconnections*. Fuentes, A. and Wolfe, L.D. (eds.). New York: Cambridge University Press, pp. 208-239.
- Ruliang Pan, Xeulong Jiang, and Milne, N. (2008). Mandibular morphometric variation among Chinese cercopithecoids and the unique structure of the snub-nosed monkey (*Rhinopithecus*) mandible. *Primates* 49: 195-203.
- Sack, R.D. (1983). Human territoriality: A theory. *Annals of the Association of American Geographers* 73(1): 55-74.
- Salafsky, N. (1993). Mammalian use of a buffer zone agroforestry system bordering Gunung Palung National Park, West Kalimantan, Indonesia. *Conservation Biology* 7(4): 928-933.
- Salafsky, N., Margoluis, R., Redford, K.H., and Robinson, J.G. (2002). Improving the practice of conservation: A conceptual framework and research agenda for conservation science. *Conservation Biology* 16(6): 1469-1479.
- Salafsky, N., Salzer, D., Stattersfield, A.J., Hilton-Taylor, C., Neugarten, R., Buchtart, S.H.M., Collen, B., Cox, N., Master, L.L., O'Connor, S.O., and Wilkie, D. (2008). A standard lexicon for biodiversity conservation: Unified classifications of threats and actions. *Conservation Biology* 22(4): 897-911.
- Sappington, J.M., Longshore, K.M., and Thompson, D.B. (2007). Quantifying landscape ruggedness for animal habitat analysis: A case study using bighorn sheep in the Mojave Desert. *Journal of Wildlife Management* 71(5): 1419-1426.
- Sauther, M.L. (1994). Wild plant use by pregnant and lactating ringtailed lemurs, with implications for early hominid foraging. *In: Eating on the Wild Side: The Pharmacologic, Ecologic, and Social Implications of Using Noncultigens*. Tucson, Arizona: University of Arizona Press, pp. 240-246.
- Sauther, M.L., Sussman, R.W., and Gould, L. (1999). The socioecology of the ringtailed lemur: Thirty-five years of research. *Evolutionary Anthropology* 8(4):120-132.
- Sauther, M.L., Cuzzo, F.P., Youssouf Jacky, I.A., Fish, K.D., LaFleur, M., Ravelohasindrazana, A.L., and Ravoavy, J.F. (2013). Limestone cliff-face and cave use by wild ring-tailed lemurs (*Lemur catta*) in southwestern Madagascar. *Madagascar Conservation and Development* 8(2): 73-80.

- Sayers, K. and Lovejoy, O. (2008). The chimpanzee has no clothes: A critical examination of *Pan troglodytes* in models of human evolution. *Current Anthropology* 49(1): 87-114.
- Schoener, T.W. (1968). The *Anolis* lizards of Bimini: Resource partitioning in a complex fauna. *Ecology* 49(4): 704-726.
- Schrauf, R.W. and Sanchez, J. (2008). Using freelisting to identify, assess, and characterize age differences in shared cultural domains. *Journal of Gerontology* 63(6): 385-393.
- Schwitzer, C., Mittermeier, R.A., Rylands, A.B., Chiozza, F., Williamson, E.A., Wallis, J. and Cotton, A. (2016). Primates in Peril: The World's 25 Most Endangered Primates 2014–2016. Arlington, Virginia: IUCN SSC Primate Specialist Group (PSG), International Primatological Society (IPS), Conservation International (CI), and Bristol Zoological Society.
- Sequin, E.S., Jaeger, M.M., Brussard, P.F., and Barrett, R.H. (2003). Wariness of coyotes to camera traps relative to social status and territory boundaries. *USDA National Wildlife Research Center – Staff Publications*. Paper 233. Retrieved April 22, 2016: http://digitalcommons.unl.edu/icwdm_usdanwrc/233.
- Setiawan, A., Nugroho, T.S., Djuwantoko, and Pudyatmoko, S. (2009). A survey of miller's grizzled surili, *Presbytis hosei canicrus*, in East Kalimantan, Indonesia. *Primate Conservation* 24: 139-143.
- Sheil, D., Puri, R., Wan, M., Basuki, I., van Heist, M., Liswanti, N., Rukmiyati, I.R., and Samsedin, I. (2006). Recognising local people's priorities for tropical forest biodiversity. *Ambio* 35(1): 17-24.
- Shephard, G.H. (2002). Primates in Matsigenka subsistence and world view. In: Primates face to face: Conservation implications of human-nonhuman primate interconnections. Fuentes, A. and Wolfe, L.D. (eds.). New York: Cambridge University Press, pp. 101-136.
- Siex, K.S. and Struhsaker, T.T. (1999). Colobus monkeys and coconuts: A study of perceived human-wildlife conflicts. *Journal of Applied Ecology* 36: 1009-1020.
- Smith, J.J. (1993). Using Anthropac 3.5 and a spreadsheet to compute a free list salience index. *Cultural Anthropology Methods Newsletter* 5(3): 1-3.
- Smith, J.J. and Borgatti, S.P. (1998). Salience counts – and so does accuracy: Correcting and updating a measure for free-list-item salience. *Journal of Linguistic Anthropology* 7(2): 208-209.
- Songtao Guo, Baoguo Li, and Wantanabe, K. (2007). Diet and activity budget of *Rhinopithecus roxellana* in the Qinling Mountains, China. *Primates* 48: 268-276.

- Songtao Guo; Ji, WH; Li, BG; and Li, M (2008). Response of a group of Sichuan snub-nosed monkeys to commercial logging in the Qinling Mountains, China. *Conservation Biology* 22(4):1055-1064.
- Sponsel, L.E. (1997). The human niche in Amazonia: Explorations in ethnoprimateology. *In: New World Primates: Ecology, Evolution, and Behavior*. Kinzey, W.G. (ed.). New York: Aldine DeGruyter Publishing, pp. 143-165.
- Sterling, E.J., Hurley, M.M., and Le Duc Minh (2006). Vietnam: A Natural History. New Haven, Connecticut: Yale University Press.
- Stem, C., Margoluis, R., Salafsky, N., and Brown, M. (2005). Monitoring and evaluation in conservation: A review of trends and approaches. *Conservation Biology* 19(2): 295-309.
- Strum, S.C. (2010). The development of primate raiding: Implications for management and conservation. *International Journal of Primatology* 31(1): 133–56. doi:10.1007/s10764-009-9387-5.
- Struhsaker, T.T. (1999). Primate communities in Africa: The consequence of long-term evolution or the artifact of recent hunting? *In: Primate Communities*. Fleagle, J.G., Janson, C.H., and Reed, K.E. (eds.). Cambridge: Cambridge University Press, pp. 289-294.
- Sushma, H.S. and Singh, M. (2006). Resource partitioning and interspecific interactions among sympatric rain forest arboreal mammals of the Western Ghats, India. *Behavioral Ecology* 17(3): 479-490.
- Takai, M., Zhang, Y., Kono, R.T., and Jin, C. (2014). Changes in the composition of the Pleistocene primate fauna in southern China. *Quaternary International* 354: 75-85.
- Tan, C.L., Songtao Guo, and Baoguo Li (2007). Population structure and ranging patterns of *Rhinopithecus roxellana* in Zhouzhi National Nature Reserve, Shaanxi, China. *International Journal of Primatology* 28(3): 577–91. doi:10.1007/s10764-007-9147-3.
- Terborgh, J. (1983). Five New World Primates: A Study in Comparative Ecology. Princeton, New Jersey: Princeton University Press.
- Terborgh, J. and Janson, C.H. (1986). The socioecology of primate groups. *Annual Review of Ecological Systematics* 17: 111-135.
- Teufel, N. (1997). Development of culturally competent food-frequency questionnaires. *American Journal of Clinical Nutrition* 65(Suppl.): 1173S-8S.
- Thach Mai Hoang (2009). History of research on Tonkin snub-nosed monkeys in Vietnam and analysis of their daily ranging behavior in Khau Ca, Ha Giang province. Master's Thesis submitted to the University of Colorado Boulder.

- Thach Mai Hoang (2011). Primate survey prioritizing Tonkin snub-nosed monkey (*Rhinopithecus avunculus*) and Francois' langur (*Trachypithecus francoisi*) in Na Hang Nature Reserve, Tuyen Quang Province. Hanoi, Vietnam: People Resources and Conservation Foundation.
- Thanh Binh Nguyen (2011). The trend of Vietnamese household size in recent years. *International Conference on Humanities, Society, and Culture*. Singapore: IACSIT Press. IPEDR 20: 47-52.
- Thierry, B. (2011). The macaques. *In: Primates in Perspective*. Campbell, C.J., Fuentes, A., MacKinnon, K.C., Bearder, S.K., and Stumpf, R.M. (eds.). New York: Oxford University Press, pp. 229-241.
- Thinh, V.N., Mootnick, A.R., Thanh, V.N., Nadler, T., and Roos, C. (2010). A new species of crested gibbon, from the central Annamite mountain range. *Vietnamese Journal of Primatology* 1(4): 1-12.
- Tobler, M. W., S. E. Carrillo-Percegue, R. Leite Pitman, R. Mares, and G. Powell (2008). An evaluation of camera traps for inventorying large- and medium-sized terrestrial rainforest mammals. *Animal Conservation* 11(3): 169–78. doi:10.1111/j.1469-1795.2008.00169.x.
- Tocheri, M.W., Orr, C.M., Jacofsky, M.C., and Marzke, M.W. (2008). The evolutionary history of the hominin hand since the last common ancestor of *Pan* and *Homo*. *Journal of Anatomy* 212: 544-562.
- Tran Duc Vien (2003). Culture, environment, and farming systems in Vietnam's northern mountain region. *Southeast Asian Studies* 41(2): 180-204.
- Tran Van Phung and Troung Thanh Nam (2008). Participatory Land Use Mapping (PLUM) for the proposed protected area at Khau Ca. Hanoi, Vietnam: Fauna and Flora International Vietnam Conservation Support Programme. Unpublished Report, pp. 1-47.
- Treves, A. (2002). Predicting predation risk for foraging in arboreal monkeys. *In: Eat or Be Eaten: Predator Sensitive Foraging Among Primates*. Miller, L.E. (ed.). New York: Cambridge University Press, pp. 222-241.
- Tutin, C.E.G., Fernandez, M., Rogers, M.E., Williamson, E.A., and McGrew, W.C. (1991). Foraging profiles of sympatric lowland gorillas and chimpanzees in the Lope Reserve, Gabon. *Philosophical Transactions of the Royal Society of London B* 334: 179-186.
- Uberhuaga, P., Smith-Hall, C., Helles, F. (2011). Forest income and dependency in lowland Bolivia. *Environmental Development and Sustainability* 14: 3-23.
- Urbani, B. (2005). The targeted monkey: A re-evaluation of predation on New World primates. *Journal of Anthropological Sciences* 83: 89-109.

- Vaidyanthan, S., Krishnaswamy, J., Kumar, N.S., Dhanwatey, H., Dhawatey, P., and Karnath, K.U. (2010). Patterns of tropical dynamics and human impacts: Views from above and below the canopy. *Biological Conservation* 143: 2881-2890.
- Van Doorn, A.C., O'Riain, M.J. and Swedell, L. (2010). The effects of extreme seasonality of climate and day length on the activity budget and diet of semi-commensal chacma baboons (*Papio ursinus*) in the Cape Peninsula of South Africa. *American Journal of Primatology* 72: 104-112.
- van Schaik, C.P. (1983). Why are diurnal primates living in groups? *Behaviour* 87(1-2): 120-144.
- van Schaik, C.P. (2013). The costs and benefits of flexibility as an expression of behavioral plasticity: A primate perspective. *Philosophical Transactions of the Royal Society of London B* 368(1618): 20120339.
- van Schaik, C.P. and Brockman, D.K. (2005). Seasonality in primate ecology, reproduction, and life history: An overview. *In: Seasonality in Primates: Studies of Living and Extinct Human and Non-human Primates*. Brockman, D.K. and van Schaik, C.P. (eds.). Cambridge: Cambridge University Press, pp. 3-20.
- van Schaik, C.P., Terborgh, J.W., and Wright, S.J. (1993). The phenology of tropical forests: Adaptive significance and consequences for primary consumers. *Ecology, Evolution, and Systematics* 24: 353-377.
- Venkataraman, V.V., Kraft, T.S. and Dominy, N.J. (2013). Tree climbing and human evolution. *Proceedings of the National Academy of Sciences* 110(4): 1237-1242.
- Verhaegen, M., Munro, S., Puech, P.F., and Venechoutte, M. (2011). Early Hominoids: Orthograde aquarboreals in flooded forests? *In: Was Man More Aquatic in the Past? Fifty years after Alister Hardy-Waterside hypotheses of human evolution*. Potomac, Maryland: Bentham Science Publishers, pp. 67-81.
- Vermeij, G.J. (1978). *Biogeography and Adaptation: Patterns of Marine Life*. Cambridge: Harvard University Press.
- Vietnam Culture (2016). Vietnam Culture: Bringing Vietnamese Culture to the World. Retrieved February 10, 2016: <http://www.vietnam-culture.com>.
- Vietnam Online (2016). Banh Chung: Chung cake or square rice cake. Retrieved May 15, 2016: <http://www.vietnamonline.com>.
- Vogt, K.A., Beard, K.H., Hammann, S., O'Hara Palmiotto, J., Vogt, D.J., Scatena, F.N. and Hecht, B.P. (2002). Indigenous knowledge informing management of tropical forests: The link between rhythms in plant secondary chemistry and lunar cycles. *Ambio* 31(6): 485-490.

- Vu An Tai (2013). Study on characteristics of plant species at the Tonkin snub-nosed monkey Species and Habitat Conservation Area, Khau Ca forest, Ha Giang Province. Hanoi, Vietnam: Report prepared (in Vietnamese) for the Institute of Science and Technology and the Institute of Geography.
- Wada, K., Baoguo Li, and Watanabe, K. (2015). Affiliative interactions between one-male units in a band of Sichuan snub-nosed monkeys (*Rhinopithecus roxellana*) living in the Qinling Mountains, China. *Primates* 56(4): 327-337.
- Wahungu, G.M. (1998). Diet and habitat overlap in two sympatric primate species, the Tana crested mangabey *Cercocebus galeritus* and yellow baboon *Papio cynocephalus*. *African Journal of Ecology* 36: 159-173.
- Walker, S.E. (1996). The evolution of positional behavior in the saki-uakaris (*Pithecia*, *Chiropotes*, and *Cacajao*). In: Adaptive Radiations of Neotropical Primates. Norconk, M.A., Rosenberger, A.L., and Garber, P.A. (eds.). Washington, D.C.: Springer Science and Business Media, pp. 335-367.
- Wallace, R.B. (2006). Seasonal variations in black-faced black spider monkey (*Ateles chamek*) habitat use and ranging behavior in a southern Amazonian tropical forest. *American Journal of Primatology* 68: 313-332.
- Waser, P.M. (1984). Ecological differences and behavioral contrasts between two mangabey species. In: Adaptations for Foraging in Nonhuman Primates. Cant, J. and Rodman, P. (eds). New York: Columbia University Press, pp. 195-216.
- Wen Xiao, Wei Ding, Liang-Wei Cui, Ru-Liang Zhou, and Qi-Kun Zhao. (2003). Habitat degradation of *Rhinopithecus bieti* in Yunnan, China. *International Journal of Primatology* 24(2): 389-398.
- West, P. and Brockington, D. (2006). An anthropological perspective on some unexpected consequences of protected areas. *Conservation Biology* 20(3): 609-616.
- Wiafe, E.D. (2010). Monitoring of primates and illegal hunting activities in Kakum National Park, Ghana. *Primate Research* 26 (Suppl.): 615.
- Wolfe, L.D. and Fuentes, A. (2007). Ethnoprimateology: Contextualizing human and nonhuman primate interactions. In: Primates in Perspective. Campbell, C.J., Fuentes, A., MacKinnon, K.C., Panger, M., and Bearder, S.K., (eds.). New York: Oxford University Press, pp. 691-701.
- Wolfheim, J.H. (1983). Primates of the World: Distribution, Abundance and Conservation. Seattle, Washington: University of Washington Press.
- Woodward, E., Jackson, S., Finn, M., and McTaggart, P.M. (2012). Utilising indigenous seasonal knowledge to understand aquatic resource use and inform water resource management in northern Australia. *Ecological Management and Restoration* 13(1): 58-64.

- Workman, C. (2004). Primate conservation in Vietnam: Toward a holistic environmental narrative. *American Anthropologist* 106(2): 346-352.
- Workman, C. (2010). The Foraging Ecology of the Delacour's Langur (*Trachypithecus delacouri*) in Van Long Nature Reserve, Vietnam. Dissertation submitted to the Department of Evolutionary Anthropology, Duke University.
- Wright, P.C. (1998). Impact of predation risk on the behavior of *Propithecus diadema edwardsi* in the rain forest of Madagascar. *Behaviour* 135(4): 483-512.
- Wright, P.C., Razafindratsita, V.R., Pochron, S.T., and Jernvall, J. (2005). The key to Madagascar frugivores. In: Tropical Fruits and Frugivores: The Search for Strong Interactors. Dew, J.L. and Boubli, J.P. (eds). The Netherlands: Springer Science and Media, Inc., pp. 121-138.
- Wright, B.W., Ulibarri, L., O'Brien, J., Sadler, B., Prodhan, R., Covert, H.H., and Nadler, T. (2008). It's tough out there: Variation in the toughness of ingested leaves and feeding behavior among four Colobinae in Vietnam. *International Journal of Primatology* 29: 1455-1466.
- WWO [World Weather Online] (2016). Ha Giang Monthly Climate Average, Vietnam. Retrieved May 8, 2016: <http://www.worldweatheronline.com/Ha-Giang-weather-averages/VN.aspx>.
- Xiang, Z.F., Huo, S., Xiao, W., Quan, R.C., and Grueter, C.C. (2007). Diet and feeding behavior of *Rhinopithecus bieti* at Xiaochangdu, Tibet: Adaptations to a marginal environment. *American Journal of Primatology* 69: 1141–1158.
- Xuecong Liu (2012). Behavioral ecology of the Sichuan snub-nosed monkey (*Rhinopithecus roxellana*) in Shennongjia, China. Dissertation submitted to the University of Southern California.
- Yeager, C.P. (1991). Possible antipredator behavior associated with river crossings by proboscis monkeys (*Nasalis larvatus*). *American Journal of Primatology* 24(1): 61-66.
- Yiming Li (2001). The seasonal diet of the Sichuan snub-nosed monkey (*Pygathrix roxellana*) in Shennongjia Nature Reserve, China. *Folia Primatologica* 72: 40-43.
- Yiming Li (2002). Winter feeding tree choice in Sichuan snub-nosed monkeys (*Rhinopithecus roxellana*) in Shennongjia Nature Reserve, China. *International Journal of Primatology* 23(3): 657-675.
- Yiming Li (2004). The effect of forest clear-cutting on habitat use in the Sichuan snub-nosed monkey (*Pygathrix roxellana*) in Shennongjia Nature Reserve, China. *Primates* 45:69-72.

- Yiming Li (2006). Seasonal variation of diet and food availability in a group of Sichuan snub-nosed monkeys in Shennongjia Nature Reserve, China. *American Journal of Primatology* 68: 271-233.
- Yiming Li (2007). Terrestriality and tree stratum use in a group of Sichuan snub-nosed monkeys. *Primates* 48: 197-207.
- Yixin Chen, Zuofu Xiang, Xinwen Wang, Wen Xiao, Zhishu Xiao, Baoping Ren, Chengxiang He, and Haishu Li (2015). Preliminary study of the newly discovered primate species *Rhinopithecus strykeri* at Pianma, Yunnan, China using infrared camera traps. *International Journal of Primatology* 36(4):679-690.
- Youlatos, D. (1999). Comparative locomotion of six sympatric primates in Ecuador. *Annales des Sciences Naturelles* 20(4): 161-168.
- Ze Hua Liu and Qi Kun Zhao (2004). Sleeping sites of *Rhinopithecus bieti* at Mt. Fuhe, Yunnan. *Primates* 45: 241-248.
- Zhaoyuan Li and Rogers, M.E. (2005). Are limestone hills a refuge or essential habitat for white-headed langurs in Fusui, China? *International Journal of Primatology* 26(2): 437-452.
- Zurcher, E. (2001). Lunar rhythms in forestry traditions: Lunar-correlated phenomena in tree biology and wood properties. *Earth, Moon, and Plants* 85-86: 463-478.

APPENDICES

Appendix A: Master Timber Species List. Alphabetized list of timber plants, with alternative vernacular and/or ethnic translations as well as scientific and English names.

Standardized Name	Alternative Vernacular and/or Ethnic Language Names				Scientific Name (English)
Bà sọt	Máy thể	Máy Tấu	Táp e	Tram pling	Lamiaceae sp.
Bồ đề	Bo de mo				Styrax sp.
Bóng bạc					
Bứa	May bua	Máy bừa lác na	Mạc hầu		
Cà dẻ					
Cà Táp	Ca tap dang	Cà tap nôm	Cờ tap nôm		
Cay mot					
Cham pa					<i>Plumeria obtusum</i>
Chẹo	May Peo	Chieu pia	Cu pia		<i>Engelhardtia roxburghiana</i>
Chi tọng nhu					
Cho chi					
Cọ	Máy Cọ	Cay Co			Arecaceae sp. (Palm)
Dăng dằm	Máy Dằm				
Dầu	Dầu đất	Máy đầu	Dau da	Doi	Moraceae sp.
Dẻ					
Đinh	Đinh đầu				<i>Markhamia stipulata</i>
Đu đủ	Du du rung	Máy tang	Mang tang		<i>Brassaiopsis sp. (Papaya)</i>
Gạo	Máy píc lăm				
Gầu ngựa	Gầu				
Guot					
Kháo da	Khao da	Cờ rế mao			<i>Phoebe sp.</i>
Liên Vang					
Mắt túi					
Máy bện	May ban	May bin			
May cang lui					
Máy đi mi	May di mi	May my	Mật gấu		
Máy kết					

Standardized Name	Alternative Vernacular and/or Ethnic Language Names				Scientific Name (English)
Máy khền	Máy khen khoả	Nha kheng khôa			Rutaceae sp.
Máy ma					
Máy nặm chí					
Máy nằng khìn					
Máy nhội					
Máy phá					
Máy pông					
Máy rô ỏi					
Máy réc	May roec				Diospyros sp.
Máy tâm pa					
Máy thang	Máy thang mủ	May thang dong			
May tim pet					
Máy Trầu					
Máy xá đan					
Máy trang	Noi trang	Mat trang	Nhôi trắng	Minh trắng	Dong trắng
Mỡ	Kum num dăng	May mốt			Eucalyptus sp.
Muồng	May cham				Manglieta dandyi
Năng đăm	Máy léc	May dam			Cassia sp.
Nanh					Polyalthia cerasoides
Nghiên					Excentrodendron tonkinense
Ngõa	Co ngoa	Máy ngoa	Bò ngoa	Mặc ngoa	Lung ngoa
Nhu bản chúa					
Nội đồ	Nhội đồ				
Ốc chó					
Pá tong					
Phay	Phay soi				Duabanga grandiflora
Sà gài lằng					
Sa mộc	Móc				
Sa mu					
Sâng	Nấu lía	May tra	Củ nâu		Pometia pinnata
Sấu	May tru				Dracontomelon duperreanum

Note: Speakers of the same ethnic language often referred to the same plant resources using different vernacular terms; therefore, to carefully cross-reference all plants listed, the above table represents all possible vernaculars for each plant rather than focusing on which ethnic language was used to describe the plant. Thus, the five columns in the middle of the table above do not necessarily represent specific ethnic languages, but rather represent each of up to five alternative vernaculars used to describe the same plant. The plant name used by the majority of respondents was then considered the standardized name for further analysis. The same is true for Appendix B below.

Appendix B: Master Non-Timber Forest Product List. Alphabetized list of non-timber forest products, with alternative vernacular and/or ethnic translations as well as scientific and English names.

NTFP Species	Alternative Vernacular and/or Ethnic Language Names				Scientific Name (English)
A bó dĩnh					
Ba lạng	Kim trang	Phạm trắng	Khẩu thâm trang		
Bà ngôm					
Bà thả					
Bac thang					
Bằng phả					
Bờ pòm	Bờ thả				
Bong lau					
Bông chít	Cỏ chít	Máy mu	Bờ mờ		<i>Thysanolaena maxima</i> (Grass)
Brồng kón tóng					
Bưởi					
Cây men	Lá men	Lạc mề	Men	Thuốc men	Du pỉnh mà <i>Psychotria</i> sp.
Chắc má					
Ché					<i>Camellia sinensis</i>
Chó đẻ	Phân xanh				<i>Phyllanthus</i> sp.
Chuối					<i>Musa</i> sp. (Banana)
Cỏ gianh					
Cỏ lạc	Giàng gĩ				
Cỏ lau					
Cỏ ngựa					
Cỏ nhung					
Cỏ voi	Máy ẻm	Bờ em			
Cỏ vùng					<i>Arachis hypogaea</i> (Peanut)
Cu li					
Củ mài					
Củ nâu					

NTPF Species	Alternative Vernacular and/or Ethnic Language Names			Scientific Name (English)
Đắng cây				
Day ba lang				
Dây rừng	Ráy rừng	Mon rừng	Khấu cát Sắn dây rừng Mít rừng	<i>Pueraria</i> sp.
Dóc cua nân				
Dóc ta nhu				
Dóc xá dẻ				
Đông	Dón	Đông quân nánh		<i>Phrynium</i> sp.
Dương				
Fec tổng thau	Fec tổng			
Giăng chà piếu	Giăng chén thu			
Gieng				<i>Languas officinarum</i>
Khau				
Khoai				<i>Araceae</i> sp. (Taro)
Khom				
Khuc khac				<i>Smilacaceae</i> sp.
Kim tuyen				
Lac khoi				
Lanh				
Linh chi				
Lô nùng piếu				
Máy lóc má	Loak má			
Long ban tay				
Ma dầy nôm				
Mác củ mỷ				
Mạc Lóa				
Mạc như	Chôm chôm	Mặc nhiều		
Mau cho	Máu chó	Tốt chó	Buồn do chó	<i>Knema globularia</i>
Mạc rọa				
Mạc tưng than				
Mắt dầy nôm				

NTFP Species	Alternative Vernacular and/or Ethnic Language Names			Scientific Name (English)
Máy đốc láp				
Máy man	Bở man			
Máy Pang				
Máy thả				
Máy Vảo	Bở vảo			
Máy tạo				
Mác củ mỳ				
Mat thanh				
Mùn xo	Mọt xo			
Nép tề				
Nghe				
Nha hừng mèo po				
Nha khùm thón				
Nha mặt vài				
Nha nọc khóa	Cốc nọc khóa			
Nhả nhùng				
Nhân trần				
Nhội				
Pá nặng nòm				
Pàn				
Phéc kim trang				
Phéc Ong hai				
Phíc chần				
Phôi mật				
Phong lan				Orchidaceae sp. (Orchid)
Rau dẳng	Sắc giá	Phéc giá	Lá dẳng	Giao cổ lam Schefflera sp.
Rau dón	Fec cút			Diplazium esculentum
Rau dút	Rau dút rừng			
Rau hoi				

NTP Species	Alternative Vernacular and/or Ethnic Language Names		Scientific Name (English)
Rau khai	Bò khai		<i>Erythralium scandens</i>
Rau ngót rừng	Sáng		<i>Meliantha suavis</i>
Rau quay	Phéc sáng	Sóc sáng	
Rau tàu bay	Tàu bay		
Ráy mon	Ráy	Mon	
Riềng núi	Khà		Solanaceae sp. (Pepper)
Sà Pông			
Séc lung			
Sì			
Hạ pầu pò đá	Ta po da		
Tam gui nghien			
Thảo	Tam thảo đất		
Thong van			
Thôm lôm			
Tiểu rừng	Ranh tiu	Tiểu	Solanaceae sp. (Pepper)
Tong do			
Tu la hua			
Tung mà			
Vắt véo	Thiên niên kiện		<i>Homalomena aromatica</i>
Xổ	Xà pòm piếu	Sổ	
Xơ mùng piếu			

Appendix C: Interview Script (IRB Protocol # 11 - 0123)

Project Title: **Evaluating Human and Nonhuman Primate Forest
Resource Use in Ha Giang Province, Vietnam**

Principal Investigator: **Amy L. Harrison-Levine**

Respondent ID: _____

GPS Location: _____

PART A: THE INTERVIEW

Introduction and Pre-screening

Good morning (afternoon). My name is _____. I and my colleague, Ms. Amy Harrison-Levine, are here today to see if we might be able to recruit an adult female (male), who is at least 18 years of age, who lives in _____ commune, and who speaks fluent Vietnamese for participation in a research interview. Is someone who fits this description present? (If not, ascertain if such a person lives at the residence in question and whether there might be a good time to return and request an interview with that person. Once recruit is present, continue.)

Preamble/Consent Form Instructions

Are you interested in hearing more about our research and would you like to consider enrolling as a participant? (If yes, then continue.) I have with me two copies of our informed consent form; one copy for you and one copy for us (hand recruit the form with contact information card attached). I would like to read this form to you and if after hearing more about this research you choose to participate in the interview, we will need you to sign our copy of the form. (Read informed consent form aloud, in Vietnamese, word-for-word.)

Instructions

(If recruit decides to enroll and signs consent form, continue.) This interview involves three parts. The first part will focus on questions about you – your age and ethnicity, for example. This information will help us determine whether patterns of forest resource use are different or the same for different groups of people. The second section will be a set of questions where you will be asked to list all of the things you can think of that belong in a particular category. I will read the category and will also help you to continue adding to your list until you feel your list is complete. Your list can be considered complete when no matter how hard or how much longer you think, you will not be able to add more items to the list. Your lists will be compared to lists of other participants to gain a better understanding of how (for what purpose) specific forest resources are used, which plant species and plant parts are used, and which forest plant species are most important in your community. In the third section of the interview, you will be asked to complete a simple task. I will give you instructions for

completing the task once we have finished your free-listing questions. Lastly, we would like to ask for a household tour so that we can better understand your socio-economic status and your daily life.

For each section of the interview, there are no right or wrong, desirable or undesirable answers. We would like you to feel comfortable with saying what you really think and how you really feel.

We will be recording our conversation with this digital voice recorder. The purpose of this is so that we can get all the details of your answers but at the same time be able to carry on an attentive conversation with you. I assure you that all your comments will remain confidential. We will be compiling a report which will contain all participants' responses without any reference to individuals. Your identity will in no way be tied to the audio recording of your responses. Is it OK if we turn on the recorder now? (If yes, continue.)

Section I

In this section, questions will focus on you.

Q1. In what year were you born? _____

Q2. To what ethnicity do you most closely self-ascribe? _____

Q3. How long have you lived in this commune? _____ years

Q4. Have you ever lived in _____ or _____ communes?

Yes

No

→ Skip to Q5



Q4a. In which commune and village did you live?

Q4b. When did you live there?

Q4c. For how long did you live there?

Section II

In this section, you will be asked to list as many things as you can think of that belong to a particular category. Please remember to refrain from describing locations from which resources were procured and remember not to provide dates when plants were harvested. (Record answers on separate data collection sheet.)

- Q6. List all of the forest plants (including trees) and other items you can think of that are good to use as firewood/fuelwood.
- Q7. List all of the forest plants/trees that are good to use in building things like homes and fences and tell me which part(s) of the plant are used.
- Q8. List all of the forest plants/trees you can recall ever using to make rice wine or other spirits and tell me which part(s) of the plant were used.
- Q9. List all of the forest plants/trees you can recall ever using for ornamental purposes (for decorating your home, garden, grave sites, clothing, hair, etc.).
- Q10. List all of the forest plants/trees that you can recall ever using to feed your domestic animals (chickens, goats, water buffalo, pigs, fish, etc.) and tell me which part(s) of the plant were used.
- Q11. List all of the forest plants/trees that people in your community like to eat and tell me which part(s) of the plant they eat.
- Q12. List all of the forest plants/trees that are good to use when you are sick or not feeling well, tell me what you use each plant for (stomach ache, fever, treating an open wound, etc.) and tell me which part(s) of the plant are used.
- Q13. List all of the forest plants/trees that people in your community trade or sell to others.
- Q14. List the all of the forest plants/trees that are easy to grow in your garden.
-

Section III

In this section of the interview I will ask you to work on a short activity using this calendar and some symbols (show calendar data sheet). Notice that it is not a calendar for a specific year but a generic one representing any average or typical year. We would like for you to place stamps on the calendar representing times of year when people usually harvest and/or use particular plant resources. The purpose of gathering this information is to determine when specific plant resources are used, so that we can determine the seasonal importance of each resource. Please remember to refrain from describing locations from which resources were procured and remember not to provide specific years when plants were harvested.

Each resource is associated with a different color and shape as shown on this sheet (show resource data collection sheet with symbols). Using each resource symbol, please place a mark on all of the weeks when that particular resource is harvested or used. Please think carefully about all potential uses for each plant and take your time in completing this activity.

Section IV

Now we are wondering if we could please have a tour of your household, including the rooms of your home, your gardens and fields, any other buildings or structures and similar parts of your household. The purpose of gathering this information is to have a better understanding of both your socio-economic status and of your daily life.

Interview Conclusion

(Collect calendar.) Great! Thank you – we're all done with the interview. We hope that you've enjoyed sharing your knowledge and experiences with us. We apologize for any inconvenience we may have caused and we want you to know that your time is very much appreciated. If you ever have any questions about the research or study results, please remember that you have our contact information on the card attached to your copy of the consent form. Please do not hesitate to contact us at any time. We will be sure to provide all members of your community an opportunity to learn the results of our research.

Thanks, again, for your time and helpful comments. Have a great day!