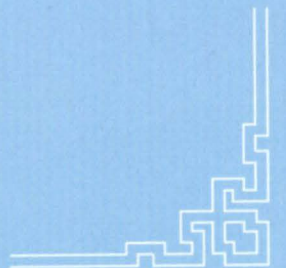
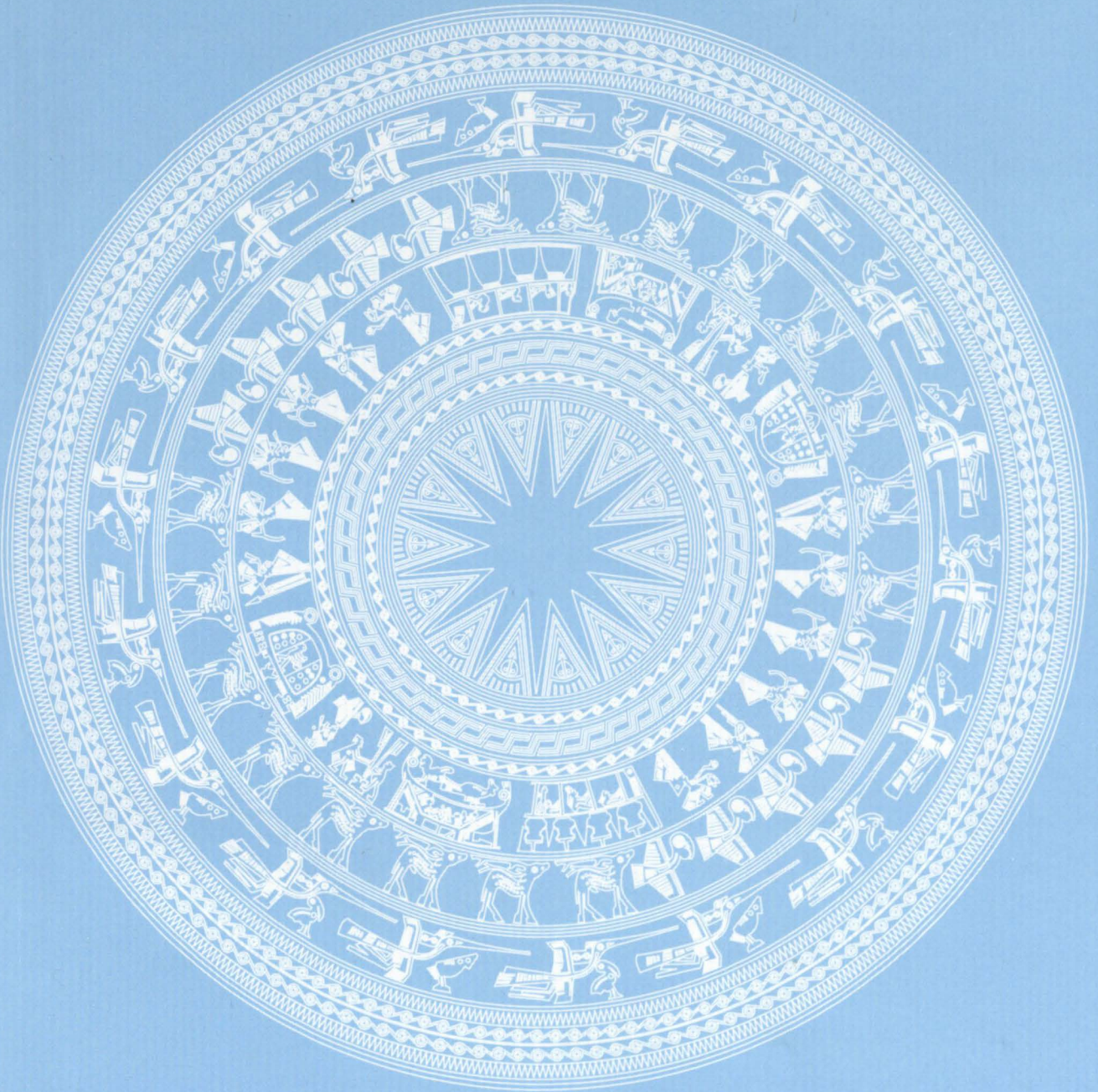
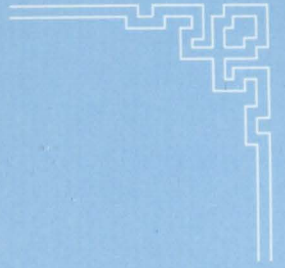

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**Ecology, Behavior and Conservation of the Tonkin
Snub-nosed Monkey (*Rhinopithecus avunculus*) in Vietnam**

by
Dong Thanh Hai

A thesis submitted for the degree of Doctor of Philosophy of The Australian National
University

Submitted in September 2011



Adult male and female of Tonkin snub-nosed monkey (*Rhinopithecus avunculus*) in Khau Ca. All pictures presented in this thesis captured by Dong Thanh Hai.

Acknowledgements

I am firstly heartily thankful to my supervisors, Professor Colin Groves and Dr. Ramesh Boonratana, who encouraged, guided and supported from the initial to the final step of my study. I specially thank to Dr. Ramesh Boonratana, who first inspired me with his efforts on primate conservation and introduced me to Professor Colin Groves. A special thank for his taking time and effort to visit and guide me in the field. These things I will never forget. Thanks to my advisor, Associate Professor Le Xuan Canh for his enthusiastic support in the process of data collection in Vietnam.

I would like to thank the Provincial Forest Protection Departments of Tuyen Quang, Ha Giang, Bac Kan, and Thai Nguyen, the management boards of Na Hang, Cham Chu and Than Sa-Phuong Hoang Nature Reserves (NR), Chau Ca and Nam Xuan Lac Habitat and Species Conservation Areas (HSCA), Ba Be NP (NP) for their permission and support to undertake this study. In particular I would like to thank the directors of Na Hang NR, Mr. Le Hong Binh and Chau Ca HSCA, Mr. Hoang Van Tue for their equipment and human resources support.

I would like to show my gratitude to my colleagues who provided support to this study. Dr. Craig Kirkpatrick for providing useful comments during my first year in the field; Mr. Nguyen Van Huy for plant identification; Mr. Do Quang Huy, Mr. Nguyen Hai Ha, Mr. Ngo Duy Bach, Mr. Luu Quang Vinh, Mr. Nguyen Dac Manh for joining surveys in Cham Chu NR.

For local assistance and support, I thank Le Xuan Hiep, Quan Van Tinh, Dong Khac Thanh, Ma Van Tu, Ma Van Huong, Quan Van Thiet, Vu Duc Kham. Special thanks go

to Ms. Susan Hua, from Cornell University, for her dedication, support, and assistance during this study. I am grateful to all the reserve forest rangers, and patrollers for their assistance. I learnt so much from them.

I would like to thank all the guides and porters who helped in the survey, and to households from Tat Ke, Minh Son, Fia Deng, Tung Ba, Binh Ba, Khoi Loa, Cham Chu, Ba Be, Nam Xuan Lac, and Than Sa-Phuong Hoang villagers who provided information and supported with accommodation to the research team.

I express deep gratitude to the parents and family who encouraged and inspired me throughout the study. To my wife, Nguyen Thi An and sons, Dong Duc Anh and Dong Hieu Anh who have always supported and helped me in the most difficult time. Their moral support and constant encouragement played an important role in the completion of this thesis.

I thank the following organizations for their financial support: Vietnam Ministry of Education and Training, BP Conservation Programme, Primate Conservation, Inc. (PCI), Wildlife Conservation Society, Rufford Small Grant, Zoological Society of San Diego Zoo, The Australian National University, Conservation International, and Margot Marsh Foundation.

Abstract

The Tonkin snub-nosed monkey (*Rhinopithecus avunculus*) is a critically endangered primate and endemic to northern Vietnam. This research was to address the questions about ecology and behavior of a relatively unstudied species in comparison with the other members of the genus *Rhinopithecus*. I carried out my study in Tat Ke Sector, Na Hang NR and Khau Ca HSCA over 24 months, from September 2004 to September 2006. In addition, four other known sites including Ba Be NP, Nam Xuan Lac HSCA, Than Sa-Phuong Hoang and Cham Chu NRs were also investigated between 2006 and 2010.

Tat Ke and Khau Ca have a relatively similar botanical structure and species composition. The main forest type here is evergreen forests associated with limestone hills. Phenological patterns at both sites were characterized by high production of young leaves throughout the year and seasonality of flowers and fruits. Rainfall correlated with the production of young leaves, flowers and fruits.

The social organization follows the typical patterns of other colobines in that the basic structure is one-male unit (OMU). Extra males form all-male units (AMUs). OMUs and AMUs frequently aggregated in large bands for traveling, feeding, resting and sleeping. The species show fission and fusion society as probably as a result of the size of food patches, the abundance and availability of quality food, and human disturbance. Members within OMU have high cohesiveness as a result of close social distance.

Social and agonistic interactions within and between units are infrequent, as with many colobines. Males respond aggressively toward the resident males of other one-male units, suggesting the defense of females. Grooming is mostly performed by adult females, suggesting high affiliation between them within OMUs. Juveniles observed provided alloparenting. Seasonality of birth may be related to food quality and the availability of food items. The colour of the newborn observed is in contrast to previous reports on *R. avunculus* and differ from the common pattern in most colobine species. Other new observations on behavior described in this study include group movement, vocalizations, rest-huddling, and terrestriality.

In contrast to previous reports, *R. avunculus* in this study is folivore and frugivore, with an emphasis on young leaves (46.2%). The species were highly selective in their choice of foods and fed mainly from trees which were quite rare and low in terms of both the number of stems and basal area. Strong selectivity for uncommon species has been reported in several colobines and may be related to nutritional quality, abundance and availability of food items. Diet of the species at Khau Ca varied according to seasonal changes in availability of food items, as with many other primates.

The total population estimated for Vietnam is ca. 215 individuals. Population sizes are decreasing in most of the sites surveyed, the only exception being Khau Ca. This results from high hunting pressure and habitat destruction. Immediate conservation measures need to be taken to protect small remaining populations of the species and its habitat before they become locally extinct as in Ba Be NP.

Table of content

Acknowledgements.....	iv
Abstract.....	vi
Table of content.....	viii
List of Tables.....	xii
List of Figures.....	xvi
Chapter 1.....	1
General introduction to colobines.....	1
1.1. Introduction.....	1
1.2. Taxonomy and distribution.....	2
1.2.1. Colobines and cercopithecines.....	2
1.2.2. Colobines in Asia.....	2
1.2.3. Colobines in Vietnam.....	4
1.3. Studies on ecology and behavior.....	5
1.3.1. Social organization.....	7
1.3.2. Social behavior.....	8
1.3.3. Range use.....	10
1.3.4. Feeding ecology.....	12
1.3.5. Diversity of diet.....	13
1.3.6. Seasonality.....	13
1.3.7. Selective feeders.....	14
1.4. Summary.....	15
Chapter 2.....	16
Introduction to genus <i>Rhinopithecus</i>	16
2.1. Introduction.....	16
2.2. Snub-nosed monkeys, <i>Rhinopithecus</i>	16
2.3. Studies on ecology and behavior of Chinese snub-nosed monkeys.....	17
2.3.1. Social organization.....	18
2.3.2. Social behavior.....	20
2.3.3. Feeding ecology.....	21
2.3.4. Range use.....	23
2.3.5. Day range length.....	24
2.3.6. Terrestriality.....	25
2.3.7. Locomotion.....	25
2.4. Tonkin snub-nosed monkey <i>Rhinopithecus avunculus</i>	26
2.4.1. Taxonomy and distribution.....	26

2.4.2. Description.....	27
2.4.3. Population and conservation status of <i>Rhinopithecus avunculus</i>	29
2.4.4. Studies on ecology and behavior of Tonkin snub-nosed monkey	34
2.5. Aims of the present study.....	38
2.6. Summary	39
Chapter 3.....	40
Study area.....	40
3.1. Introduction	40
3.2. Methods.....	42
3.2.1. Climate.....	42
3.2.2. Botany.....	43
3.2.3. Phenology	43
3.3. Na Hang NR.....	44
3.3.1. Selection of site.....	44
3.3.2. Location	44
3.3.3. Topography.....	47
3.3.4. Climate.....	47
3.3.5. Botany.....	48
3.3.6. Phenology	58
3.4. Khu Ca HSCA	59
3.4.1. Selection of study site.....	59
3.4.2. Location	60
3.4.3. Topography.....	60
3.4.4. Climate.....	61
3.4.6. Phenology	71
3.5. Comparison between Tat Ke Sector and Khu Ca Forest.....	73
3.5.1. Botanical structure	73
3.5.2. Botanical composition	74
3.5.3. Phenology	75
3.6. Summary	75
Chapter 4.....	77
Social organization and behavior.....	77
4.1. Introduction	77
4.2. Methods.....	80
4.2.1. Study sites.....	80
4.2.2. Habituation	80
4.2.3. Data collection.....	81
4.2.4. Data analysis.....	82

4.3. Results	85
4.3.1. Group size and composition	85
4.3.2. Social organization	86
4.3.3. Social behavior	98
4.3.4. Other observed behaviors	100
4.4. Discussion	107
4.4.1. Social organization	107
4.4.2. Social behavior	111
4.4.3. Other observed behaviors	113
4.5. Summary	120
Chapter 5	121
Feeding Ecology	121
5.1. Introduction	121
5.2. Methods	123
5.3. Results	124
5.3.1. Feeding techniques	124
5.3.2. Feeding heights and sites	125
5.3.3. Diurnal patterns of feeding	128
5.3.4. Diet	129
5.3.5. Food selection	130
5.3.6. Monthly variation in feeding	132
5.3.7. Age/Sex variation in feeding	144
5.4. Discussion	146
5.4.1. Dietary diversity	146
5.4.2. Folivore versus frugivore	147
5.4.3. Food selection	148
5.4.4. Seasonal variation in diet	149
5.4.5. Sex differences in feeding	151
5.5. Summary	155
Chapter 6	156
Population size, distribution and conservation status of	156
<i>Rhinopithecus avunculus</i> in Vietnam	156
6.1. Introduction	156
6.2. Method	157
6.2.1. Study areas	157
6.2.2. Data collection	164
6.3. Results	165
6.3.1. Population size and distribution	165

6.3.2. Conservation issues	177
6.4. Discussion	186
6.4.1. The evidence of decline in populations of <i>R. avunculus</i> in Vietnam	186
6.4.2. Threats	187
6.5. Summary	192
Chapter 7	194
Conclusion and recommendations	194
7.1. Introduction	194
7.2. Conclusion.....	194
7.3. Recommendations for conservation	197
7.3.1. Conducting additional surveys and locating remaining populations of <i>R. avunculus</i> in Vietnam	198
7.3.2. Suppression of hunting of <i>R. avunculus</i> in the areas surveyed.....	198
7.3.3. Improving protection of critical <i>R. avunculus</i> habitat	199
7.3.4. Establishment of a long-term monitoring program	200
7.3.5. Increase public awareness for <i>R. avunculus</i> conservation.....	200
7.3.6. Conduct long-term research on <i>R. avunculus</i> ecology and behavior.....	201
7.4. Recommendations for future research.....	201
References.....	204
Appendix 1: Tree species and their proportions in the botanical plots at Tat Ke Sector.	227
Appendix 2: Tree species and their proportions in the botanical plots at Khau Ca Forest.	236
Appendix 3. Food species and items reported for <i>R. avunculus</i>	244
Appendix 4.1 Ranking of Threats in Tat Ke Sector, Na Hang NR.....	253
Appendix 4.2. Ranking of Threats in Cham Chu NR.....	254
Appendix 4.3. Ranking of Threats in Than Sa-Phuong Hoang NR.....	255
Appendix 4.4. Ranking of Threats in Ba Be NP.....	256
Appendix 4.5. Ranking of Threats in Nam Xuan Lac HSCA.....	257
Appendix 4.6. Ranking of Threats in Khau Ca HSCA.....	258

List of Tables

Table 1.1. Classification of Asian colobine monkeys since 1967	3
Table 1.2. Classification of Vietnam Colobines	4
Table 2.1. Measurement of <i>Rhinopithecus avunculus</i>	27
Table 3.1. Species richness between plots at Tat Ke Sector	52
Table 3.1. Species richness between plots at Tat Ke Sector (continued)	53
Table 3.2. Abundance and basal area of tree families in botanical plots at Tat Ke Sector	54
Table 3.2. Abundance and basal area of tree families in botanical plots at Tat Ke Sector (continued)	55
Table 3.3. The twenty eight commonest tree species in 64 plots at Tat Ke Sector	56
Table 3.3. The twenty eight commonest tree species in 64 plots at Tat Ke Sector (continued)	57
Table 3.4. Species richness between plots at Khau Ca Forest	66
Table 3.4. Species richness between plots at Khau Ca Forest (continued).....	67
Table 3.5. Abundance and basal area of tree families in botanical plots at Khau Ca.....	68
Table 3.5. Abundance and basal area of tree families in botanical plots at Khau Ca (continued)	69
Table 3.6. Twenty nine commonest tree species in 58 plots at Khau Ca Forest	70
Table 3.6. Twenty nine commonest tree species in 58 plots at Khau Ca Forest (continued)	71
Table 4.1. Activity categories used in this study (adapted from Boonratana and Le, 1993).....	83
Table 4.2. Age/sex categories used in this study (adapted from Boonratana and Le, 1993).....	84

Table 4.3. The three highest counts of the band and their age/sex composition at Tat Ke.....	88
Table 4.4. Age/sex composition different units of <i>R. avunculus</i> at Tat Ke.	88
Table 4.5. Age/sex composition of the bands of <i>R. avunculus</i> at Khau Ca HSCA.	89
Table 4.6. Age/sex composition of the one-male units of <i>R. avunculus</i> at Khau Ca HSCA.....	89
Table 4.7. Percentage of time for which individuals of different age/sex classes were nearest to the subject at Khau Ca Forest (n= 2263, weighted data).....	96
Table 4.8. Percents for grooming dyads seen during scan observations at Khau Ca.....	99
Table 4.9. Percents for social and self-play of <i>R. avunculus</i> at Khau Ca (n = 68, weighted data).....	101
Table 4.10. Band and units sizes for selected previous studies of the members of genus <i>Rhinopithecus</i>	117
Table 4.10. Band and units sizes for selected previous studies of the members of genus <i>Rhinopithecus</i> (Continued).	118
Table 4.11. Social behavior for selected studies of Asian Colobines.....	119
Table 5.1. Percent time feeding on specific food items by <i>R. avunculus</i> at Khau Ca. .	134
Table 5.1. Percent time feeding on specific food items by <i>R. avunculus</i> at Khau Ca (continued).	135
Table 5.2. List of food plants and plant parts eaten by <i>R. avunculus</i> at Khau Ca.	136
Table 5.2. List of food plants and plant parts eaten by <i>R. avunculus</i> at Khau Ca (continued).	137
Table 5.2. List of food plants and plant parts eaten by <i>R. avunculus</i> at Khau Ca (continued).	138
Table 5.3. Six commonest tree species eaten by <i>R. avunculus</i> at Khau Ca.	139

Table 5.4. Selection ratio based on stem of <i>R. avunculus</i> for food items and species during scan observations.....	140
Table 5.5. Selection ratio based on basal area of <i>R. avunculus</i> for food items and species during scan observations.....	141
Table 5.6. A comparison of selection ratios for food items of highly synchronized species based on stem with their availability	142
Table 5.7. A comparison of selection ratios for food items of highly synchronized species based on basal area with their availability.....	142
Table 5.8. Results of Spearman rank correlations between proportion of different plant parts in the diet of <i>R. avunculus</i> and synchrony of phenology among trees in the plots sampled.	145
Table 5.9. Percent time spent feeding by different age/sex classes of <i>R. avunculus</i> at Khau Ca (N=401, weighted data).	145
Table 5.10. Percent food items in the diet of <i>R. avunculus</i> from current and previous studies	152
Table 5.11. Diet in selected Asian colobines	153
Table 5.11. Diet in Asian Colobines (Continued).....	154
Table 6.1. Number of working days and areas covered in six sites surveyed.	174
Table 6.2. Population sizes of <i>R. avunculus</i> at six sites surveyed.	175
Table 6.3. Interview information on group size and distribution of <i>R. avunculus</i> in Cham Chu NR.....	176
Table 6.4. Interview information on group sizes and distribution of <i>R. avunculus</i> in Nam Xuan Lac HSCA.	176
Table 6.5. Ranking of threats to each sites studied. The higher the number the greater the impact, extent and urgency of the threat.	182

Table 6.6. Population sizes of <i>R. avunculus</i> in Vietnam reported between 1995 and 2010.....	190
Table 6.7 A comparison of current and past <i>R. avunculus</i> population sizes between sites studied/surveyed.	191

List of Figures

Figure 3.1. Position map of Na Hang NR and Khau Ca HSCA	46
Figure 3.2. Mean monthly maximum and minimum temperatures, and mean monthly rainfall recorded at Tuyen Quang for 2004-2005.	48
Figure 3.3. Frequency distribution of girths at breast height of plots at Tat Ke Sector (n=612).....	51
Figure 3.5. Phenological patterns at Tat Ke, Na Hang NR (n= 333).....	59
Figure 3.6. Mean monthly maximum and minimum temperatures, and mean monthly rainfall recorded at Ha Giang for 2005-2006.....	62
Figure 3.8. Relationship between area surveyed and number of tree species in plots at Khau Ca Forest	65
Figure 3.9. Phenological patterns at Khau Ca Forest (n=512).....	73
Figure 4.1. One-male unit of <i>R. avunculus</i> during resting time in Khau Ca.	87
Figure 4.2. One male unit of <i>R. avunculus</i> spacing during resting time in Khau Ca.....	92
Figure 4.3a. Percentage of time for which the nearest neighbor was within the specified distance of the subject (Weighted data).....	93
Figure 4.3b. Percentage of time for which the nearest neighbor was within the specified distance of the subject (Weighted data).....	93
Figure 4.4a. Percentage of time for which different number of individuals were within 2.5m of the subject at Khau Ca (weighted data).....	94
Figure 4.4b. Percentage of time for which different number of individuals were within 2.5m of the subject at Khau Ca (weighted data).....	94
Figure 4.5a. Percentage of time for which different number of individuals were within 5m of the subject at Khau Ca (weighted data).....	95

Figure 4.5b. Percentage of time for which different number of individuals was within 5m of the subject at Khau Ca (weighted data).	95
Figure 4.6. Percentage of time spent in vigilance by the different age/sex classes of <i>R. avunculus</i> at Khau Ca (n=218).	102
Figure 4.7. <i>R. avunculus</i> traveling within tree by quadrupedal walking.	104
Figure 4.8 & 4.9. <i>R. avunculus</i> exhibited vertical climbing and hanging.....	105
Figure 4.10. <i>R. avunculus</i> traveling and resting on the ground at Khau Ca.	105
Figure 4.11. <i>R. avunculus</i> resting on lower branches of the trees.	106
Figure 5.1. Adult male sitting and eating young leaves of <i>Diospyros choboensis</i>	126
Figure 5.2. Adult female sitting, pulling the branch to the mouth with both hands, and eating young leaves of <i>Diospyros choboensis</i>	127
Figure 5.3. Adult female hanging and feeding on ripe fruit of <i>Celtis sinensis</i>	127
Figure 5.4. Adult females hanging and sitting/hanging eating whole ripe fruits of <i>Celtis sinensis</i>	127
Figure 5.5. Diurnal variation in the percentage of feeding time of <i>R. avunculus</i> at Khau Ca (n = 401).	128
Figure 5.6. Monthly variation in plant parts eaten by <i>R. avunculus</i> at Khau Ca (N = 326).	143
Figure 5.7a. Monthly variation in young leaves in the diet, compared to that in the forest and to rainfall.	143
Figure 5.7b. Monthly variation in fruits and seeds in the diet, compared to that in the forest and to rainfall.	144
Figure 6.2. Map of areas surveyed for <i>R. avunculus</i>	171
(Note: The larger circles depict higher population sizes).	171
Figure 6.3. Locations of <i>R. avunculus</i> sightings in Tat Ke.....	171
Figure 6.5. A distribution map of <i>R. avunculus</i> in Khau Ca HSCA.	172

Figure 6.4. A distribution map of <i>R. avunculus</i> in Cham Chu NR.....	172
Figure 6.6. A distribution map of <i>R. avunculus</i> in Nam Xuan Lac HSCA.....	173
Figure 6.7. A distribution map of <i>R. avunculus</i> in Than Sa-Phuong Hoang NR.....	173
Figure 6.8. Hunting and destruction signs in each site surveyed (larger circles indicate higher encounter rate. Red circles: hunting; Yellow circles: Habitat destruction).	183
Figure 6.9. Hunting and destruction signs in Na Hang NR (larger circles indicate higher encounter rate. Red circles: hunting; Yellow circles: Habitat destruction).	183
Figure 6.10. Hunting and destruction signs in Cham Chu NR (larger circles indicate higher encounter rate. Red circles: hunting; Yellow circles: Habitat destruction).	183
Figure 6.11. Hunting and habitat destruction signs in Ba Be NP (larger circles indicate higher encounter rate. Red circles: hunting; Yellow circles: habitat destruction).	183
Figure 6.10. Hunting and destruction signs in Cham Chu NR (larger circles indicate higher encounter rate. Red circles: hunting; Yellow circles: Habitat destruction).	184
Figure 6.11. Hunting and habitat destruction signs in Ba Be NP (larger circles indicate higher encounter rate. Red circles: hunting; Yellow circles: habitat destruction).	184
Figure 6.13. Hunting and destruction signs in Nam Xuan Lac (larger circles indicate higher encounter rate. Red circles: hunting; Yellow circles: Habitat destruction).	185
Figure 6.12. Hunting and destruction signs in Than Sa Phuong Hoang NR (larger circles indicate higher encounter rate. Red circles: hunting; Yellow circles: Habitat destruction).	185

Chapter 1

General introduction to colobines

1.1. Introduction

The Colobinae or leaf-eating monkeys are different from Cercopithecinae in many aspects of their anatomy and morphology which greatly influence on their feeding strategies and social behavior (Chivers & Hladik, 1980; Oates et al., 1994). The main distinguishing feature is that the colobines have a special digestive system with enlarged salivary glands that allows them to balance the acidity of the forestomach fluid (Oates et al., 1994); specialized dentition (higher cusps and longer crests) that enable them to fold and cut leaves better than cercopithecines do (Oates et al., 1994; Lucas & Teaford, 1994); and an enlarged, complex ruminant-like stomach containing a diverse microflora that helps to ferment fibrous food such as leaves (Bauchop & Martucci, 1968; Chivers, 1994; Chivers & Hladik, 1980; Kavanagh, 1983, Kay and Davis, 1994). Further, the colobines lack cheek pouches, whereas this feature is conspicuous in the Cercopithecinae (Groves, 1989; Oates et al., 1994). Last, the colobines have long legs, reduced or absent thumbs, and longer hindlimbs which are related to arboreality and leaping (Groves, 1989; Fleagle, 1988; 1999; Napier & Napier, 1985; Strasser, 1992).

1.2. Taxonomy and distribution

1.2.1. Colobines and cercopithecines

The Old World monkeys (family Cercopithecidae) are divided into two sub families, Cercopithecinae and Colobinae, both of which are found throughout Africa and Asia. The former is more diverse in Africa and only one genus, *Macaca*, is found in Asia or Europe (Fleagle, 1988; 1999), whereas the latter have their greatest diversity and abundance in Asia (Fleagle, 1988; 1999). Seven out of nine or ten genera are found in Asia and two or three in Africa: *Semnopithecus*, *Trachypithecus*, *Presbytis*, *Nasalis*, *Simias*, *Pygathrix*, *Rhinopithecus*, and *Colobus*, *Piliocolobus* and *Procolobus* (the latter two being sometimes combined in a single genus), respectively (Brandon-Jones et al., 2004; Fleagle, 1999; Groves, 2000; 2001)

1.2.2. Colobines in Asia

Compared with African colobines, the classification of Asian colobines has been a subject of debate over time: from three (Groves, 1970) to five (Napier & Napier, 1967; 1985), and to seven genera (Brandon-Jones et al., 2004; Fleagle, 1999; Groves, 2001) (Table 1.1). Recent work has tended to support the view that Asian colobines comprise seven genera, *Semnopithecus*, *Trachypithecus*, *Presbytis*, *Nasalis*, *Simias*, *Pygathrix*, *Rhinopithecus* (Brandon-Jones et al., 2004; Fleagle, 1999; Groves, 2001), and include some 77 species with as many as 183 subspecies sometimes being recognized (Brandon-Jones et al., 2004). They are grouped into two informal groupings: the langurs and the odd-nosed group (Groves, 2001; Jablonski & Peng, 1993). The former grouping includes three genera: Grey langur or Hanuman langur *Semnopithecus*, Lutong *Trachypithecus*, and Surili *Presbytis*, and exhibits a great diversity of species: seven, seventeen, and eleven species, respectively. The latter contains 10 species in four genera: (Groves, 2001) *Nasalis* (one species), *Simias* (one species), Douc *Pygathrix*

(three species), Snub-nosed Monkey *Rhinopithecus* (traditionally containing four species, recently increased to five: Geissmann et al., 2010).

Table 1.1. Classification of Asian colobine monkeys since 1967

Family	Subfamily	Genera	References
		(3), (4), (5), (6), (7)	Napier & Napier (1967; 1985)
Cercopithecidae	Colobinae	(4), (7), (6 subgenus)	Groves (1970)
		(3), (4), (5), (6), (7)	Peng (1987)
		(2), (3), (4), (5), (6), (7)	Fleagle (1988)
Cercopithecidae and Colobidae	Nasalinae and Colobinae	(1), (2), (3), (4), (7)	Groves (1989)
		(3), (4), (5), (6), (7), (8)	Peng et al. (1993)
		(1), (2), (3), (4), (5), (7)	Oates et al. (1994)
		(1), (2), (3), (4), (5), (6), (7)	Brandon-Jones et al. (2004); Fleagle (1999); Groves (2001)

(1) *Semnopithecus*, (2) *Trachypithecus*, (3) *Presbytis*, (4) *Nasalis*, (5) *Simias*, (6) *Rhinopithecus*, (7) *Pygathrix*, and (8) *Presbytiscus*

Asian colobines occupy a wide range of environments. *Semnopithecus* is the most widespread colobine genus in Asia (Bennett & Davies, 1994; Groves, 2001), ranging from the temperate Himalayas in the north to tropical Sri Lanka in the south including parts of China, Pakistan, India, Nepal, Bhutan, and Sri Lanka (Bennett & Davies, 1994; Kirkpatrick, 2007). *Trachypithecus* and *Presbytis* are sympatrically distributed in Indonesia and Malaysia, but *Trachypithecus* are also found farther north into southern China, Indochina, Burma, northeastern India, Bhutan and Bangladesh (Groves, 2001; Kirkpatrick, 2007; Oates et al., 1994). In contrast, the genera of the odd-nosed group, *Nasalis*, *Pygathrix*, *Rhinopithecus*, and *Simias*, are characterized by a more limited

distribution. Genus *Rhinopithecus* is allopatric in northern Vietnam, southern and central China, and northernmost Burma (Groves, 2001; Kirkpatrick, 1995; Geissmann et al., 2010); *Nasalis* on the island of Borneo (Bennett & Gombek, 1993; Groves, 2001; Napier & Napier, 1967); *Simias* only on the Mentawai Islands of Indonesia (Groves, 2001; Napier & Napier, 1967); and *Pygathrix* in Vietnam, Laos and Cambodia (Groves, 2001; Napier & Napier, 1967).

1.2.3. Colobines in Vietnam

Vietnam has been known to harbour a great diversity of primates. To date, 25 species and subspecies have been recognized belonging to three families: Lorisidae (2 species), Cercopithecidae (17 species), and Hylobatidae (6 species). There are eleven taxa in three genera of leaf monkeys in Vietnam (Table 1.2), six of which are endemic to Vietnam: *Rhinopithecus avunculus*, *Trachypithecus* [cf. *poliocephalus*] *poliocephalus*, *Trachypithecus delacouri*, *Trachypithecus hatinhensis*, *Trachypithecus germaini caudalis*, and perhaps *T.margarita*; *Trachypithecus ebenus* is found in Vietnam and Laos; *Pygathrix cinerea*, *Pygathrix nemaus*, and *Pygathrix nigripes* are found in Laos, Vietnam and Cambodia; *Trachypithecus francoisi* in Vietnam and China; *Trachypithecus germaini germaini* in southern Vietnam, Thailand, Cambodia and Burma (Groves, 2001).

Table 1.2. Classification of Vietnam Colobines

Common name	Scientific name	Distribution
Indochinese Silvered Langur	<i>Trachypithecus germaini germaini</i> (Milne-Edwards, 1876)	Southern Vietnam, west of Mekong
	<i>Trachypithecus germaini caudalis</i> (Dao, 1977)	Northern Vietnam
	<i>Trachypithecus margarita</i>	East of Mekong

Francois' langur	<i>Trachypithecus francoisi</i> (Pousargues, 1898)	
Hatinh langur	<i>Trachypithecus hatinhensis</i> (Dao, 1970)	Vietnam
White-headed Langur or Cat Ba langur	<i>Trachypithecus</i> (cf. <i>poliocephalus</i>) <i>poliocephalus</i> (Trouessart, 1911)	Vietnam
Delacour's Langur	<i>Trachypithecus delacouri</i> (Osgood, 1932)	Vietnam
Indochinese Black Langur	<i>Trachypithecus ebenus</i> (Brandon-Jones, 1996)	Vietnam and Laos
Red-shanked Douc	<i>Pygathrix nemaeus</i> (Linnaeus, 1771)	Vietnam, Laos, and Cambodia
Black-shanked Douc	<i>Pygathrix nigripes</i> (Milne-Edwards, 1876)	Vietnam, Laos, and Cambodia
Grey-shanked Douc	<i>Pygathrix cinerea</i> (Nadler, 1997)	Vietnam
Tonkin Snub-nosed Monkey	<i>Rhinopithecus avunculus</i> (Dollman, 1912)	North Vietnam

Reference: Groves (2001)

The most obvious feature of the leaf monkeys in Vietnam is their limited distribution. *Trachypithecus poliocephalus*, for example, only occurs in the Cat Ba Island (Groves, 2001; Fooden, 1996). *Rhinopithecus avunculus* is restricted to northeast parts of Vietnam on fragmented forest associated with limestone hills (Boonratana & Le, 1998a; Fooden, 1996; Groves, 2001; Pham, 2002; Ratajszczak et al., 1990). *Trachypithecus delacouri* is currently found at nineteen fragmented locations in three provinces: Ninh Binh, Thanh Hoa, Hoa Binh (Groves, 2001; Nadler et al., 2003; Pham, 2002).

1.3. Studies on ecology and behavior

The colobines have received less attention than other species of primates in the past because of ecological differences, difficulties of observing monkeys in the dense vegetation of rain forests, and political and practical problems (Oates et al., 1994; Struhsaker, 1969).

Detailed studies of the ecology and behavior of colobines really began in the 1970s. Examples include Clutton-Brock (1974;1975) on *Ptilocolobus tephrosceles*, in Gombe NP; Struhsaker (1974;1975) on the same species in Kibale NP; Oates (1977) on *Colobus guereza* at various sites East Africa; Hladik (1977) on *Trachypithecus vetulus* and *Semnopithecus priam* in Sri Lanka; and several other studies on *Semnopithecus* spp. Early attempts were made to investigate relationships among social organization and behavior, ranging behavior, feeding behavior, and ecology; how they are interrelated; and what are the functional significances for adaptation and evolution. Here, I briefly review some critical results of these works related to my study; they can be summarized as follows.

1.3.1. Social organization

To date, the social organization of most colobines has been recognized as comprising one-male units and multi-male groups. Extra males often form all-male units (Eisenberg et al., 1972; Kirkpatrick, 1999; Newton & Dunbar, 1994; Rawson, 2009; Struhsaker & Leland, 1987; Yeager & Kool, 2000). One-male units (OMUs) consist of one adult male, several adult females and their offspring. Examples are Proboscis Monkey *Nasalis larvatus* (Boonratana, 1993; Yeager, 1990) and Capped langur *Trachypithecus pileatus* (Stanford, 1991b); Black-shanked Douc *Pygathrix nigripes* (Rawson, 2009). Multi-male units comprise two or more males, many females, and many immatures (Eisenberg et al., 1972; Kirkpatrick, 1999). Examples are Ugandan Red Colobus *Ptilocolobus tephrosceles* (Struhsaker, 1975) and Dusky leaf monkey *Trachypithecus obscurus* (Aggimarangsee, 2004; Curtin, 1980). Exceptions have been reported for *Presbytis potenziani* and *Simias concolor*, which in some localities, at least, live in monogamous groups (Watanabe, 1981). These structures can vary both within species and across species, and sites. For instance, Banded leaf monkeys (*Presbytis femoralis*) show both OMUs and multi-male units in Krau Game Reserve in western Malaysia (Mackinnon & Mackinnon, 1980; Curtin, 1980, respectively) and OMUs in other parts of Malaysia (Bernstein, 1968). In some species, they display a great flexibility in social organization: fission and fusion. For example, *Nasalis larvatus*' social organization is a relatively stable one-male unit, and extra males form all-male units (AMUs); these groups frequently come together at sleeping sites and exhibit a secondary level of social organization, the band (Bennett & Sebastian, 1988; Boonratana, 1993). The most likely explanation of these variations in social organization is a variety of environmental factors such as habitat, food resources, predators, competitors and population density, and phylogeny (Clutton-Brock & Harvey, 1977; Eisenberg et al., 1972; Struhsaker, 1969; Wrangham, 1987).

Among colobines, group size is highly variable both within species and across species. For example, Mentawai leaf-monkeys live in small groups of fewer than four animals (Newton & Dunbar, 1994), whereas Golden snub-nosed monkeys form large troops of more than 400 animals (Bleisch & Xie, 1998); Red colobus in the Kibale Forest live in large groups of 50 individuals, while their group size is about half of that in Senegal-Gambia and on the Tana River, Kenya (Struhsaker, 1975). Group size of colobines can be regulated by a number of ecological and social factors, such as food availability, intra and intergroup competition, predators, infanticide risk, and phylogeny (Clutton-Brock & Harvey, 1977; Chapman & Chapman, 2000; Chapman & Pavelka, 2005; Gillespie & Chapman, 2001; Isbell, 1991; Janson & Goldsmith, 1995; Steenbeek & van Schaik, 2001; Terborgh & Janson, 1986; Wrangham et al., 1993) and feeding competition (*Pygathrix nemaeus*, Phiapalath et al. 2011). For example, comparative study by Chapman and Chapman (2000) suggested that group sizes of Red colobus and Red-tailed guenons appear to be larger in areas where food resources are abundant. They also noted that the effect of increasing group sizes in the two species is to reduce predation risk or to increase effectiveness in intergroup competition; but at the same time, an increase in group size will increase intragroup feeding competition. Larger groups have to travel further to search for adequate food supplies, and may be more prone to predation risks (foraging costs over foraging benefits), thereby setting an upper limit to group size (Gillespie & Chapman, 2001; Isbell, 1991; Janson & Goldsmith, 1995).

1.3.2. Social behavior

Agonistic interactions have been reported to be less frequent in colobines than cercopithecines (Newton & Dunbar, 1994; Struhsaker & Leland, 1987). When they do occur, they usually involve male-male aggression during copulation and intergroup encounters (Struhsaker & Leland, 1987; Yeager & Kool, 2000) and in some cases,

agonistic interactions were as a result of predation threats and displacement from sleeping sites (*Nasalis larvatus*, Matsuda et al. 2012). For example, Struhsaker (1975) found no aggressive interactions either within or between groups of *Ptilocolobus tephrosceles*. Similarly, members of *Nasalis larvatus* groups spent only 0.8% of their time in agonistic interactions, and about 30% of this was devoted to intergroup interactions and most involved males' aggression towards other groups (Boonratana, 1993). There are some possible explanations for these differences. McKenna (1979) suggested that, unlike cercopithecines, the possession by members of the Colobinae of specialized digestive systems that permit them to digest leaves, which are relatively abundant and evenly distributed, may reduce intragroup feeding competition. Recent work, however, has found that colobines are actually highly selective feeders, and in some species, such as *Trachypithecus pileatus* (Stanford, 1991a) and *Semnopithecus priam* (Hladik, 1977), seeds and fruits, which were often clumped, scattered and seasonal, were also consumed. Thus, the presence of cheek pouches in cercopithecines may be an answer to higher levels of feeding competition (McKenna, 1979). Dominance hierarchies among females within groups are either weak or not obvious (Newton & Dunbar, 1994; Struhsaker & Leland, 1987). The lack of status differences between females within groups may correlate with allomothering behavior (McKenna, 1979).

Social grooming among colobines has been recognized as a "female affair". Males are rarely involved (Struhsaker & Leland, 1987; Kirkpatrick, 2007); when they are, it is generally directed to adult females (Struhsaker & Leland, 1987). For example, allogrooming accounted for ca. 3% of *Nasalis larvatus*' total activity time, of which 65% involved female groomers, and adult males did not involve themselves in this behavior (Boonratana, 1993). Asian colobines are characterized as an "unsocial lot". Social grooming makes up an average of no more than 2% of their total time (Kirkpatrick, 2007).

Allomothering behavior has been reported in most colobines (McKenna, 1979; Newton & Dunbar, 1994; Yeager & Kool, 2000). Juveniles and adult females are often involved in this behavior. Possible functional explanations for this behavior are providing more feeding time for mothers (Poirier, 1968), increasing the probability of an infant's adoption if its mother should die or become disabled (Lancaster, 1971), improving maternal skills for allomothers by handling infants and thereby enhancing the likelihood of survival of her own future infants (Hrdy, 1977), and reducing feeding competition for allomothers' offspring by abusive handlers (Waser & Barash, 1981).

Copulations initiated by females have been documented among colobines, especially Asian colobines (Kirkpatrick, 2007; Newton & Dunbar, 1994; Yeager & Kool, 2000). Exceptions are western red colobus (*Ptilocolobus badius*), olive colobus (*Procolobus verus*) and western black-and-white colobus (*Colobus polykomos*) (Newton & Dunbar, 1994). Females display some behavioral patterns during solicitation, such as "head shake" in *S. entellus* (Hrdy, 1977) and "crouch" in *R. roxellana* (Ren et al., 1991; 1995).

Birth and copulation seasons have also been found in some colobines (*Semnopithecus* spp., Borries et al., 1999; *Trachypithecus vetulus*, Rudran, 1973; *Trachypithecus pileatus*, Stanford, 1991b) and may last for 2-6 months (Kirkpatrick, 2007). Factors that control birth and copulation seasons remain poorly documented. Rudran (1973) and Ziegler et al. (2000) suggested that food quality and availability may regulate birth and breeding seasons of the two langurs which they studied, *Trachypithecus vetulus* and *Semnopithecus priam*, respectively.

1.3.3. Range use

Ranging behavior varies both within and between species. For example, range defense occurs in some species (*Colobus guereza*, Marler, 1969; Oates, 1977; *Presbytis thomasi*, Gurmaya, 1986), while others show range overlap (*Semnopithecus entellus*, Dolhinow,

1972; *Trachypithecus pileatus*, Stanford, 1991b). Home range size ranges from 2.5ha for *Trachypithecus vetulus* to more than 100 ha for Uganda Red colobus *Ptilocolobus tephrosceles* (Struhsaker and Leland, 1987). Day range length varies between 200m for *Trachypithecus cristatus* (Bernstein, 1968) and 2950m for *Rhinopithecus bieti* (Kirkpatrick, 1996).

Home range and day range length, it has been proposed, is influenced by group size and availability of food resources (Clutton-Brock & Harvey, 1977; Gillespie & Chapman, 2001; Terborgh & Janson, 1986; Wrangham et al., 1993). Day range length and home range are positively related to group size. Larger groups have greater home ranges and longer day ranges than smaller groups, since larger groups can deplete food patches more quickly than small groups, forcing the groups to travel over larger areas to achieve enough food for all members (Clutton-Brock & Harvey, 1977; Gillespie & Chapman, 2001; Terborgh & Janson, 1986; Wrangham et al., 1993). For example, maximum home range and mean day range of a large group (48 individuals) of Red Colobus (*Ptilocolobus tephrosceles*) at Kibale NP, Uganda reached at 12.9ha and 770m, respectively, whereas these Figures were about 3.1ha and 463.8m, respectively in a small group (24 individuals) (Gillespie & Chapman, 2001).

In contrast, Isbell (1991), Steenbeek and van Schaik (2001) and Struhsaker and Leland (1987) found no relationship between group size and day range length. Isbell (1991) argued that day range lengths are affected by the distribution and abundance of food resources and may be determined by a trade-off between the energetic benefits of obtaining food and the energetic costs of moving from one food site to another. Larger groups have to travel farther and visit more unfamiliar food areas, increasing the risk of predation and energetic costs. Instead of increased day range length, larger groups widen their travel path (Isbell, 1991) or feed on more of the same food (Steenbeek &

van Schaik, 2001). Chapman and Chapman (2000) found a similar result in Red colobus (*Piliocolobus tephrosceles*). They postulated that larger groups appear to occur in areas with a high density of potential food resources where food intake per individual remains the same regardless group size, thereby retaining constant travel distance. Thus, it is the distribution and availability of food resources which would appear to have the most important influence on day range length. For instance, *Presbytis rubicunda* traveled farther on the days when they were feeding on seeds, and the distance decreased on the days when the diet was based on young or mature leaves (Davies, 1984).

1.3.4. Feeding ecology

Members of the Colobinae exhibit a number of anatomical adaptations associated with leaf-eating. These include sharp crests and high cusps on the molars which allow them to cut leaves; enlarged salivary glands that help to reduce the acidity of the forestomach fluid; and the ruminant-like forestomach with bacterial microflora that enable them to utilise cellulose and hemicellulose and probably neutralize plant secondary compounds (Chivers & Hladik, 1980; Kay & Davies, 1994). These adaptations have the potential to profoundly influence social organization and behavior, population density, and ranging behavior (Chivers & Hladik, 1980; Yeager & Kool, 2000). For example, folivores appear to have smaller home ranges and shorter day range lengths than frugivores; arboreal folivores have some of the highest densities among primates (Clutton-Brock & Harvey, 1977).

The proportion of time spent feeding on leaves in colobines varies both within and between species. *Nasalis larvatus*' diet comprised 73% leaves at Sukau, whereas the figure was only 50% at Abai (Boonratana, 1994); about 77% of *Colobus guereza*'s diet at Kibale consisted of leaves (Oates, 1977), while leaves made up only 30% in the diet of *Presbytis femoralis* (Bennett, 1983). Among leaves, young leaves appear to account

for a greater proportion of most colobines' diet than mature leaves. For example, of the 65% leaves consumed by *Presbytis comata* at Kamojang, young leaves made up 59% (Ruhayat, 1983); similarly, 70% young leaves in the 52% of total dietary leaves was consumed by *Nasalis larvatus* at Tanjung Puting (Yeager, 1989); and 60% young leaves in the 79% foliage was eaten by *Trachypithecus delacouri* at Van Long (Workman, 2010). These differences can probably be explained by the digestibility of food items. Young leaves tend to be more readily digested and of higher nutrient quality than mature leaves, reducing the cost of food digestion (Kay & Davies, 1994; Waterman & Kool, 1994).

1.3.5. Diversity of diet

Although the colobine digestive system is adapted to leaf consumption, calling them "leaf-eaters" does not reflect their diversity of diets, especially in the case of Asian colobines. Apart from leaves, colobines are able to digest a variety of food items, including fruits, seeds, flowers, lichens, bark, insects and others. For example, annual diets of *Trachypithecus johnii* at Kakachi consisted of leaves (55%), seeds and fruits (25%), flowers and flower buds (9%), buds (9%), and stem or bark (1%) (Oates et al., 1980); *Semnopithecus entellus* in Kanha Tiger Reserve consumed 35% of mature leaves, 24% of fruits, 11% of leaf buds, 10% of flowers and flower buds, 4% of young leaves, 3% of insects, and gum (1%) (Newton, 1992); *Trachypithecus delacouri* in Van Long Nature Reserve ate trees and shrubs (45%), climbers (53%), and herb (2%) (Workman, 2010). Such ability allows Asian colobines to inhabit a wide variety of habitats and to respond to seasonal changes in those habitats (Kirkpatrick, 2007).

1.3.6. Seasonality

Seasonality has a pronounced impact on the diets of colobines, especially among Asian colobines whose habitats are often highly seasonal (Bennett & Davies, 1994;

Kirkpatrick, 2007). The proportion of time feeding on food items varies between seasons and corresponds to food availability and the animals' preference (Davies, 1984; Davies et al., 1988). For example, *Presbytis rubicunda* in Sabah consumed over 70% seeds in the diet from July to September, coinciding with when seeds of leguminous lianas were available, and about 40% of young leaves between November and May (Davies, 1984); *Presbytis femoralis* at Kuala Lompat fed heavily on fruits and seeds (90%) from June to July, followed by flowers (55%) in May, and the rest of year they fed on young leaves (40%). Both these species appeared to increase their dietary diversity when fruits and seeds were scarce and to be more specialised during the fruit and seed season (Bennett, 1983).

1.3.7. Selective feeders

Although colobines possess an enormous capacity for digesting a diversity of different plants and plant parts, they are in fact highly selective feeders (Davies et al., 1988; Kool, 1993; Oates et al., 1980). Leaves, fruits, seeds and other plant parts contain not only nutrients but defensive chemicals including digestion inhibitors (lignin, tannin) and toxins (phenolics, pyrrolizidine alkaloids) that interfere with digestive processes (Waterman & Kool, 1994). Thus, colobines must select for foods of high nutrient quality and low digestion-inhibiting compounds (Kool, 1992; Yeager & Kool, 2000), and the degree of selection varies between species and sites. For example, *Presbytis femoralis* in Krau Game Reserve and *Presbytis rubicunda* in the Sepilok Virgin Jungle Reserve tended to eat foods of high digestibility and high levels of protein, and seeds and fruits with high concentrations of storage carbohydrates or fats (Davies et al., 1988). The latter, however, is more selective than the former. Annual diets of *Presbytis rubicunda* consisted of only 6% of the five commonest tree families, which made up 83% of the basal area at Sepilok, whereas the five commonest tree families, which

accounted for 49% of the basal area at Krau Game Reserve, contributed 46% of *Presbytis femoralis*' annual diet (Davies et al., 1988).

1.4. Summary

The colobines or leaf-eating monkeys are different from cercopithecines in many aspects of their anatomy and morphology, and this greatly influences their feeding strategies and social behavior. These adaptations, it has been argued, have a profound influence on social organization and behavior, population density, and ranging behavior. Social organization in most colobines has been shown to comprise one-male and multimale units. Extra males form all-male units. Colobines exhibit dietary diversity, especially Asian colobines. Their diets are not restricted to leaf-eating but they consume a variety of food types such as fruits, seeds, barks, lichens and other items. Food availability and distribution, day range length and home range are interrelated.

Chapter 2

Introduction to genus *Rhinopithecus*

2.1. Introduction

Genus *Rhinopithecus* has five species, of which four are found in China (*Rhinopithecus roxellana*, *Rhinopithecus bieti*, *Rhinopithecus brelichi*, Groves, 2001) and one in Vietnam (*Rhinopithecus avunculus*, Groves, 2001), and one is new described from Myanmar (*Rhinopithecus strykeri*, Geissmann et al., 2010). Compared with other species in the subfamily Colobinae, the ecology and behavior of the snub-nosed group are comparatively poorly known, especially *R. avunculus*.

The Tonkin snub-nosed monkey is a slender-bodied, sexually dimorphic, arboreal primate, endemic to northern Vietnam, and is Critically Endangered (IUCN, 2010). It remains relatively unstudied in comparison with the other members of the genus, the only in-depth information being from Boonratana and Le' s six-month preliminary study at Na Hang NR. This thesis represents the first long-term study of its ecology and behavior. The primary goal is to elucidate information on the species' social organization and behavior, feeding ecology, and habitat. The information gathered will result in conservation and management recommendations for the species and its habitats.

In this chapter I attempt to briefly review the genus *Rhinopithecus* and my study species (*R. avunculus*) with regard to taxonomy, distribution, description, conservation issues, and ecology and behavior, before describing the specific aims of the study.

2.2. Snub-nosed monkeys, *Rhinopithecus*

The taxonomy of the snub-nosed langurs has been in dispute for several decades. Groves (1970; 1989) and Napier (1985), for example, placed the snub-nosed group as a subgenus of *Pygathrix*, but phylogenetic analysis of "odd-nosed monkeys" has indicated

that *Pygathrix* and *Rhinopithecus* are distinct, and probably not sister-groups, and should be recognized as two separate genera (Jablonski, 1995; 1998; Jablonski & Peng, 1993). Different views on the taxonomy of the snub-nosed monkeys can be attributed to several reasons: lack of study animals in captive breeding and museum collections, difficulties of study sites, and political and practical problems (Jablonski, 1998; Jablonski & Peng, 1993). Recent work by Groves (2001) suggested that the snub-nosed group comprises four species as follows: the Golden snub-nosed monkey, *R. roxellana*; Black snub-nosed monkey, *R. bieti*, Grey snub-nosed monkey, *R. brelichi*; and Tonkin snub-nosed langur, *R. avunculus*. A completely new snub-nosed species (*R. strykeri*) has been recently described in Myanmar (Geissmann et al., 2010).

The first three species inhabit temperate forests at high altitudes in southern China (Bleisch et al., 1993; Groves, 2001; Kirkpatrick, 1998): *R. brelichi*: 1500-2200m; *R. roxellana*: 1500-3300m; *R. bieti*: 3300-4500m, Kirkpatrick, 1995). *R. strykeri* is likewise found in Cool Temperate Rain Forest, Mixed Temperate Forest, and Silver Fir Forest at elevations of 2745–3660m (Geissmann et al., 2010). *R. avunculus*, however, is restricted found in tropical forests, ranging in elevation from 200m to 1200m (Boonratana & Le, 1994, 1998a; Groves, 2001; Kirkpatrick, 1995; 1998; Le & Boonratana, 2006; Napier & Napier, 1967; Ratajszczak et al., 1990).

2.3. Studies on ecology and behavior of Chinese snub-nosed monkeys

The ecology and behavior of the Chinese snub-nosed monkeys, which live at high altitudes and in temperate forests with highly seasonal climates, have been relatively well documented. Habitats range from mixed deciduous and evergreen broadleaf forest (*R. brelichi*, Bleisch et al., 1993) to deciduous and evergreen broadleaf coniferous forest (*R. roxellana*, Li et al., 2002) to mixed coniferous forest and broadleaf forest (*R. bieti*, Long et al., 1994; Ding & Zhao, 2004). These features influence the ecology and behavior of the three species of *Rhinopithecus* in China.

2.3.1. Social organization

Social organizations of Chinese snub-nosed monkeys are similar to those of some other colobines. Although there are some debates surrounding social organization within the bands of the three Chinese species, subunits have been recognized to exist within the bands (Bleisch & Xie, 1998; Bleisch et al., 1993; Ding & Zhao, 2004; Kirkpatrick, 1996; Kirkpatrick et al., 1998; Ren et al., 1998; Tan et al., 2007; Zhang et al., 2006). Kirkpatrick (1998) suggested that the social organization of snub-nosed monkeys is multi-tiered: the bands contain sub units which are probably either one-male, multi-male, multi-female, and all-male units (Kirkpatrick, 1996; Kirkpatrick et al., 1998) or only OMUs and AMUs (Bleisch & Xie, 1998; Bleisch et al., 1993; Ren et al., 1998; Tan et al., 2007).

The social organization of subunits within bands may vary both within and between species. For example, social organization within the bands of *R. roxellana* at Shennongjia (Bleisch & Xie, 1998; Bleisch et al., 1993) and Zhouzhi (Tan et al., 2007), and *R. brelichi* at Fanjing Shan (Ren et al., 1998) consists of OMUs and AMUs. At other sites, one-male and multi-male, multi-female units have been described as coexisting within the band of *R. bieti* at Wuyapiya (Kirkpatrick, 1996; Kirkpatrick et al., 1998) and at Dequin (Cui et al., 2008), and *R. roxellana* at Baihe (Kirkpatrick et al., 1999). In addition, all male or "bachelor" units comprising adult and subadult males (Bleisch & Xie, 1998) and juveniles (Kirkpatrick, 1996; Kirkpatrick et al., 1998; Kirkpatrick et al., 1999; Ren et al., 1998) are found on the periphery of the bands in the three species. These one-male, multi-male, multi-female and all-male units aggregate into large bands for traveling, foraging, resting and sleeping (Bleisch & Xie, 1998; Bleisch et al., 1993; Kirkpatrick, 1996; Kirkpatrick et al., 1998; Ren et al., 1998).

The average sizes of OMUs and bands varies among species. Mean size of OMUs of *R. roxellana* at Shennongjia is 12 (Ren et al., 1998), whereas this figure is six for *R. brelichi* at Fanjing Shan (Bleisch & Xie, 1998). Band size ranges from 19 individuals at Laojunshan (*R. bieti*, Bai et al., 1988) to 430 individuals at Fanjing (*R. brelichi*, Bleisch & Xie, 1998), and to 600 individuals at Choushuigou (*R. roxellana*, Hu et al., cited in Kirkpatrick, 1998). The reasons why snub-nosed monkeys form large bands remain unclear. Bleisch and Xie (1998) attempted to explain this phenomenon for *R. brelichi* based on the presumed adaptive significance of large groups in contexts such as food availability and utilization, antipredator strategy, infanticide risk, intergroup competition, thermal regulation and food information sharing. Of all concerns, food availability and information sharing seem most likely. Patches of food resource size at Fanjing Shan are probably large enough to support large bands, and individuals in large bands may benefit from each other in terms of increasing chances of finding high quality of food patches or decreasing the risk of entering already depleted food patches (Bleisch & Xie, 1998).

In another attempt to explain why *Rhinopithecus* form large bands and show fission and fusion, Kirkpatrick (1998) suggested that forming large bands in *Rhinopithecus* is probably a result of predation, spatial distribution of food resource, and travel logistics. He pointed out that large groups can be formed under even slight predation pressure, if the cost of grouping is low with regard to food competition (also see Wrangham, 1987). For example, the hesitation of *R. bieti* before crossing gullies terrestrially and before moving above the tree line may be an antipredator strategy (Kirkpatrick, 1996; Kirkpatrick & Long, 1994). Kirkpatrick also noted that Hamilton's (1971) model of the selfish herd may be a key to understanding fission and fusion in the genus. This model stated that an individual lowers its chance of being a potential victim by joining the largest possible pool of potential victims (Hamilton, 1971). Grueter (2009) suggested

that fission in *R. bieti* in Samage Forest may result from increasingly patchy distribution of valued food resources such as winter fruits. This is a strategy to increase the efficiency of resource use in times of overall food scarcity.

2.3.2. Social behavior

Interactions between bands of Chinese snub-nosed monkeys vary between species and are little described. For example, bands of *R. brelichi* have home range overlaps and no aggressive inter-band encounters or displacement are recorded (Bleisch & Xie, 1998), while *Rhinopithecus bieti* at Wuyapiya seem to live in a single cohesive band, and there is no evidence of overlap between the range of the Wuyapiya band and any other *R. bieti* bands (Kirkpatrick, 1996; Kirkpatrick et al., 1998).

The degree of band cohesion is variable between species. For example, while the bands of *R. bieti* at Wuyapiya and at Mt. Fuhe are cohesive (Kirkpatrick, 1996; Kirkpatrick et al., 1998; Liu & Zhao, 2004), those of *R. brelichi* and *R. roxellana* are semicohesive and often split up or coalesce to form larger bands (Bleisch & Xie, 1998; Bleisch et al., 1993; Ren et al., 1998).

Interactions between subunits within bands remain relatively unstudied. In general, subunits in none of the three species appear to show territorial behavior since they often come together to travel, feed, rest, and sleep (Bleisch & Xie, 1998; Bleisch et al., 1993; Kirkpatrick, 1996; Kirkpatrick et al., 1998; Ren et al., 1998). Agonistic interactions, involving male-male aggression, have been reported for wild population of *R. bieti* at Wuyapiya (Kirkpatrick, 1996). Females in *R. roxellana* had more social interactions with unit members than with nonunit individuals and female transfer sometimes occurred (Zhang et al., 2008)

Social grooming in Chinese *Rhinopithecus* is high, compared with other colobines (Kirkpatrick, 1998). Grooming occupies 6.7% of total activity in *R. roxellana* in Qinling in autumn and winter (Li et al., 2004); grooming in *R. bieti* at Wuyapiya accounts for 6.1% of total activity, most occurring between adult females (Kirkpatrick, 1996).

Alloparental care has been found in *R. bieti* (Ding, as cited in Gruter, 2003; Gruter, 2003; Grueter, 2009; Kirkpatrick, 1996) and *R. roxellana* (Hu, as cited in Gruter, 2003; Zhu et al., 1994). Age/sex involvement in this behavior varies between species and sites. For example, while only juveniles of *R. bieti* at Wuyapiya have been observed to provide alloparental care (Kirkpatrick, 1996), it is adult males of *R. bieti* at Tacheng who provide alloparental care (Ding, as cited in Gruter, 2003; Gruter, 2003).

A mating season has been reported both in wild and captive populations of *R. bieti* and *R. roxellana*. The wild population of *R. bieti* at Wuyapiya appears to have a mating season between August and September, and birth season is from March to April (Kirkpatrick, 1996). The mating season of *R. roxellana* in captivity is around October and the birth season is from March to June (Zhang et al., 2000) and March to May (Qui et al., 2008). Similarly, *R. brelichi* concentrated their birth season between March and May. The mean interbirth interval was slightly different between *R. brelichi* and *R. roxellana* (38.2 ± 4.4 , Yang et al., 2009 and 21.88 ± 6.01 months, Qui et al., 2008, respectively)

2.3.3. Feeding ecology

Chinese snub-nosed monkeys show great diversity and considerable seasonal changes in their dietary habits. They feed on leaves, leaf petioles, fruits and seeds, buds, and insect larvae (*R. brelichi*, Bleisch & Xie, 1998; Bleisch et al., 1993); leaves, fruits, buds, barks, bamboo leaves and lichens (*R. bieti*, Kirkpatrick, 1996; Ding & Zhao, 2004; Yang,

2003; Yang & Zhao, 2001); leaves, buds, flowers, fruits, seeds, barks, lichens, and insects (*R. roxellana*, Li, 2001; Li, 2006).

Diet is highly variable between seasons. For example, *R. roxellana*'s diet shifts from lichens (51%), buds and bark (43%) in winter to leaves (90%) and lichens (8%) in summer (Kirkpatrick, 1999), and to fruits or seeds in autumn (Li, 2006). Similarly, *R. brelichi* change their diet from buds (Jan-Mar, 90% of feeding records) to leaves (Apr-Jun, 93% of feeding records), and to leaves and fruits (including seeds) (Jul-Sep, 58% and 35% of feeding records, respectively) (Bleisch & Xie, 1998). An exception is *R. bieti* at Wuyapiya, whose diets appear to remain stable throughout the year, primarily consuming lichens (*Bryoria* spp: 79% of all feeding records, Kirkpatrick, 1996; Kirkpatrick, 1998; Kirkpatrick et al., 1998). One possible explanation for these variations is food availability. Li (2006) documented that lichens and buds are available throughout the year at Shennongjia, while other items are seasonal. Leaves, fruits, seeds, and flowers are either relatively low or not available during winter season, forcing *R. roxellana* in this region to feed heavily on lichens and buds to supply their energy requirements.

Relative to other colobines, Chinese snub-nosed monkeys are highly selective; their diets depend on very few species at a given time of year. For example, *R. brelichi* at Fanjiing favoured from four to five species in each season: leaves of *Parumus vaniotii*, leaf buds and leaves of *Ficus* spp., and fruit and seeds of *Dendrobenthamia agustana* (Bleisch & Xie, 1998). Of 23 plant species eaten by *R. roxellana* at Shennongjia, only 10 broadleaf deciduous tree species and lichens on nine tree species are their preferred foods (Li, 2006).

2.3.4. Range use

Compared with other colobines, the home range of Chinese snub-nosed monkeys is characterized by large size. It ranges from over 10km² (*R. brelichi* at Fanjing, Bleisch et al., 1993) to 16.25km² (*R. bieti* at Wuyapiya, Kirkpatrick et al., 1998), and to 18.3 and 40km² (*R. roxellana* at Shennongjia, Su et al., 1998 and at Zhouzhi, Tan et al., 2007). The large home range of Chinese snub-nosed monkeys may result from their large body size and group size (Li et al., 2000), and the distribution and abundance of food resources (Bleisch et al., 1993; Bleisch & Xie, 1998; Kirkpatrick et al., 1998; Li et al., 2000). Thus, *R. brelichi* lives in large bands, reaching 430 animals, and their dietary diversity is highly seasonal and patchily clumped (Bleisch & Xie, 1998).

Seasonal patterns of home range use have been documented in Chinese snub-nosed monkeys and seem to be driven by feeding ecology (Kirkpatrick & Long, 1994; Li et al., 2000). For example, the band of *R. roxellana* in the Qinling appears to have the largest home range in spring (14.1km²), coinciding with when buds and tender leaves are available, followed by winter and autumn (12.3 and 12.1km², respectively), and smallest in summer (9.5km²) coinciding with when leaves are available in large quantities (Li et al., 2000). He also noted that the home ranges overlap considerably between seasons: between spring and winter there is 92.4% overlap (12.2km²), and 71.6% between autumn and summer (Li et al., 2000), and although they tend to prefer deciduous broadleaf forest, this accounted for 82.6% of the range in winter and spring and 76.5% in autumn, but and only 40.5% in summer (Li et al., 2000).

Seasonal altitudinal migration has been reported for *R. roxellana* at Wolong, favoring higher altitudes in summer and lower altitudes in winter (Hu et al., cited in Kirkpatrick, 1998). However, there was no evidence supporting this report in Zhouzhi (Tan et al., 2007). Kirkpatrick (1996) and Kirkpatrick et al. (1998) found no significant relationship

between the band's altitude and ambient temperature in *R. bieti* at Wuyapiya; This species uses high altitudes throughout the year probably because of the greater density of lichens at higher altitudes (Kirkpatrick, 1996). In contrast, the same species at Jinsichang shows a positive correlation between altitude and seasonal temperatures; here, the distribution of food resources may regulate altitudinal ranging patterns (Yang, 2003).

2.3.5. Day range length

Compared to other colobines, Chinese snub-nosed monkeys have longer day ranges. Mean day range length of *R. bieti* at Wuyapiya varies between 810m and 2080m (Kirkpatrick, 1996; Kirkpatrick et al., 1998), and that of *R. roxellana* at Shennongjia ranges from 690m to 1900m (Su et al., 1998) and 750m to 5000m at Zhouzhi (Tan et al., 2007). Su et al. (1998) found no relationship between day range length and group size in this area. Long day ranges in *R. bieti* may result from their food habits; lichens, the primary food of *R. bieti*, offer a readily digestible energy supply, and this may allow them to travel farther than other colobines whose day range distance is relatively more constrained by energetics (Kirkpatrick, 1996).

There are variations in day range length between seasons. For example, *R. roxellana* at Shennongjia (Su et al., 1998) and *R. bieti* at Wuyapiya (Kirkpatrick, 1996; Kirkpatrick et al., 1998) have shorter daily ranges in winter months than summer months; *R. roxellana* at Yuhuangmiao traveled farthest in autumn months coinciding with when fruits are available, and least in winter months when food resources are scarce (Li et al., 2000). Thus, energetic costs and food availability (Kirkpatrick, 1996) and food distribution and abundance (Li et al., 2000; Tan et al., 2007) may regulate day range length in Chinese snub-nosed monkeys.

2.3.6. Terrestriality

Although there have been debates in the earlier literature, terrestriality has been reported for all three species in China more recently (*R. bieti*, Kirkpatrick, 1996; Kirkpatrick & Long, 1994; Kirkpatrick et al., 1998; Long et al., 1998; Wu, 1993; Zhao et al., 1988; *R. roxellana*, Ren et al., 2001; Li et al., 2000; Su et al., 1998; *R. brelichi*, Bleisch et al., 1993). Terrestriality is involved in crossing open areas, resting and feeding activities (Bleisch et al., 1993; Kirkpatrick, 1996; Long et al., 1998; Su et al., 1998; Wu, 1993). Obtaining accurate data on terrestriality is difficult since observations were made from a long distance (Kirkpatrick et al., 1998; Su et al., 1998). The proportion of time spent on the ground varies within and between species. *R. bieti* at Wuyapiya spent 22% of its time on the ground (Long et al., 1998), while at Yeri terrestriality: makes up 70% of the total activity of adults (Wu, 1993), *R. roxellana* at Zhouzhi spent 15.3% of its time on the ground (Ren et al., 2001), *R. brelichi* at Fanjing Shan spent "occasional periods" on the ground (Bleisch et al., 1993).

There is variation in terrestriality between months and between age/sex classes. For example, *R. bieti* at Wuyapuya spent 32% of its activity time on the ground in June, whereas terrestriality accounts for only 10% of its total time in December (Kirkpatrick et al., 1998). In *R. bieti* and *R. roxellana*, males spend more time on the ground than individuals in other age/sex classes (Kirkpatrick et al., 1998; Ren et al., 2001, respectively). For instance, males of *R. bieti* at Wuyapuya spend 43% of their time on the ground in May, while this figure is only 32% in females and 27% in juveniles (Kirkpatrick et al., 1998).

2.3.7. Locomotion

To date, little information on the locomotor and positional behavior of Chinese snub-nosed monkeys has been reported. In general, quadrupedal walking, climbing, leaping and jumping are found in all three species (*R. brelichi*, Bleisch et al., 1993; *R.*

roxellana, Su et al., 1998; *R. bieti*, Wu, 1993); Semibrachiation occurs in *R. brelichi* and *R. bieti* (Bleisch et al., 1993; Wu, 1993); full brachiation has been reported only in *R. brelichi* (Bleisch et al., 1993). Locomotor behavior varies considerably with ontogenetic stage. For example, arm-swinging is commonly used in juveniles of *R. bieti*, but disappears during the subadult and adult stage; leaping and jumping are found in juveniles and retained until adulthood (Wu, 1993); bipedal walking has been seen in juveniles of *R. bieti* and *R. roxellana* (Isler & Gruter, 2006; Su et al., 1998, respectively).

2.4. Tonkin snub-nosed monkey *Rhinopithecus avunculus*

2.4.1. Taxonomy and distribution

Rhinopithecus avunculus was first described by Dollman in 1912 based on 8 specimens collected in Yen Bai Province, and was later placed in its own genus *Presbytiscus* by Pocock (1924). Hence it has been variously known as *Presbytiscus avunculus* (Pocock, 1924; Thomas, 1928), *Pygathrix (Rhinopithecus) avunculus* (Groves, 1970; 1989; Napier, 1985; Oates et al., 1994; Thorington & Groves, 1970), *Rhinopithecus (Presbytiscus) avunculus* (Jablonski, 1998; Jablonski & Peng, 1993; Jablonski & Pan, 1995), and simply *Rhinopithecus avunculus* (Napier & Napier, 1967; Groves, 2001). *R. avunculus*, as suggested by Groves (2001), will be used throughout my study.

The Tonkin snub-nosed monkey is endemic to northern Vietnam. It was historically distributed throughout five provinces: Tuyen Quang, Cao Bang, Yen Bai, Bac Thai and Quang Ninh (Ministry of Science and Technology [MoST], 2000). More recent observations suggest that the species is restricted to Bac Kan (Separated from Bac Thai Province), Tuyen Quang, Quang Ninh and Thai Nguyen Provinces (Thai Nguyen separated from Bac Thai Province, MoST, 2007). An extension of distribution of *R. avunculus* was discovered in Ha Giang Province (La & Trinh, 2001; Le, 2001; Le & Simmons, 2002; Long & Le, 2001). As noted earlier, *R. avunculus*, unlike Chinese

snub-nosed monkeys, live in tropical forests (mixed broadleaf and bamboo forests), at relatively low elevations (Le & Boonratana, 2006). Its current range is limited to the fragmented forest patches associated with limestone hills, and is still dramatically declining in size (Boonratana & Le, 1994; 1998b; Le & Boonratana, 2006; Nadler et al., 2003; Pham, 2002; Ratajszczak et al., 1990; 1992). At the present time it is found only at Quan Ba and Khau Ca, Ha Giang Province (Le, 2004), and Cham Chu and Na Hang NR, Tuyen Quang Province (Dong, 2007). The detailed status and distribution of *R. avunculus* is presented in Chapter 6.

2.4.2. Description

The Tonkin snub-nosed monkey has the least sexual dimorphism among the members of the snub-nosed group (Jablonski & Pan, 1995). Average body mass of adult males is 14.8kg, with a head and body 65cm and tail 83cm in length, whereas adult females weigh an average of 7.8kg, with a head and body length of 52cm and tail 68cm (Pham, 1993). The nose is upturned and the tip reaches toward the forehead, although not as much as in *R. roxellana* (Boonratana & Le, 1994; 1998a; Le & Boonratana, 2006; Nadler et al., 2003; Napier & Napier, 1967; Pocock, 1924). The digits of the hands and feet are similar to those of *Pygathrix*, *Nasalis* and *Presbytis* (Groves, 1970), and are longer and more slender than those of other *Rhinopithecus* species (Pocock, 1924; Thomas, 1928; Napier & Napier, 1967).

Table 2.1. Measurement of *Rhinopithecus avunculus*

Measurement	Adult males (n=3)	Adult females (n=7)
Body length (mm)	658.33 (640-670)	520.00 (484-565)
Tail length (mm)	823.00 (820-850)	685.71 (660-725)
Hindlimb (mm)	217.67 (210-223)	173.29 (150-190)

Weight (g) 14866.67 (13000-16000) 7883.33 (7000-9000)

Reference: Pham (1993)

The species has short body hair (Dollman, 1912; Groves, 1970). Back and outer sides of limbs are black in adults, whereas inner sides of limbs, back of thighs and elbows are creamy-white (Boonratana and Le, 1994; 1998a; Dollman, 1912; Le & Boonratana, 2006; Napier & Napier, 1967). The fur on the forehead and face is also creamy-white. The face around the eyes is naked and is described as flesh-coloured (Dollman, 1912), pale bluish white (Groves, 1970), or pale blue in colour (Boonratana & Le, 1994; 1998a; Le & Boonratana, 2006); my description of the facial skin is similar to that by Groves (1970). Ears have creamy-white tufts arising from their inner sides (Dollman, 1912; Nadler et al., 2003). Lips are pink (Chaplin & Jablonski, 1998; Nadler et al., 2003), and very prominent. There is bluish black coloration around the mouth and an orange patch on the throat; these colours are outstanding in adult males (Boonratana and Le, 1994; 1998a; Dollman, 1912; Le & Boonratana, 2006; Napier & Napier, 1967). Two prominent buffy white patches lie on the rump on either side of the tail (Dollman, 1912; Nadler et al., 2003)

Tail is longer than head and body (Groves, 1970; Napier & Napier, 1967; Pham, 1993) and has a creamy-white tuft (Boonratana & Le, 1994; 1998a). The dorsal surface of the tail is black, whereas ventrally it is creamy-white. Strands of long creamy-white hairs, which are most prominent in the adult males, are clearly seen from the base to just above the tufted tip when viewed from the rear (Boonratana & Le, 1994; 1998a; Le & Boonratana, 2006).

Pelage of infants and young juveniles is grey in their back rather than black as in adults, inner sides of limbs and belly have white colour. The orange throat patch are absent in infants and lighter in juveniles. Strands of creamy-white hairs on their tails are absent.

The dark region around the mouth is also inconspicuous (Boonratana & Le, 1994; 1998a; Le & Boonratana, 2006).

2.4.3. Population and conservation status of *Rhinopithecus avunculus*

Population status

Estimates of the total population of *R. avunculus* have remained unclear and are largely based on local reports and short surveys. An exception is the estimation of a population of at least 130 animals in Na Hang NR by Boonratana and Le (1993). The highest estimate for the total population of *R. avunculus* in the 1990s is 350 (Cao & Pham, 1995). Further review by Nadler et al. (2003) estimated 307 individuals, with 95 to 135 animals in Na Hang NR (in two sub-populations), 30 to 70 in Cham Chu NR, and 21 to 50 in Du Gia NR. This last population, discovered by Le (2001), is not in fact in Du Gia but in Khau Ca HSCA near Du Gia (Dong & Boonratana, 2006; Le & Boonratana, 2006). The most recent estimate for total world population is 250 individuals according to Le & Boonratana (2006), although these authors noted that the actual population may be higher than this Figure since the possibility of the occurrence of the species at some provisionally recorded areas is likely.

It is evident that there is a downward trend for the global population of *R. avunculus*, and the Figure is possibly even lower than the actual estimate. Recent survey by Dong et al. (2006) at Cham Chu NR, for example, reported no sighting of *R. avunculus* during the course of forty-three field days, and the population is under high pressure from human activities. It is likely, however, according to local reports, that there is a small group of 8-12 individuals still living there. If this is the case, the Figure is considerably reduced since the early report by Long and Le (2001) (70 individuals) in the same area.

Conservation status

Much attention has been paid by both the Vietnamese government and international conservation communities to protect *R. avunculus* since Ratajszczack and his colleagues' rediscovery of a population of the species in Tuyen Quang in 1989.

At the national level, *R. avunculus* has been a fully protected species since 1994 under the Forest Resources Development and Protection Law, and is listed as Endangered in the Vietnam Red Data Book (2000), in Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) and in group IB of Decree No. 32/2006/ND/CP. A number of protected areas have been established primarily to protect the species, including Na Hang NR in 1994 and Cham Chu NR in 2001, and Khau Ca HSCA.

At the international level, it is currently listed as Critically Endangered in the IUCN's red list of threatened animals (IUCN, 2010), and as one of the top 25 critically endangered primates of the world (Le et al., 2009; Mittermeier et al., 2006). To take action, international conservation communities such as the World Wide Fund for Nature (WWF), Conservation International (CI), Primate Conservation Inc. (PCI), the International Union for the Conservation of Nature (IUCN), Fauna and Flora International (FFI), Munster Allwetter Zoo and others have provided both financial and technical support for the conservation of the species in Na Hang and Cham Chu NRs in Tuyen Quang Province, Ba Be NP in Bac Kan Province, and Khau Ca HSCA in Ha Giang Province.

In addition to law enforcement, both short surveys and long-term studies have been conducted to establish the population status of *R. avunculus*, and to better understand its ecology and behavior. The data gathered have assisted in developing conservation and management recommendations for the species and its habitats. Na Hang NR, for

instance, has been established and received enormous support from internal and external conservation organizations since Boonratana and Le's study in 1993; and FFI has been running field research and conservation awareness raising programs at Khau Ca HSCA where the new population of 55-60 individuals of *R. avunculus* was discovered by Le (2001).

Although conservation activities have been carried out in the langur's habitat, some have proved unsuccessful, and the population size of *R. avunculus* is still declining. Tat Ke Sector, Na Hang NR, for example, has been reported to be home to a population of 80 individuals (Boonratana & Le, 1994; 1998b) and hunting pressure has been claimed to have been successfully controlled (Le, 2003), but an eleven-month study by Dong (2007) reported that the best count for the population there is now 17 individuals (estimate 22) and hunting pressure is very high.

Threats

Hunting and habitat destruction are major threats to the survival of *R. avunculus* across its range (Boonratana & Le, 1994; 1998b; Cao & Pham, 1995; Dong, 2007; 2008; 2009a; Dong et al., 2006; Le & Boonratana, 2006; Long & Le, 2001; Nadler et al., 2003).

Hunting

Hunting has been a severe problem throughout the range of *R. avunculus* in the past, and remains so at the present. The use of guns is widespread and common. Surveys by Boonratana and Le (1994) in the vicinity of Na Hang NR estimated that every household owned at least one gun and probably more than one. Although gun confiscation and conservation programmes have been carried out in the range of *R. avunculus*, and some reduction in hunting has been successfully reported (Le, 2003), it is evident that hunting pressure is still high. For instance, on a daily basis, the survey

team would hear between five and seven gun shots in Tat Ke Sector (H.T. Dong, pers. obs., 2005) and from three to ten gun shots in Cham Chu NR (Dong et al., 2006). Further, groups of two to five hunters, and both old and recent huts, were encountered during surveys (Dong, 2007; 2009a).

R. avunculus meat has been known as “bad tasting” and it is not the target of the hunters, but they would nonetheless kill them whenever encountered (Boonratana & Le, 1994; 1998b; Dong et al., 2006). Meat of *R. avunculus* fried with ginger was used only for family consumption, and bones were made into traditional medicine called “Cao” (Dong et al., 2006). The latter product and other body parts such as liver are sold at the market or traded to China (Boonratana & Le, 1994; 1998b)

In addition to the use of guns, a variety of hunting tools, such as crossbows or stone and metal traps, were widely used to catch other wildlife, especially small mammals such as Masked Palm Civet (*Paguma larvata*), Hoary bamboo rats (*Rhizomys pruinosus*), Large bamboo rats (*Rhizomys sumatrensis*), Asiatic Brush-tailed porcupine (*Atherurus macrourus*), Noisy rats (*Leopoldamys sabanus*) and others (Boonratana & Le, 1994; 1998b; Dong et al., 2006). For example, about 200 traps were found in Tat Ke Sector, placed along animal trails and in rock crevices; of these, more than 50% were successful per night (Boonratana & Le, 1998b).

Habitat destruction

Human activities such as past legal and illegal logging, slash/burn and shifting cultivation, mining exploitation, non forest timber product collection and dam construction have remarkable impact on suitable habitats of *R. avunculus* and other wildlife.

Historically, intensive and unsustainable legal logging by forest enterprises were operated over almost the whole range of *R. avunculus*. Although there is no longer any

legal logging, the widespread occurrence of this practice in the past has meant that habitats available for *R. avunculus* have been reduced, fragmented, and degraded (Le & Boonratana, 2006; Nadler et al., 2003; Pham, 2002; Ratajszczak et al., 1990). Illegal logging is currently still continuing in some NRs, including Tat Ke Sector (Dong, 2007; 2009a), Ba Be NP (Dong, 2009b), Nam Xuan Lac HSCA (Dong, 2010), Than Sa-Phuong Hoang (Dong, 2010), and Cham Chu NR and (Dong et al., 2006).

Burning and shifting cultivation are a traditional practice of the ethnic minority groups living in and around the protected areas. Forests are replaced by orange farms and other crops such as rice, cassava and maize (Boonratana & Le, 1994; 1998b; Dong et al., 2006). This is considered wasteful and has considerable impact on the population of *R. avunculus* since some of the farms that have replaced forests tend to be used and abandoned every three years.

A variety of non timber forest products are collected by villagers. For instance, bamboo for making houses and household utensils; bamboo shoots for family consumption and sale; rattan for local use and sale; and a number of wild fruits, especially of *Dracontomelum dipreanum* and *Canarium album* (Boonratana & Le, 1994; 1998b). These products bring high income to local people. Each adult villager in Tat Ke Sector Na Hang NR, on average, earns from four to five million Vietnam dong (equal to US\$250-310) per bamboo season (H.T. Dong, pers. obs., 2005).

Mining has been reported to be a common activity at some of the known habitats of *R. avunculus* in the past. This has not only destroyed the forest, but increased demand for wildlife products (Boonratana & Le, 1994; 1998b; Nadler et al., 2003; Dang & Nguyen, 1999; Ratajszczak et al., 1992). Past gold mining operations in Na Hang NR is a case in point. In some areas where gold mines operated, clearings in the forest were as large as

100ha (Boonratana & Le, 1994; 1998b). Currently, mining exploitation is still operating in some areas adjoining the *R. avunculus* habitats. Gold mining was seen on Pac Van and Gam Rivers bordering Na Hang NR. Mining of zinc and aluminum based in the Lung Vay area, Minh Son commune (about two kilometers away from Khau Ca Forest), emits a number of very loud explosions everyday at noon and in the late afternoon (H.T. Dong, pers. obs., 2004-2006).

Dam construction

Another major concern for *Rhinopithecus avunculus* in Na Hang NR is the construction of a dam that began in 2002. First, the population of Na Hang was increased by 8,500 workers, resulting in increased demand for wildlife and other forest products (Le & Boonratana, 2006; Nadler et al., 2003, Mittermeier et al., 2006). Wild meat become available at Na Hang Town, most of this being consumed by workers (H.T. Dong, pers. obs., 2004-2006). Secondly, some parts of Na Hang NR along the Gam and Pac Van Rivers, amounting to about 220 hectares, have been or will be flooded by the Na Hang Hydropower Plant (Le & Boonratana, 2006; Nadler et al., 2003). Lastly, dam and road construction are increasing the accessibility of the reserve to human activities, and the increased noise may have negative impact on the population dynamics of *R. avunculus* and other wildlife, affecting breeding patterns and causing the animals to avoid preferred feeding areas (Nadler et al., 2003).

2.4.4. Studies on ecology and behavior of Tonkin snub-nosed monkey

The ecology and behavior of the Tonkin snub-nosed monkey is the least known among the snubnosed monkeys, and the species is poorly understood throughout most of its range. Details of social behavior, feeding behavior, locomotion, sleeping sites, home range and diet remain to be studied, although Boonratana and Le (1994; 1998a), Pham

(1993; 1994; 2002), Ratajszczak et al. (1992), and Nguyen (2000) all presented preliminary data.

Social organization of *R. avunculus* remains in dispute between authors. For example, Ratajszczak et al. (1990; 1992) and Le et al. (2006) reported that the basic social structure of *R. avunculus* consist of multi-male and multi-female units. In contrast, Boonratana and Le (1994; 1998a) and Dong and Boonratana (2006) postulated that the species lives in OMUs comprising a single full adult male, several adult females and young animals, and that extra males form loosely-bonded all-male units; they further reported that the species lives in a fission-fusion society with the different units frequently coming together to sleep, travel and feed. Possible explanations for these debates are that previous fieldwork has been conducted over short periods of time; assumptions are largely based on villagers' reports and "brief observations" (number of contact hours was not specified in the reports).

The size of one-male units in *R. avunculus* is reported to be similar to those of the Chinese taxa, and has been reported to range from 10 to 20 animals for one-male units at Na Hang (average: 14.8, Boonratana & Le, 1994). Band size however is said to be smaller than in Chinese species: in Khau Ca Forest ranging from 22 to 81 individuals (Dong & Boonratana, 2006), and between 23 and 72 animals at Na Hang (Boonratana & Le, 1998b). Bands of *R. avunculus* appeared to be less cohesive than Chinese snub-nosed monkeys, and subunits frequently coalesce or split up (Boonratana & Le, 1994; 1998a), although factors that drive fission and fusion in *R. avunculus* remain unclear. Kirkpatrick (1998) suggested that the tropical forests of *R. avunculus* are more heterogeneous and may hold smaller food patches than the subtropical and temperate forests of *R. roxellana* and *R. brelichi*, thereby allowing *R. avunculus* to break up into small units.

Behavior

Social behavior is poorly described. Grooming are said to be relatively high in *R. avunculus* at Na Hang (9.7%, Boonratana & Le, 1998a), compared with Chinese species (*R. bieti*, 6.1%, Kirkpatrick, 1996; *R. roxellana*, 6.7%, Li et al., 2004). Most of this involves allogrooming, and adult females are the groomers on all occasions (Boonratana & Le, 1998a). Playing, which made up 2.9%, was found only in juveniles and infants. Vigilance contributes to 23.3% of total activity.

Feeding ecology

Tonkin snub-nosed monkeys have been reported to feed on leaves, fruits and seeds (Boonratana & Le, 1998a; Pham, 1993; 1994; Ratajszczak et al., 1990), but the proportion of plant parts reported varies between authors. For example, Ratajszczak et al. (1990) stated that *R. avunculus* is folivorous, primarily consuming leaves. In contrast, based on direct observations (n=34 feeding observations), Boonratana and Le (1994; 1998a) documented that fruits and seeds accounted for 62% of feeding time, and 38% of leaves. Similarly, Pham (1994; 2002) suggested that *R. avunculus* rely heavily on fruits rather than leaves; for instance, of 61 species consumed, 52 species are fruit (63%) (Pham, 2002). These latter Figures are just based on local reports and six stomach examinations, and do not specify the number of direct observations.

There are some possible explanations for these differences. First, it is likely that different work has been conducted at different times of year. For example, Boonratana and Le (1993)'s study was carried out between September and February, while the survey by Ratajszczak et al. (1990) was from July to October. Second, information on the diet is largely based on local reports and brief observations, an exception being Boonratana and Le's six-month study in 1993. Lastly, although Pham (1994; 2002)

presented a list of plant parts eaten by *R. avunculus*, he did not provide the date and period of study, thereby making his data hard to compare with other reports.

Range use and day range

Home range of *R. avunculus* appears to be smaller than that of Chinese snub-nosed monkeys. Boonratana and Le (1994; 1998a) suggested that home range size for the population in Tat Ke sector seems to be at least 10km². Subunits of *R. avunculus* have considerable home range overlap.

Locomotion

Tonkin snub-nosed monkeys have been reported to be totally arboreal. Traveling accounted for 39.8% (n=82) of the total activity time. Quadrupedal walking, climbing and leaping were used to travel within trees, and leaping, arm-swinging, and brachiation were used to move between trees. Only adult males and females exhibited arm-swinging and brachiation (Boonratana & Le, 1994; 1998a).

Vocalization

Two types of vocalizations have been recorded to date. Adults and juveniles of *R. avunculus* display distinct and loud vocalizations "huu chhhk". The functions of these vocalizations can be alarm or contact calls, depending on given contexts. Continuous alarm calls were used when the monkey detected observers. During traveling, feeding and other activities, group members also occasionally emitted "huu chhhk" vocalizations, probably contact calls between members of a unit or between units (Boonratana & Le, 1994; 1998a)

Sleeping sites

Tonkin snub-nosed monkeys usually select lower branches of trees that are close to steeper sides of mountains as sleeping sites. This may protect them from strong and cold northeast winds (Boonratana & Le, 1994; 1998a)

2.5. Aims of the present study

I commenced my field study on the ecology and behavior of *R. avunculus* in Na Hang NR, Tuyen Quang Province, and later switched my focus to Khau Ca HSCA, Ha Giang Province, for reasons explained further on. I hoped to conduct the first relatively long-term and in-depth field study, to make comparisons with the Chinese species and with other colobines, and to attempt to examine the effects of phylogeny versus ecology. I also aim to draw attention to the critical conservation status of the species. The specific objectives of my study are as follows:

1. To describe the botany of the karst mountain forests in Tat Ke Sector, Na Hang NR, and in Khau Ca Forest.
2. To monitor and compare the phenology of the study sites, and to assess seasonal changes in food availability.
3. To provide data on the population size of *R. avunculus* in Tat Ke Sector, Na Hang NR, Cham Chu, Than Sa-Phuong Hoang NRs, Ba Be NP, and Nam Xuan Lac and Khau Ca HSCAs.
4. To study the social organization and social behavior of *R. avunculus* in relation to habitat and food availability.
5. To study the feeding ecology of *R. avunculus* in relation to the botany and phenology of the habitat.
6. To assess current and potential threats to *R. avunculus* and its natural habitat.

7. To make appropriate conservation and management recommendations for the species and its habitat.

2.6. Summary

Chinese snub-nosed monkeys are characterized by large home ranges and long daily travel distances. Their social organization in general resembles those of many other colobines. They live in large bands and some species display fission and fusion (e.g., *R. brelichi* and *R. roxellana*). The diets of Chinese taxa are diverse and often marked by seasonality. The Tonkin snub-nosed monkey (*R. avunculus*) is a slender-bodied, apparently fully arboreal species, Critically Endangered primate, endemic to northern Vietnam. Its range is currently restricted to the fragmented forest patches associated with limestone hills; its ecology and behavior have been poorly studied until recently. Although the Vietnam government and international conservation communities have taken action to protect the species, the population of the species is still decreasing because of hunting pressure and habitat destruction, and its global population is currently estimated at only 250 individuals. This is the first long-term study. The aim of the study is to reveal information on the species' social organization and behavior, feeding ecology, and habitat. The information gathered will result in conservation and management recommendations for the species and its habitats.

Chapter 3

Study area

3.1. Introduction

Study of ecology plays an important role in understanding social organization, feeding and behavior, ecology, ranging behavior, abundance and densities of primates. Forest composition has been viewed as the main factor determining the abundance and distribution of primates (Worman and Chapman, 2006). Several studies found that densities of trees $\geq 10\text{cm}$ were significantly correlated with primate abundance (*Cercocebus galeritus*, Wieczkowski, 2004).

A great variation in social organization within species between sites may regulate by a number of factors in which ecology is an important one (Clutton-Brock & Harvey, 1977; Eisenberg et al., 1972; Struhsaker, 1969). For instance, Banded leaf monkeys (*Presbytis femoralis*) show both OMUs and multi-male units in Krau Game Reserve in western Malaysia (Mackinnon & Mackinnon, 1980; Curtin, 1980, respectively) and OMUs in other parts of Malaysia (Bernstein, 1968). Comparative study by Chapman and Chapman (2000) suggested that group sizes of Red colobus and Red-tailed guenons appear to be larger in areas where food resources are abundant.

Phenological cycles may influence on feeding, ranging and reproductive behavior of primates. Food quality and availability are important factors. For example, birth and breeding seasons of *Trachypithecus vetulus* (Rudran, 1973), *Semnopithecus priam* (Ziegler et al., 2000), and *R. brelichi* (Yang et al., 2009) were regulated by food quality and availability. Further, the availability of food resources influences on home range and day range length of colobines (Clutton-Brock & Harvey, 1977; Gillespie & Chapman,

2001; Terborgh & Janson, 1986; Wrangham et al., 1993). For example, *R. roxellana* at Yuhuangmiao traveled farthest in autumn months coinciding with when fruits are available, and least in winter months when food resources are scarce (Li et al., 2000). Having understanding phonological cycles in the forest may help to explain seasonal changes in proportion of food items in the diet, sexual behavior, and ranging behavior of colobines. These all have important implications for the species and its habitat management

Members of the Colobinae exhibit a number of anatomical adaptations associated with leaf-eating. These adaptations have the potential to profoundly influence social organization and behavior, population density, and ranging behavior (Chivers & Hladik, 1980; Yeager & Kool, 2000). For example, folivores appear to have smaller home ranges and shorter day range lengths than frugivores; arboreal folivores have some of the highest densities among primates (Clutton-Brock & Harvey, 1977).

Colobines have diversity of diets. Apart from leaves, colobines are able to digest a variety of food items, including fruits, seeds, flowers, lichens, bark, insects and others. Such ability allows Asian colobines to inhabit a wide variety of habitats and to respond to seasonal changes in those habitats (Kirkpatrick, 2007). Seasonality has a pronounced impact on the diets of colobines, especially among Asian colobines whose habitats are often highly seasonal (Bennett & Davies, 1994; Kirkpatrick, 2007). The proportion of time feeding on food items varies between seasons and corresponds to food availability and the animals' preference (Davies, 1984; Davies et al., 1988).

Rhinopithecus avunculus lives in tropical forest in northern Vietnam and is an arboreal primate. The ecology of the Tonkin snub-nosed monkey is the least known among the snubnosed monkeys. Details of forest composition and structure and seasonal changes in food pattern in the forest remain to be studied, although Boonratana and Le (1994;

1998a), Pham (1993; 1994; 2002), Ratajszczak et al. (1992), and Le et al., (2010) all presented preliminary data. This chapter will describe the structure, composition and phenology of the forests at Tat Ke Sector and Khau Ca HSCA.

3.2. Methods

I studied the ecology and behavior of *Rhinopithecus avunculus* at two sites: Tat Ke Sector, Na Hang NR, Tuyen Quang Province (from September 2004 to July 2005); and Khau Ca HSCA, Ha Giang Province (between August 2005 and September 2006). These are two of the four known areas of occurrence of *R. avunculus*, the other two being Ban Bung Sector of Na Hang NR, and Cham Chu NR.

3.2.1. Climate

Rainfall and temperature data were first recorded at base camp during the first months of the study in Tat Ke Sector, but unfortunately the rain gauge was broken during transportation over the rough roads, and daily temperature was not recorded regularly since team members had to spend time between sub-camps to search for the monkeys. Therefore, the climate data used in this thesis were from the Tuyen Quang Weather Station (about 70km from the Na Hang NR) and Ha Giang Weather Station (about 20km from the Khau Ca HSCA).

Based on field observations, there could be some differences in climate between field sites and weather stations in terms of temperature, humidity, rainfall and foggy days. Temperature, for example, was expected to be lower at the field sites during winter; the field sites appeared to receive more rain than the weather stations; heavy mist and fog days were more than expected from January to the early of April at the two study sites; and humidity was unexpectedly high (more than 90% recorded during the first months

of the study in Tat Ke). With these qualifications, the Weather Station records are the closest estimates we can achieve to the weather at the field sites.

3.2.2. Botany

To describe the species and structural composition of the forest, and to monitor the phenology of the trees and to compare the habitats of the two study sites, 64 and 58 systematically placed botanical plots measuring (10m x 10m) were established at each study site (Tat Ke and Khau Ca, respectively) during the first month of the study. This work was aided by my three assistants. Only 10m x 10m plots were feasible for the steep and karstic terrain of the habitats. All trees in the plots equal to or greater than 19cm girth at breast height (equivalent to 6cm in diameter) were tagged, measured, and identified. Sampled trees were identified by Mr. Nguyen Van Huy from the Forestry University of Vietnam. Samples from trees that could not be identified in the field were collected and later identified at the Forestry University of Vietnam. The general locations for each sample plot were selected to represent the monkeys' habitat. Voucher specimens were collected for all plant species encountered in plots, and for other species not found in plots.

3.2.3. Phenology

Observations were recorded monthly from October 2004 through August 2005 at Tat Ke Sector, Na Hang NR, and from September 2005 to September 2006 at Khau Ca HSCA. My assistants and I visited each tree in a plot during the first day of the month and recorded for the presence or absence of mature and young leaves, flower and flower buds, and ripe and unripe fruits. For some species, it was difficult to distinguish between ripe and unripe fruits; unripe and ripe fruits were therefore combined as "fruits" in these data analyses. Flowering buds and flowers were also combined as

“flowers” in data analyses to avoid missed flowering events of species with short blooming times since phenological characteristics were recorded only once a month.

3.3. Na Hang NR

3.3.1. Selection of site.

The study site was chosen for the following reasons:

1. Tat Ke Sector was reported to hold the largest population of *R. avunculus* in Vietnam until recently (80 individuals, Boonratana & Le, 1994; 1998b).
2. Na Hang NR has been established since 1994, and hunting pressure has been successfully controlled (B.H. Le, 2003; C.X. Le, 2003).
3. I had the opportunity to work in the Na Hang NR with Dr. Boonratana on the “Na Hang Rainforest Conservation Project” for three months in 1998. This would be a great advantage with regard to understanding the study site and local people living in and around the Reserve.
4. At the time this study was carried out, there had been only a six-month study (by Boonratana & Le) since 1993 in this area. Data gathered in this study, therefore, would greatly add to our knowledge of social organization and behavior, feeding ecology and range use, as well as the population and conservation status of *R. avunculus*.
5. Information on the presence of wildlife, other than *R. avunculus*, was also recorded during surveys. This would provide important information for making management and conservation plans in the Reserve.

3.3.2. Location

Na Hang NR, established in 1994, is located in Na Hang District, Tuyen Quang Province, between 22^o16'-22^o31'N and 105^o22'-105^o29'E (Boonratana, 1998), and consists of two sectors: Ban Bung to the south and Tat Ke to the north (Figure 2.1). It falls within the biogeographical subdivision of Tonkin (Delacour & Jabouille, 1931, as

cited in Boonratana, 1999), or Thaiandian Monsoon Forest (unit 4.10.4) (Udvardy, 1975, as cited in Boonratana, 1999), or South China (unit 6a) of the Indo-Malayan Realm (MacKinnon & MacKinnon, 1986). The reserve covers an area of 41,930ha, comprising a strictly protected area (27,500ha), a forest rehabilitation area (12,910ha), and an administration area (1,500ha) (Le, 2003; Le et al., 2004). It borders on five communes: Con Lon, Khau Tinh, Vinh Yen, Son Phu and Thanh Tuong (Le, 2003).

The main study site was in the Tat Ke Sector ($22^{\circ}22'$ - $22^{\circ}31'$ N and $105^{\circ}22'$ - $105^{\circ}29'$ E), which covers an area of 12,500ha, about 3km to the north of Na Hang Town. The Sector is bordered by the Gam River and Nam Vang Stream on the northwest and the Nang River and Ta Lan Stream on the northeast.

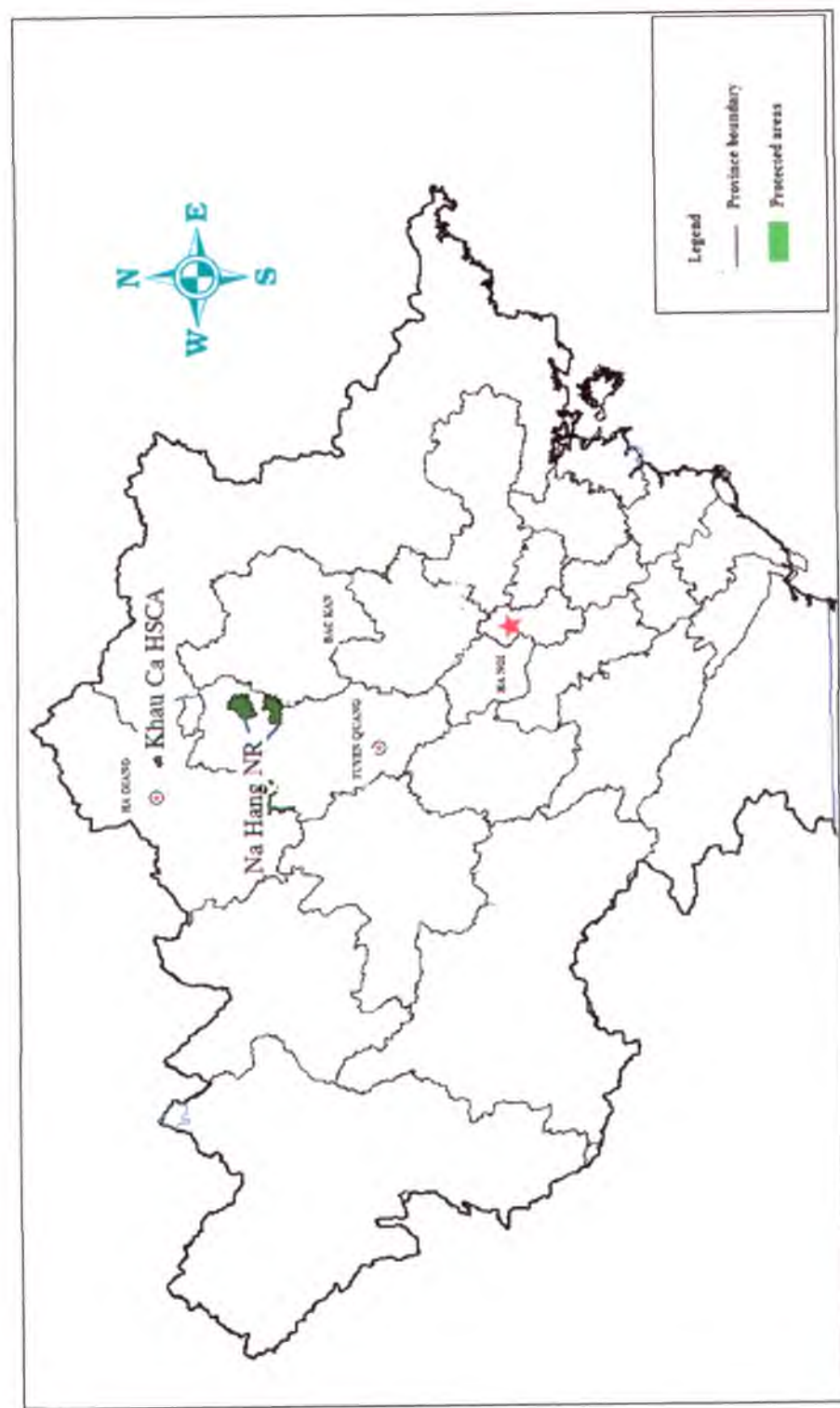


Figure 3.1. Position map of Na Hang NR and Chau Ca HSCA

3.3.3. Topography

The terrain of Tat Ke Sector is characterized by steep rugged limestone hills and mountains. Altitude ranges from 100 to ca. 1100m; the highest point in the Sector is the summit of Khau Tep, 1064m above sea level (F-48-31-D, 2001). There are several permanent and intermittent streams in the Sector, draining into the Gam and Nang Rivers; due to the limestone geology, which allows much of the surface water to be quickly absorbed into underground streams, there is a shortage of surface water during the dry season. Some small floodplain areas exist in the sector that have been converted into cultivation areas, mainly rice (Boonratana, 1999).

3.3.4. Climate

Like other parts of northern Vietnam, Na Hang NR climate has a monsoon tropical climate. The four distinct seasons (spring, summer, autumn, and winter) can be grouped into two main seasons: a cold and dry season from October to April, and a hot and wet season from May to September.

The cold and dry season (between October 2004 and April 2005) was characterized by relatively low temperature and rainfall (Figure 3.1); maximum and minimum temperatures of 32.5⁰C and 11.1⁰C were recorded in October 2004 and in March 2005, respectively, the mean temperature being 14.9⁰C. It rained on a total of 73 days, and total rainfall was 293mm. In contrast, from May 2005 to September 2005, there were 85 rainy days and total rainfall was 1247mm, and temperatures ranged between 18.8⁰C and 35.4⁰C, the mean temperature being 30.4⁰C. These months, therefore, constitute the hot and wet season.

Although the cold and dry period lasts for 7 months and appears to be the ideal time for observing the monkeys, the best time for observation was in fact only in three months

(between October and December). During the rest of the season (from January to April), there was heavy mist and fog, resulting in poor visibility.

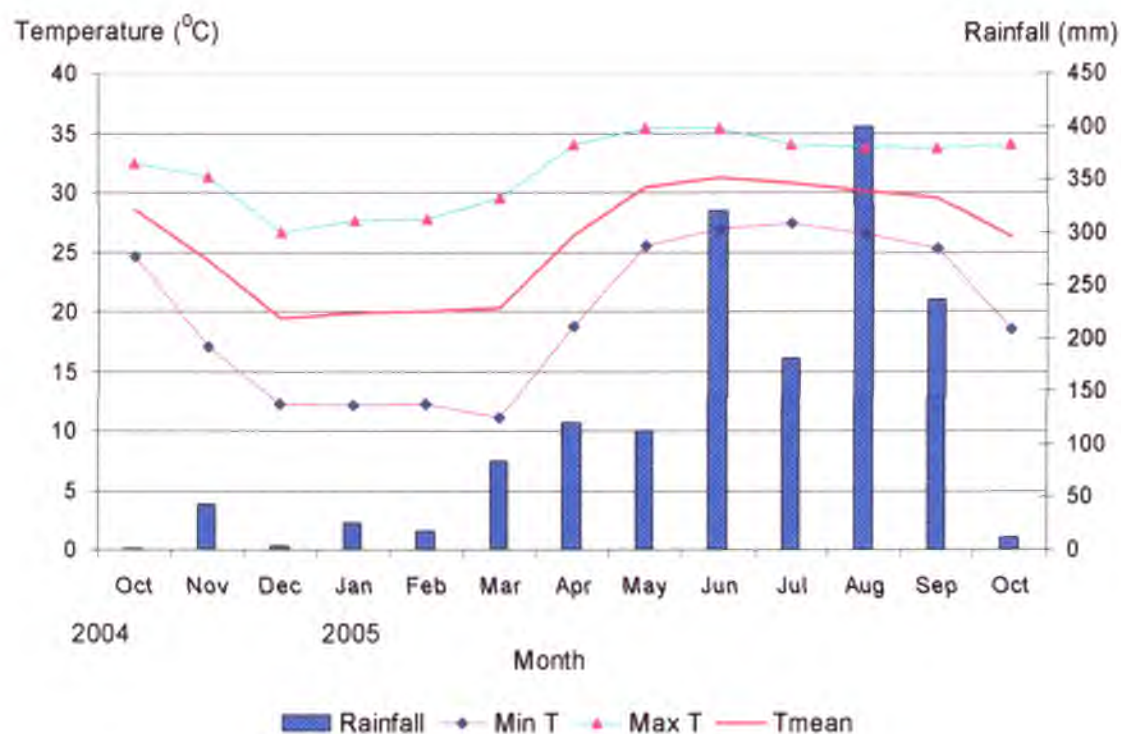


Figure 3.2. Mean monthly maximum and minimum temperatures, and mean monthly rainfall recorded at Tuyen Quang for 2004-2005.

3.3.5. Botany

Forest Structure

A total of 612 trees was counted in the 64 plots of the study area. The total plot area covered 0.64ha, and the density of trees of ≥ 19 cm at breast height (g.b.h.) was 956 per hectare. Most trees (92.5% of the total trees sampled) were between 19 and 110cm girth at breast height, of which those with a girth ranging from 19 to 30cm made up largest proportion (34.9%) (Figure 3.3). There were few trees exceeding 120cm (only 7.5% of the total trees sampled). The maximum girth at breast height was 646cm, recorded in an

example of *Excentrodendron tonkinensis*. The mean girth of trees in the plots was 60cm.

Species composition of the forest

The list of the species, the number of stems and the basal area of each are provided in Appendix 1. Out of a total 612 trees sampled, 151 species were identified, belonging to 50 families, for a ratio of ca. 4 trees/species and 3 species/family. A maximum basal area of 33,280.88cm² was recorded (*Aporosa sp*), and the mean basal area for all trees was 616.57cm². The area of plots sampled was 64,000m², with a total basal area of 37.73 m². Therefore, the total basal area per hectare was 58.95m².

The number of trees and species per plot meeting the sample criterion of 19cm girth at breast height averaged 10 (range from 3 to 30) and 6 (range between 1 and 21), respectively. For some plots (plots 39 and 45), there was only one species (*Streblus macrophyllus*) even though six trees were sampled. Plot 31 had the highest number of trees and species (30 trees and 21 species) (Table 3.1). The relationship between area surveyed and species richness is shown in Figure 3.4. The number of species increased considerably in the first 0.32ha surveyed (from six species in 0.1ha to 123 species in 0.32ha, contributing 81.46% to the total of species in all plots sampled). From this point, there was a gradual increase in the number of species and it seemed to level off by the end. Of course, the number of species would probably be expected to increase if the area surveyed would be increased since the total area sampled may not be large enough to describe the full species composition of Tat Ke Sector.

Table 3.2 shows the abundance and basal area of tree families in botanical plots at Tat Ke Sector. Moraceae was the most abundant tree family in terms of stem-number, followed by Lauraceae. Next were Euphorbiaceae and Ebenaceae which contributed almost equal proportions of stem-number to total number of stems in the plots. Other

abundant families included Apocynaceae (25 stems, 4.08%), Rubiaceae (24 stems, 3.92%), and Annonaceae (20 stems, 3.27%). Families that had a large number of trees do not necessarily make up largest proportion of total basal area. Tiliaceae, for instance, had only six stems in total, but accounted for the largest proportion of total basal area (25.68%), and basal area and mean basal area were 96,882.89 and 16,147.15cm²; Lauraceae with 69 stems (less than half of Moraceae) ranked second in terms of basal area (11.64%). Next were Moraceae and Ebenaceae which made up 10.44 and 8.70% of total basal area. A possible explanation for these differences is most of the trees in the family Moraceae had small g.b.h. (average 46.6cm and range from 19.3 to 201cm), while g.b.h. of trees in the family Tiliaceae had an average of 406.53 cm and in a range of between 157.6 and 646.7cm. The twenty eight commonest tree species in terms of stem number and basal area are presented in Table 3.3 (five or more individuals). They made up 63.07% of total stem-number and 57.89% of total basal area in 64 botanical plots. *Streblus macrophyllus* (Moraceae) was the commonest tree species (Table 3.3). The next commonest tree species was *Diospyros susarticulata*, followed by *Ficus harmandii* (Moraceae), *Kitabalia macrophylla* (Apocynaceae), and *Miliusa filipes* (Annonaceae). If basal area is considered, *Excentrodendron tonkinensis* (Tiliaceae) was the commonest large tree though it ranked fifteenth in terms of number of stems (6 individuals). It accounted for highest proportion of basal area (25.68%), followed by *Diospyros susarticulata* (8.55%, Ebenaceae) and *Streblus macrophyllus* (5.49%, Moraceae).

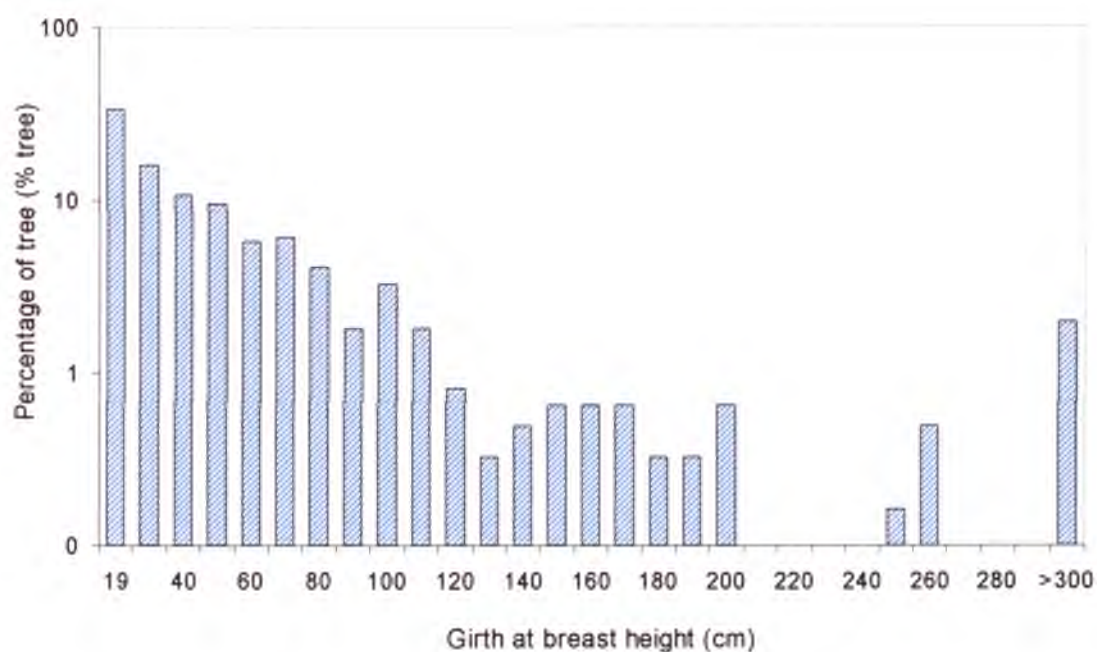


Figure 3.3. Frequency distribution of girths at breast height of plots at Tat Ke Sector (n=612)

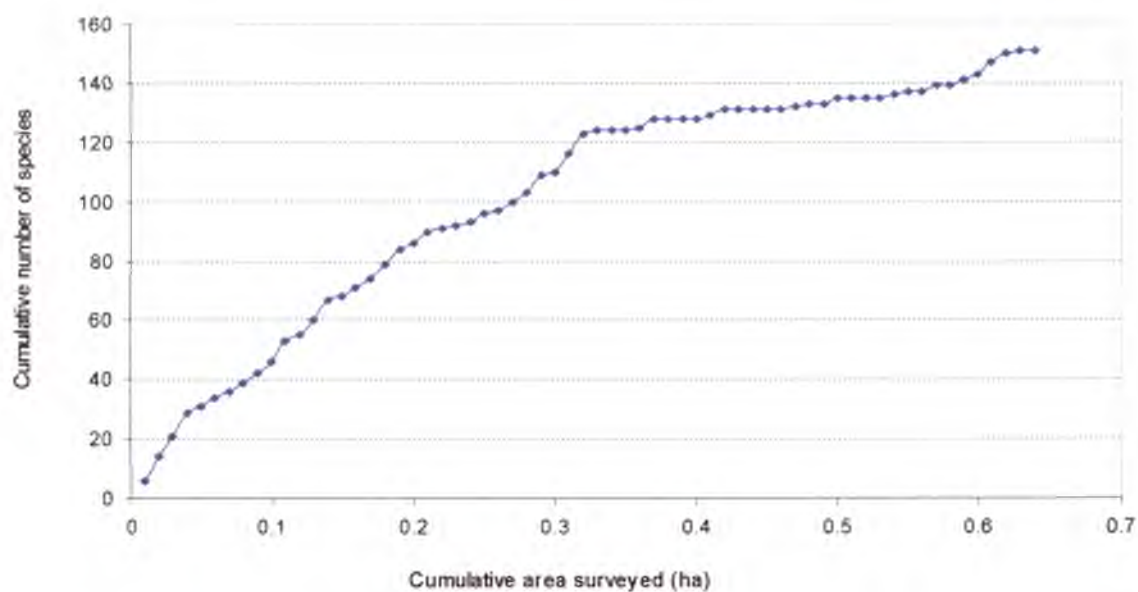


Figure 3.4. Relationship between area surveyed and number of tree species in plots at Tat Ke Sector, Na Hang NR.

Table 3.1. Species richness for plots at Tat Ke Sector

Plots	#ID	#Species	#Genus	#Family	Plots	# IDs	# Species	#Genus	#Family
TK1	10	6	6	5	TK33	8	3	3	3
TK2	9	8	8	7	TK34	12	4	4	4
TK3	10	9	9	8	TK35	7	6	6	4
TK4	12	12	11	8	TK36	10	4	4	4
TK5	6	4	4	4	TK37	9	10	9	9
TK6	6	4	4	3	TK38	4	2	2	2
TK7	8	6	6	5	TK39	6	1	1	1
TK8	7	5	5	5	TK40	9	2	2	1
TK9	10	5	5	5	TK41	13	5	5	5
TK10	7	7	7	6	TK42	11	6	5	4
TK11	15	12	11	10	TK43	10	3	3	2
TK12	8	6	6	6	TK44	8	6	6	5
TK13	9	8	8	6	TK45	6	1	1	1
TK14	11	10	10	8	TK46	6	3	3	3
TK15	12	9	8	7	TK47	8	5	5	3
TK16	9	8	7	6	TK48	9	3	3	3
TK17	12	7	6	5	TK49	11	4	4	4
TK18	12	7	7	6	TK50	10	4	4	4
TK19	10	8	6	5	TK51	7	3	3	3
TK20	11	8	8	8	TK52	10	4	4	4

IDs: number of Individuals TK: Tat Ke

Table 3.1. Species richness for plots at Tat Ke Sector (continued)

Plots	#ID	#Species	#Genus	#Family	Plots	# IDs	# Species	#Genus	#Family
TK21	11	8	7	7	TK53	8	3	3	3
TK22	4	4	4	4	TK54	13	5	5	5
TK23	7	5	5	5	TK55	4	3	3	3
TK24	6	5	5	5	TK56	6	5	5	5
TK25	5	5	5	5	TK57	8	8	8	8
TK26	10	7	7	7	TK58	8	6	6	6
TK27	13	6	6	6	TK59	11	6	6	6
TK28	7	6	5	5	TK60	12	9	8	8
TK29	14	12	11	9	TK61	13	11	11	10
TK30	19	14	12	11	TK62	4	3	3	3
TK31	30	21	16	11	TK63	9	6	6	6
TK32	14	13	12	12	TK64	8	3	3	3

Table 3.2. Abundance and basal area of tree families in botanical plots at Tat Ke Sector

Family	No. of stems	% of stems	BA	%TBA	Mean BA
Actinidiaceae	13	2.12	4582.83	1.21	352.53
Anacardiaceae	11	1.80	3553.25	0.94	323.02
Annonaceae	20	3.27	12215.17	3.24	610.76
Apocynaceae	25	4.08	2980.68	0.79	119.23
Aquifoliaceae	3	0.49	322.70	0.09	107.57
Araliaceae	9	1.47	1698.00	0.45	188.67
Asteraceae	1	0.16	524.69	0.14	524.69
Bigoniaceae	2	0.33	168.59	0.04	84.30
Burseraceae	1	0.16	43.57	0.01	43.57
Caesalpiniaceae	3	0.49	248.72	0.07	248.72
Clusiaceae	17	2.78	3885.28	1.03	228.55
Daphniphyllaceae	2	0.33	186.13	0.05	93.06
Dilleniaceae	1	0.16	761.14	0.20	761.14
Ebenaceae	41	6.70	32820.27	8.70	800.49
Elaeocarpaceae	5	0.82	1751.13	0.46	350.23
Euphorbiaceae	42	6.86	23419.85	6.21	557.62
Fabaceae	7	1.14	3278.58	0.87	468.37
Flacoutiaceae	2	0.33	616.44	0.16	308.22
Icacinaceae	2	0.33	74.26	0.02	37.13
Iteaceae	1	0.16	82.51	0.02	82.51
Juglandaceae	4	0.65	619.15	0.16	154.79
Kygelariaceae	15	2.45	4550.05	1.21	303.34
Lauraceae	69	11.27	43931.79	11.64	636.69
Linnaceae	1	0.16	29.95	0.01	29.95
Magnoliaceae	4	0.65	1119.45	0.30	279.86
Meliaceae	4	0.65	10286.15	2.73	2571.54
Mimosaceae	3	0.49	532.31	0.14	177.44
Moraceae	158	25.82	39413.18	10.44	249.45
Myristicaceae	5	0.82	1446.44	0.38	289.29
Myrsinaceae	10	1.63	2108.84	0.56	210.88
Myrtaceae	18	2.94	4836.81	1.28	268.71

Table 3.2. Abundance and basal area of tree families in botanical plots at Tat Ke Sector (continued)

Family	No. of stems	% of stems	BA	%TBA	Mean BA
Oleaceae	4	0.65	896.40	0.24	224.10
Podocarpaceae	1	0.16	3091.45	0.82	3091.45
Proteaceae	1	0.16	94.72	0.03	94.72
Rosaceae	4	0.65	2976.68	0.79	744.17
Rubiaceae	24	3.92	21643.45	5.74	901.81
Rutaceae	2	0.33	1037.09	0.27	518.55
Sapindaceae	5	0.82	3739.55	0.99	747.91
Sarcospermaceae	4	0.65	9911.63	2.63	2477.91
Simarubaceae	4	0.65	23085.84	6.12	5771.46
Stalhyllaceae	5	0.82	662.39	0.18	132.48
Staphyleaceae	1	0.16	100.85	0.03	100.85
Sterculiaceae	16	2.61	1990.33	0.53	124.40
Styracaceae	3	0.49	2271.68	0.60	757.23
Theaceae	8	1.31	2410.01	0.64	301.25
Tiliaceae	6	0.98	96882.89	25.68	16147.15
Ulmaceae	13	2.12	2320.99	0.62	178.54
Urticaceae	8	1.31	904.15	0.24	113.02
Verbenaceae	1	0.16	945.46	0.25	945.46
Xanthophyllaceae	3	0.49	289.21	0.08	96.40

BA: Basal area

%TBA: Percent of total basal area

Mean BA: Mean basal area (cm²)

Table 3.3. The twenty eight commonest tree species in 64 plots at Tat Ke Sector

Family/species	No. of stems	% of stems	BA	%TBA
Moraceae				
<i>Streblus macrophyllus</i>	121	19.77	20734.49	5.49
Ebenaceae				
<i>Diospyros susarticulata</i>	35	5.72	32249.79	8.55
Moraceae				
<i>Ficus harmandii Gagnep.</i>	24	3.92	11490.51	3.05
Apocynaceae				
<i>Kitabalia macrophylla</i>	22	3.59	2786.07	0.74
Annonaceae				
<i>Miliusa filipes</i>	17	2.78	11863.55	3.14
Kygelariaceae				
<i>Hydnocarpus hainanensis</i>	15	2.45	4550.05	1.21
Sterculiaceae				
<i>Sterculia lanceolata</i>	14	2.29	1123.18	0.30
Actinidiaceae				
<i>Saurauja tristylla</i>	13	2.12	4582.83	1.21
Myrsinaceae				
<i>Ardisia tsangii</i>	10	1.63	2108.84	0.56
Myrtaceae				
<i>Syzygium zeylanicum</i>	10	1.63	3514.23	0.93
Anacardiaceae				
<i>Drimycarpus racemosus</i>	8	1.31	2434.25	0.65
Lauraceae				
<i>Phoebe cuneata</i>	8	1.31	2621.52	0.69
Urticaceae				
<i>Pouzolzia sanguinea</i>	8	1.31	904.15	0.24
Lauraceae				
<i>Litsea balansae</i>	7	1.14	1219.08	0.32
Tiliaceae				
<i>Excentrodendron tonkinense</i>	6	0.98	96882.89	25.68
Clusiaceae				
<i>Garcinia fagraeoides</i>	6	0.98	2025.54	0.54

Table 3.3. The twenty eight commonest tree species in 64 plots at Tat Ke Sector (continued)

Family/species	No. of stems	% of stems	BA	%TBA
Myrtaceae				
<i>Syzygium jambos</i> var. <i>jambos</i>	6	0.98	754.44	0.20
Araliaceae				
<i>Trevesia palmata</i>	6	0.98	1370.23	0.36
Euphorbiaceae				
<i>Antidesma tonkinense</i>	5	0.82	848.71	0.22
Rubiaceae				
<i>Canthium parvifolium</i>	5	0.82	1256.95	0.33
Euphorbiaceae				
<i>Chaetocarpus castanocarpus</i>	5	0.82	2272.98	0.60
Lauraceae				
<i>Cryptocarya concinna</i>	5	0.82	669.51	0.18
Clusiaceae				
<i>Garcinia bonii</i>	5	0.82	590.72	0.16
Myristicaceae				
<i>Knema conferta</i>	5	0.82	1446.44	0.38
Lauraceae				
<i>Neolitsea aurata</i>	5	0.82	5368.45	1.42
Rubiaceae				
<i>Pavetta graciliflora</i>	5	0.82	800.37	0.21
Stalhyllaceae				
<i>Turpinia nepalensis</i>	5	0.82	662.39	0.18
Ulmaceae				
<i>Ulmus</i> sp	5	0.82	1335.61	0.35
Total	386	63.07	218467.73	57.90

BA: Basal area (cm²)

%TBA: Percent of total basal area in plots

3.3.6. Phenology

Phenological characteristics of 333 tagged trees representing 150 species from the botanical plots were investigated in the Tat Ke Sector. Observations were recorded monthly from October 2004 through August 2005. Each tree was recorded for presence or absence of mature leaves, young leaves, flowers, and fruits (Figure 3.5).

The production of young leaves was high throughout the course of the study and reached a peak of 100% at the start of the dry season (October). Trees produced fewer young leaves from February to May (73.5% in May), corresponding to the end of the dry season and the early rainy season. There was a weak negative correlation between young leaf production and rainfall per month (Spearman's rank correlation $r_s = -0.369$, $n=11$, $p>0.05$).

Flowering occurred year-round, but appeared to be more frequent at the start of the dry season (from October to December) and the early part of the rainy season (from April to June) (Figure 3.5). There were two distinct peaks. The first peak was in November, when 14.1% of trees bore flowers, coinciding with the early part of the dry season. There was a suggestion of a second, minor peak early in June when 9.6% of trees produced flowers, corresponding to the early part of the rainy season. There was a moderate correlation between young leaf production and rainfall per month (Spearman's rank correlation $r_s = -0.524$, $n=11$, $p>0.05$).

Fruiting was also recorded throughout of the study, and fruiting peaks seemed to follow the flowering peaks (Figure 3.4). Fruiting was also bimodal with a major peak occurring in the early part of the dry season (November), when 18.2% of trees produced fruits, and a minor peak during the middle of the rainy season (July 2006) when 7.2% of trees

bore fruits. There was a moderate correlation between young leaf production and rainfall (Spearman's rank correlation $r_s = -0.642$, $n=11$, $p>0.05$).

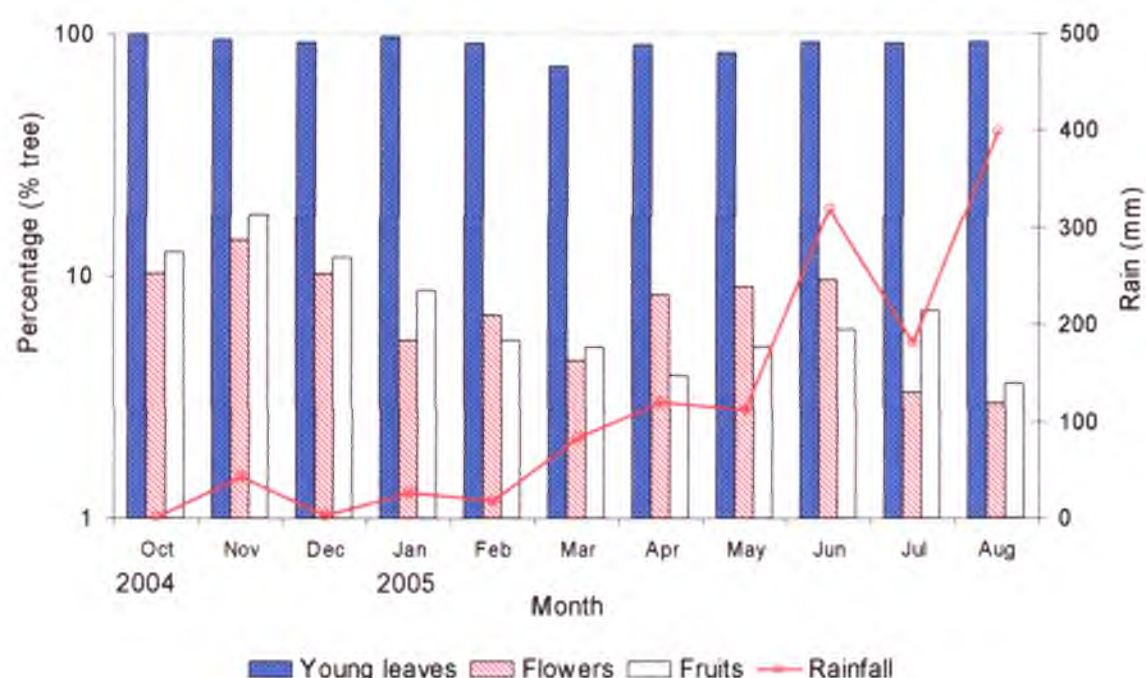


Figure 3.5. Phenological patterns at Tat Ke, Na Hang NR (n= 333)

3.4. Khau Ca HSCA

3.4.1. Selection of study site

The choice of the second study site was made for the following reasons:

1. After an eleven-month study in Tat Ke Sector, less than 10 contact hours had been made and the population size there was much smaller than we had originally expected, because of severe hunting pressure. I therefore decided to expand my study to another area in the known range, Khau Ca HSCA, Ha Giang Province.
2. Khau Ca Forest has been reported to contain a population of 50-60 individuals in a small area (ca. 1600ha, Le, 2004), so that the probability of encountering the monkeys could be higher than for other known parts of the range.
3. The results collected from this site would be comparable with previous study sites.

4. Information on the presence of wildlife, other than *R. avunculus*, had also been recorded during surveys. This would provide important information for making management and conservation plans in the area studied.

3.4.2. Location

Khau Ca HSCA had been reported to belong to Du Gia NR (Le, 2004), but it was later confirmed that the area was outside the Reserve, and was an isolated area without any legal special use status (Dong & Boonratana, 2006; Le & Boonratana, 2006). It has been known under several names, such as Khau Ca Area (Le, 2006) and Khau Ca Tonkin snub-nosed monkey Conservation Area (T.V.Dam, pers.comm., 2006). Khau Ca Forest has been officially recognized as Habitat and Species Conservation Area since 2010.

Khau Ca HSCA is located between 22⁰49'-22⁰52'N and 105⁰05'-105⁰09'E, and is about 15-20km to the east of Ha Giang Town (Figure 3.1). It covers an area of 1000ha and borders on three communes and two districts: Minh Son and Yen Dinh Communes in Bac Me District, and Tung Ba Commune in Vi Xuyen District.

3.4.3. Topography

Like Tat Ke Sector, the terrain of Khau Ca Forest is characterised by limestone mountains, but is steeper and more rugged. It features deep and narrow valleys, and sharp and loose outcrops. Altitude varies greatly between 450m and 1339.9m, the highest point being in the south east (F-48-43-C, 2001). Khau Ca Forest can be divided into two areas in terms of altitude: the higher part is in the southeast with several peaks above 1000m, the lower part in the north west with or peaks under 1000m above sea level. There is no water source inside the forest. All these features make Khau Ca Forest a very difficult study site, and full day follows of the monkeys are impossible on most occasions.

3.4.4. Climate

Khau Ca Forest has a climate similar to Tat Ke Sector and other parts of northern Vietnam, with a strong monsoon influence and four distinct seasons (spring, summer, autumn, and winter) but, like Tat Ke, it is also possible to divide the seasons into two main seasons: a cold and dry season from October to April, and a hot and wet season from May to September.

Mean temperatures are high and variable between seasons (Figure 3.6). The mean temperature ranges between 19.4⁰C and 31.2⁰C. The mean minimum temperature was lowest (12.2⁰C) in January 2006, and the mean maximum temperature was highest (35.6⁰C) in July 2006. The mean temperature during the cold and dry period (from October 2005 to April 2006) was 22.9⁰C and that during the hot and wet season (from May 2006 to September 2006) was 29.7⁰C.

There were 222 rainy days and total rainfall was 1983mm between August 2005 and September 2006. Rainy days and total rainfall varied greatly between seasons. It rained for a total of 88 days and total rainfall was 436mm during the cold and dry period, while these figures were 97 days and 1128mm, respectively, during the hot and wet season. The lowest mean rainfall was in January 2006 (5.5mm) and the highest was in August 2006 (348mm).

As in Tat Ke Sector, the best time for observing the monkeys lasts for about three months (from October to December). The rest time of the year is rainy, with heavy mist and fog, resulting in poor visibility and walking difficulties.

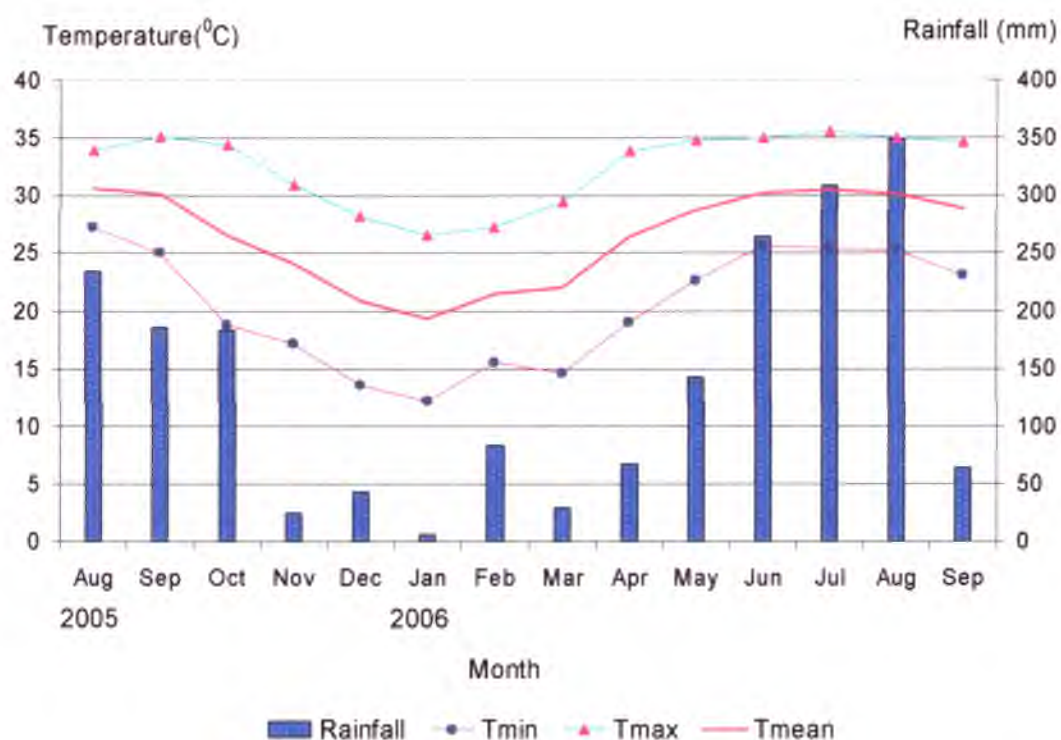


Figure 3.6. Mean monthly maximum and minimum temperatures, and mean monthly rainfall recorded at Ha Giang for 2005-2006.

3.4.5. Botany

Forest structure

A total of 512 trees was sampled from 58 plots in the study area. The total plots covered an area of 0.58ha; thus, the density of trees of at breast height (g.b.h.) was 882 per hectare. Most trees were between 19 and 130cm girth at breast height, accounting for 95.7% of the total tree sampled. As in Tat Ke Sector, girths ranging from 19 to 30cm made up largest proportion of girth categories (34.4%); only 4.3% of the total trees sampled exceeded 130cm (Figure 3.7). Maximum girth at breast height of 442cm was recorded in *Aprosa sp* species. The mean girth of trees in the plots was 54.7cm.

Species composition of the forest

The list of the species, the number of stems, and the basal area of each in Khau Ca Forest are provided in Appendix 2. Out of a total 512 trees sampled, 136 species were

identified, belonging to 49 families, for a ratio of ca. 3.7 trees/species and 2.8 species/family. The maximum basal area of 15,546.54cm² was recorded in *Aprosa sp* and the mean basal area for all trees was 393.90cm². The area of plots sampled was 58,000m², with a total basal area of 20.17m². The total basal area per hectare was 34.77m².

The numbers of trees and species per plot meeting the sample criterion of 19cm girth at breast height averaged 9 (from 1 to 25) and 7 (from 1 to 19), respectively. There was only one tree and one species in plot 38. Plot 14 had the highest number of trees and species (25 trees and 19 species) (Table 3.4). The relationship between area surveyed and species richness is presented in Figure 3.8. There was a marked increase in the number of species in the first 0.3ha surveyed (from 8 species in 0.01ha to 98 species in 0.3ha, contributing to 72.06% of the total species in all plots sampled at Khau Ca). From this point, the number of species continued to grow gradually with area surveyed (from 98 species in 0.3ha to 136 species in 0.58ha). This indicates that as the area surveyed increases, there would be an increase in the number of species before the curve levels off.

Table 3.5 shows the abundance and basal area of tree families in botanical plots at Khau Ca Forest. Lauraceae was the most abundant tree family in terms of stem-number, followed by Hamamelidaceae family. The next were Fagaceae and Rubiaceae which contributed more than 30 stems to the total of stems sampled in the plots. Other abundant families included Urticaceae, Myrtaceae, Oleaceae, Annonaceae, Euphorbiaceae. Similarly, Lauraceae was the most abundant tree family in terms of basal area when basal area is considered. Fagaceae ranked second. Other abundant families in terms of basal area were Euphorbiaceae, Meliaceae and Ulmaceae.

The twenty nine commonest tree species in terms of stem-number and basal area are listed in Table 3.6 (five or more individuals); they made up 61.72% of total stem-number and 60.78% of total basal area in 58 botanical plots. *Mytilaria lasensis* was the commonest tree species. The next commonest tree species was *Machilus bonii*, *Pouzolzia*, *Quercus chrysocalys*. If basal area is considered, *Machilus bonii* was the commonest tree, followed by *Neolitsea ellipsoidea* though it ranked in nineteenth (6 stems) in terms of stem-number.

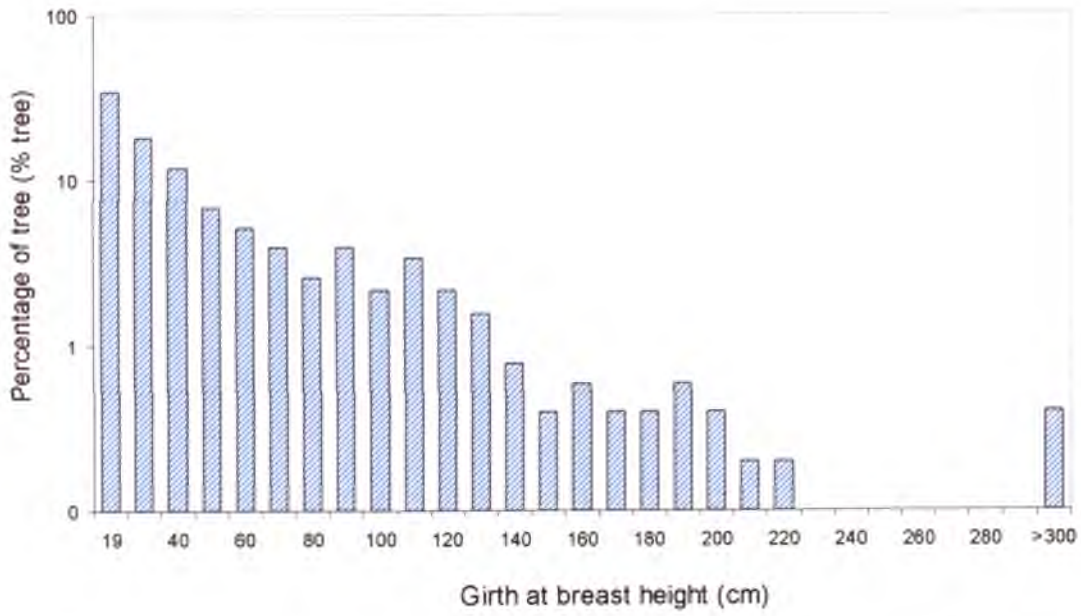


Figure 3.7. Frequency distribution of girths at breast height of plots at Khau Ca Forest (n=512)

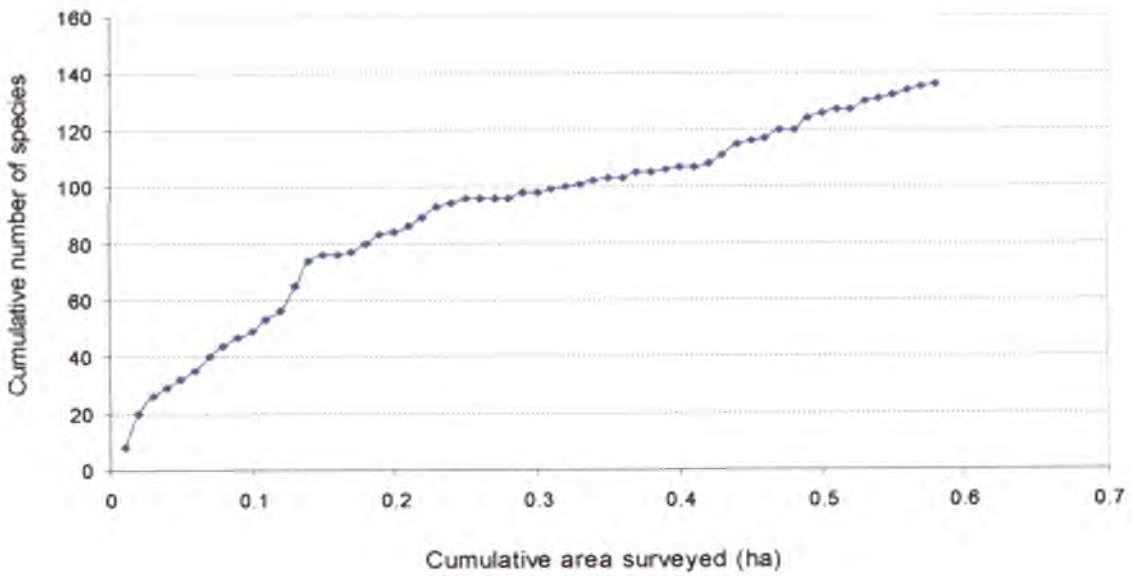


Figure 3.8. Relationship between area surveyed and number of tree species in plots at Khau Ca Forest

Table 3.4. Species richness for plots at Khau Ca Forest.

Plots	#IDs	#Species	#Genus	#Family	Plots	#IDs	#Species	#Genus	#Family
KC1	9	8	8	7	KC30	4	3	3	2
KC2	17	13	10	9	KC31	6	5	5	5
KC3	9	8	7	7	KC32	8	6	5	5
KC4	8	6	6	6	KC33	4	4	4	3
KC5	9	4	4	2	KC34	6	5	5	4
KC6	6	6	5	5	KC35	7	7	7	7
KC7	10	7	7	7	KC36	3	3	2	2
KC8	7	6	6	5	KC37	5	5	5	3
KC9	7	5	5	5	KC38	1	1	1	1
KC10	4	4	4	3	KC39	7	6	6	6
KC11	8	8	8	8	KC40	5	3	3	3
KC12	12	10	10	8	KC41	7	5	5	5
KC13	21	15	13	11	KC42	6	4	4	4
KC14	25	19	18	14	KC43	9	9	8	8
KC15	4	4	4	3	KC44	14	13	13	10
KC16	5	4	4	3	KC45	5	4	4	4
KC17	12	9	9	7	KC46	8	8	7	6
KC18	13	11	10	8	KC47	10	8	8	8
KC19	24	13	13	10	KC48	6	5	5	5
KC20	10	6	6	6	KC49	14	13	12	10
KC21	3	2	2	2	KC50	13	6	6	6
KC22	6	4	4	4	KC51	10	8	8	8
KC23	9	9	9	8	KC52	16	6	5	5

Table 3.4. Species richness for plots at Khau Ca Forest (continued)

Plots	#IDs	#Species	#Genus	#Family	Plots	#IDs	#Species	#Genus	#Family
KC24	2	2	2	2	KC53	20	10	9	8
KC25	4	4	4	4	KC54	14	7	7	7
KC26	4	4	4	4	KC55	11	9	8	7
KC27	5	3	3	3	KC56	10	8	7	7
KC28	2	2	2	2	KC57	11	7	7	5
KC29	8	6	4	4	KC58	9	7	6	3

KC: Khau Ca

IDs: Number of individuals

Table 3.5. Abundance and basal area of tree families in botanical plots at Khau Ca

Family	No.of stems	% of stems	BA	%TBA	Mean BA
Aceraceae	7	1.37	1561.24	0.77	223.03
Actinidiaceae	7	1.37	2007.16	1.00	286.74
Altingiaceae	1	0.20	221.85	0.11	221.85
Annonaceae	16	3.13	3399.50	1.69	212.47
Apocynaceae	3	0.59	799.77	0.40	266.59
Araliaceae	7	1.37	1198.99	0.59	171.28
Bigoniaceae	2	0.39	1176.24	0.58	588.12
Burseraceae	1	0.20	43.95	0.02	43.95
Clusiaceae	10	1.95	1721.97	0.85	172.20
Dilleniaceae	2	0.39	200.40	0.10	100.20
Dipterocarpaceae	1	0.20	1217.67	0.60	1217.67
Ebenaceae	9	1.76	5287.07	2.62	587.45
Elaeocarpaceae	3	0.59	485.83	0.24	161.94
Euphorbiaceae	16	3.13	17357.81	8.61	1084.86
Fagaceae	38	7.42	19167.35	9.50	504.40
Hamamelidaceae	43	8.40	5732.25	2.84	133.31
Icacinaceae	5	0.98	930.17	0.46	186.03
Illiciaceae	1	0.20	34.43	0.02	34.43
Juglandaceae	6	1.17	1712.61	0.85	285.44
Kygelariaceae	2	0.39	1625.95	0.81	812.98
Lauraceae	87	16.99	59572.52	29.54	684.74
Magnoliaceae	4	0.78	1376.34	0.68	344.08
Melastomaceae	22	4.30	2028.58	1.01	92.21
Meliaceae	12	2.34	9778.69	4.85	814.89
Mimosaceae	2	0.39	824.21	0.41	412.11
Moraceae	12	2.34	1398.39	0.69	116.53
Myricaceae	5	0.98	1503.95	0.75	300.79
Myristicaceae	1	0.20	45.84	0.02	45.84
Myrsinaceae	7	1.37	734.92	0.36	104.99
Myrtaceae	21	4.10	6401.24	3.17	304.82
Oleaceae	20	3.91	5648.98	2.80	282.45
Podocarpaceae	4	0.78	1034.90	0.51	258.72

Table 3.5. Abundance and basal area of tree families in botanical plots at Khau Ca (continued)

Family	No.of stems	% of stems	BA	%TBA	Mean BA
Rhizophoraceae	1	0.20	48.55	0.02	48.55
Rosaceae	4	0.78	669.15	0.33	167.29
Rubiaceae	35	6.84	7707.00	3.82	220.20
Rutaceae	6	1.17	600.00	0.30	100.00
Samydaceae	1	0.20	32.79	0.02	32.79
Sapindaceae	6	1.17	2224.22	1.10	370.70
Sapotaceae	1	0.20	581.73	0.29	581.73
Sarcospermaceae	6	1.17	3530.64	1.75	588.44
Stalhyllaceae	3	0.59	559.03	0.28	186.34
Sterculiaceae	3	0.59	3598.98	1.78	1199.66
Styracaceae	11	2.15	881.49	0.44	80.14
Taxaceae	1	0.20	58.87	0.03	58.87
Theaceae	12	2.34	4294.96	2.13	357.91
Tiliaceae	1	0.20	1074.49	0.53	1074.49
Ulmaceae	11	2.15	9500.62	4.71	863.69
Urticaceae	22	4.30	2035.02	1.01	92.50
Verbenaceae	11	2.15	8046.70	3.99	731.52

BA: Basal area

%TBA: Percent of total basal area

Mean BA: Mean basal area (cm²)

Table 3.6. Twenty nine commonest tree species in 58 plots at Khau Ca Forest

Family/Species	No. of stems	% of BA stems	%TBA
Hamamelidaceae			
<i>Mytilaria laosensis</i>	43	8.40	5732.25
Lauraceae			
<i>Machilus bonii</i>	33	6.45	24736.36
Urticaceae			
<i>Pouzolzia sanguinea</i>	22	4.30	2035.02
Fabaceae			
<i>Quercus chrysocalyx</i>	18	3.52	10000.91
Melastomaceae			
<i>Allomorpha arborescens</i>	17	3.32	1793.48
Oleaceae			
<i>Osmanthus pedunculatus</i>	17	3.32	3626.66
Rubiaceae			
<i>Gardenia sootepensis</i>	14	2.73	3003.08
Annonaceae			
<i>Polyalthia lauii</i>	11	2.15	914.11
Styracaceae			
<i>Alniphyllum fortunei</i>	11	2.15	881.49
Lauraceae			
<i>Cryptocarya chinensis</i>	10	1.95	8234.25
Ulmaceae			
<i>Celtis sinensis</i>	10	1.95	8877.35
Clusiaceae			
<i>Garcinia fagraeoides</i>	8	1.56	1586.47
Myrtaceae			
<i>Syzygium cumini</i>	8	1.56	1627.63
Actinidiaceae			
<i>Saurauja tristylla</i>	7	1.37	2007.16
Ebenaceae			
<i>Diospyros pilosiuscula</i>	7	1.37	4823.55
Fabaceae			
<i>Quercus variabilis</i>	7	1.37	5114.77
Myrtaceae			
<i>Syzygium zeylanicum</i>	7	1.37	3778.70
Verbenaceae			
<i>Premna aff. chevalieri</i>	7	1.37	5034.45
Lauraceae			
<i>Neolitsea ellipsoidea</i>	6	1.17	14888.71
Rubiaceae			
<i>Psydrax dicoccos</i> var. <i>dicoccos</i>	6	1.17	608.36
<i>Wendlandia paniculata</i>	6	1.17	921.11

Table 3.6. Twenty nine commonest tree species in 58 plots at Khau Ca Forest (continued)

Family/Species	No. of stems	% of BA stems	%TBA
Sarcospermaceae			
<i>Sinosideroxylon wightianum</i>	6	1.17	3530.64
Aceraceae			
<i>Acer oliverianum</i>	5	0.98	1376.43
Fabaceae			
<i>Ormosia pinnata</i>	5	0.98	288.64
Lauraceae			
<i>Machilus sp</i>	5	0.98	1610.29
Melastomaceae			
<i>Memecylon sphaerocarpum</i>	5	0.98	235.10
Meliaceae			
<i>Aglaia globosus</i>	5	0.98	1753.08
Myricaceae			
<i>Myrica esculenta</i>	5	0.98	1503.95
Sapindaceae			
<i>Amesiodendron chinense</i>	5	0.98	2048.43

BA: Basal area

%TBA: Percent of total basal area

Mean BA: Mean basal area (cm²)

3.4.6. Phenology

Phenological characteristics of 512 tagged trees representing 136 species from the botanical plots were investigated in the Khau Ca Forest. Observations were recorded monthly from September 2005 through September 2006. Each tree was recorded for the presence or absence of mature leaves, young leaves, flowers, and fruits (Figure 3.9).

The production of young leaves and leaf buds was high throughout the course of the study (more than 90% of trees produced leaves, Figure 1). Young leaves were observed less in October 2005 and January 2006 (92.4% and 94.1%, respectively), corresponding

to the early and middle of the dry season. In contrast to Tat Ke Sector, there was little correlation between young leaf production and rainfall; Spearman's rank correlation between percent individuals in young leaf for each month and mean monthly rainfall was $r_s = 0.284$, $n=13$, $p>0.05$).

Flowering occurred year-round, but was especially intense during the dry season (from October to April, Figure 3.9). A distinct peak of flowering during the course of the study was at the end of the dry season (April 2006) when 19.73% of trees produced flowers; there was a second peak early in the dry season (November 2005, 6.45%). Spearman's rank correlation between percent individuals in flower for each month and mean monthly rainfall was $r_s = -0.412$, $n=13$, $p>0.05$.

Fruiting was also recorded throughout the study, but more trees produced fruits during wet than during dry months (Figure 3.9). Fruiting was also bimodal with a major peak occurring at the end of the rainy season (September 2006) when 19.4% of trees produced fruits, and a minor peak during the middle of the dry season (January 2006) when 6.4% of trees bore fruits. There was no significant correlation between percent individuals in fruit each month and mean monthly rainfall ($r_s = 0.429$, $n=13$, $p>0.05$).

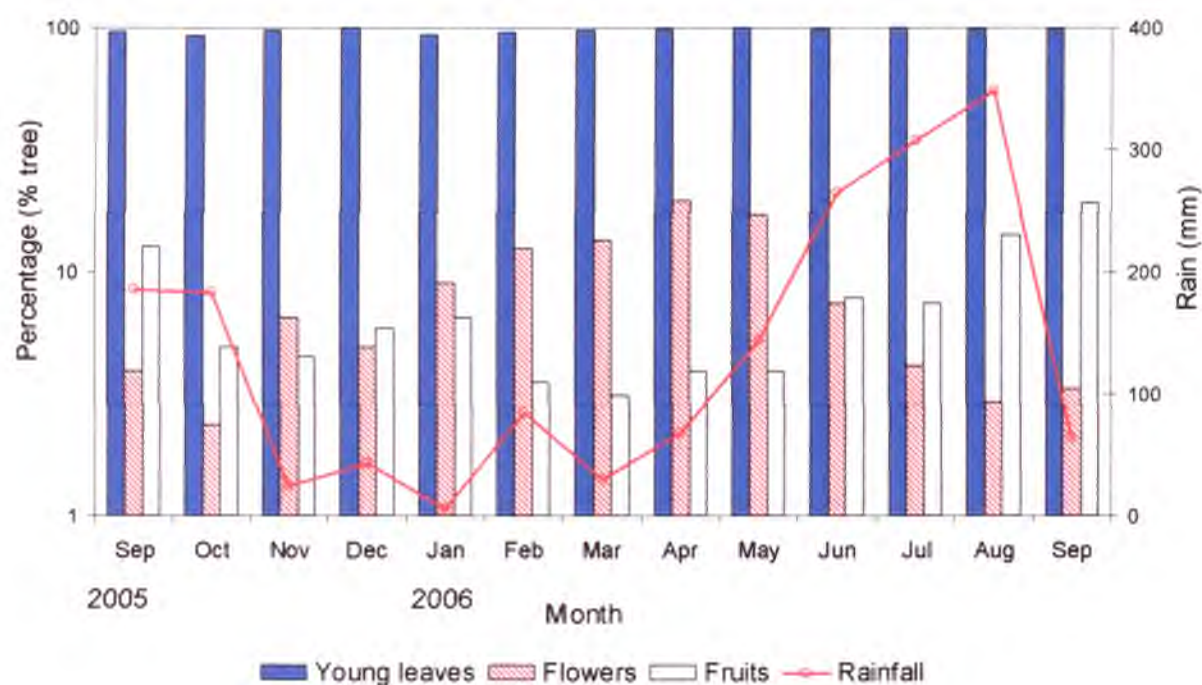


Figure 3.9. Phenological patterns at Khau Ca Forest (n=512)

3.5. Comparison between Tat Ke Sector and Khau Ca Forest

3.5.1. Botanical structure

There were differences in the number of trees, densities and mean girth of trees between two study sites. Compared to Tat Ke Sector, the number of trees meeting the sample criterion of 19cm g.b.h. in plots at Khau Ca Forest was less (512 compared with 612 trees). A possible explanation for this difference may simply be that Tat Ke Sector had a higher number of plots sampled and a larger area than Khau Ca Forest (64 compared with 58 plots). Tat Ke Sector had a total of 956 trees per hectare, while this Figure was 882 trees per hectare at Khau Ca Forest. The mean girth of trees at Tat Ke Sector (60cm) was higher than Khau Ca Forest (54.7cm). Distribution of girths at breast height of trees sampled at Tat Ke Sector was closely similar to results from Khau Ca Forest; most trees were in the range of 19 to 110cm (Tat Ke Sector) and 130cm (Khau Ca Forest), which contributed to more than 90% of the total trees sampled.

3.5.2. Botanical composition

Although Tat Ke Sector had more species than Khau Ca Forest (151 species compared with 136 species), there was only a small difference in number of families (50 and 49 families, respectively). The ratios of trees/species and species/family at Tat Ke Sector were closely similar to Khau Ca Forest (4 trees/species and 3 species/family compared with 3.7 trees/species and 2.8 species/family, respectively).

Tat Ke Sector had a smaller number of commonest families than Khau Ca Forest (24 and 29 families). Thirty-nine families were common to both areas in total; these accounted for about 89.8% of total stem-number and 84.02% of total basal area at Tat Ke Sector and 91.80% of total stem-number and 92.21% of total basal area at Khau Ca Forest. Moraceae (25.82%) contributed the highest proportion of stem-number to the total trees sampled at Tat Ke Sector, while at Khau Ca Forest this was Lauraceae (16.99%). If basal area is considered, Tiliaceae (25.68%) contributed the largest proportion of the basal area at Tat Ke Sector, whereas at Khau Ca it was Lauraceae (29.54%).

Tat Ke Sector had 28 common species, similar to Khau Ca Forest's 29 species, but they shared only four species in common: *Garcinia fagraeoides* (Clusiaceae), *Pouzolzia sanguinea* (Urticaceae), *Saurauja tristylla* (Actinidiaceae), and *Syzygium zeylanicum* (Myrtaceae). This may result from the difference in geology and soil between sites. Khau Ca Forest is restricted to limestone hills, whereas the forest at Tat Ke Sector is distributed on both limestone hills and soil mountains. At Tat Ke Sector the commonest tree species in terms of stem-number was *Streblus macrophyllus* (Moraceae) and the tree with the largest proportion of total basal area was *Excentrodendron tonkinensis* (Tiliaceae); at Khau Ca the commonest tree in terms of stem-number was *Mytilaria*

laosensis (8.40%) and the tree with largest proportion of total basal area was *Machilus bonii* (12.27%).

3.5.3. Phenology

The phenological patterns in Tat Ke Sector were close to those in Khau Ca Forest. The production of young leaves was high through the year. At Tat Ke Sector young leaves were observed less at the end of the dry season (from March to May), while at Khau Ca trees produced fewer young leaves at the early and middle of the dry season (from October to January). There was no significant difference in young leaf production (Mann-Whitney $U=23$, $n_1=11$, $n_2=13$, $p>0.05$) or in flower production between the two sites (Mann-Whitney $U=66$, $n_1=11$, $n_2=13$, $p>0.05$). Both areas exhibited bimodal flowering with a common peak in the early part of the dry season (November) and other peaks in June (Tat Ke Sector) and in April (Khau Ca Forest). Fruiting was also bimodal at the two sites, but fruiting peaks were considerably different: major and minor peaks of fruiting in Tat Ke Sector were in November and July, while in Khau Ca Forest they were in September and June, respectively. There was no significant difference in fruit production between two sites ($U=64$, $n_1=11$, $n_2=13$, $p>0.05$).

3.6. Summary

The topography of Tat Ke Sector and Khau Ca Forest is very similar. They were characterized by steep rugged limestone hills, but the forest in Tat Ke is also associated with mountains. Both Tat Ke Sector and Khau Ca Forest are influenced by a monsoon tropical climate. Tat Ke Sector had a lower mean temperature (14.9°C) and received less rainfall (293mm) than Khau Ca Forest (22.9°C and 436mm, respectively) during the cold and dry period. The mean temperatures between two sites were very similar during the wet and hot season (30.4°C , Tat Ke Sector and 29.7°C , Khau Ca Forest), but Khau Ca Forest (1128mm) received less rainfall than Tat Ke Sector (1247mm) during these months.

The average number of trees and species per plot meeting the sample criterion of 19cm girth at breast height was very similar between sites. Tat Ke Sector (151 species, 50 families) had more tree species and families compared with Khau Ca Forest (136 species and 49 families). This is probably because there were more plots sampled, and topography was more diverse at Tat Ke Sector. The production of young leaves, flowers and fruits at the two sites was correlated with rainfall, ranging from weak to moderate correlations. There was no significant difference in phenological patterns between the two sites, though differences in timing of flower and fruit peaks were recorded between sites.

Chapter 4

Social organization and behavior

4.1. Introduction

The subfamily Colobinae exhibits a great variety of social organization. Species can form one-male and multi-male units (Eisenberg et al., 1972; Kirkpatrick, 1999; Newton & Dunbar, 1994; Struhsaker & Leland 1987; Yeager & Kool, 2000), or live in monogamous pairs (*Presbytis potenziani* and *Simias concolor*, Watanabe, 1981). Some species display great flexibility in their social organization with different one-male units (OMUs) and extra males frequently coming together to exhibit a secondary level of social organization, the band (*Nasalis larvatus*, Bennett & Sebastian, 1988; Boonratana, 1993; 2002). A number of environmental factors may contribute to these variations: habitat type and quality, abundance and availability of food resources, presence of predators and competitors, population density, and phylogeny (Clutton-Brock & Harvey, 1977; Eisenberg et al., 1972; Struhsaker, 1969; Wrangham, 1987).

Colobine social interactions tend to be affiliative and relatively frequent within units, whereas those that occur between groups tend to be rarer and more aggressive (Newton & Dunbar, 1994). Compared with cercopithecine society, interactions within colobine units seem to be relatively relaxed and obvious (Newton & Dunbar, 1994). Social grooming among colobines are mostly done by females. Males are rarely involved (Grueter, 2009; Kirkpatrick, 2007; Struhsaker & Leland, 1987); when they are, it is generally directed to adult females (Struhsaker & Leland, 1987). Alloparenting behavior has been reported in most colobines, with both juveniles (Grueter, 2009) and adult females exhibiting this behavior (McKenna, 1979; Newton & Dunbar, 1994; Yeager & Kool, 2000). Copulations initiated by females have been documented among colobines, especially Asian colobines (Kirkpatrick 2007; Newton & Dunbar ,1994; Yeager &

Kool, 2000). Birth and copulation seasons are found in some colobines (*Semnopithecus* spp., Borries et al., 1999; *Trachypithecus vetulus*, Rudran, 1973; *Trachypithecus pileatus*, Stanford, 1991), and last from two to six months (Kirkpatrick 2007). Agonistic interactions in general are less frequent among colobines than cercopithecines (Newton & Dunbar, 1994; Struhsaker & Leland, 1987); when they do occur, they usually involve male-male aggression during copulation and intergroup encounters (Struhsaker & Leland, 1987; Yeager & Kool, 2000).

Rhinopithecus avunculus typically live in tropical evergreen forests associated with karst limestone hills and mountains in northern Vietnam (Boonratana & Le, 1994; 1998a; Le & Boonratana, 2006). Compared with other species in the genus *Rhinopithecus*, the social organization and behavior of the *R. avunculus* is relatively poorly known, although Covert et al., (2008), Boonratana and Le (1994; 1998a), Nguyen (2000), Pham (1993; 1994; 2002), Le (2004; 2006) and Ratajszczak et al. (1990; 1992) have all presented preliminary data.

The exact nature of the social organization of *R. avunculus* remains in dispute among different authors. Ratajszczak et al. (1990; 1992) and Le et al. (2006) reported that the basic social structure consists of multi-male and multi-female units. In contrast, Boonratana and Le (1994; 1998a) and Dong and Boonratana (2006) reported that the species lives in OMUs comprising a single adult male, several adult females and their offspring, and extra males forming loosely-bonded AMUs; with the different units frequently coming together to sleep, travel and feed, exhibiting a secondary level of social organization, the band.

The size of OMUs of *R. avunculus* is reported as similar to those of Chinese taxa, ranging from 10 to 20 animals at Na Hang (averaging 14.8; Boonratana & Le 1994). Band size, however, appears to be smaller than in Chinese species, ranging from 22 to 81 individuals at Khau Ca (Dong & Boonratana, 2006), and between 23 and 72 at Na

Hang (Boonratana & Le, 1998b). Bands appear to be less cohesive than those of Chinese snub-nosed monkeys; units frequently coalescing or splitting up into small units (Boonratana & Le, 1994; 1998a), although factors that drive fission and fusion in *R. avunculus* bands remain unclear.

Information on social behavior is relatively meager. Grooming rates are high at Na Hang (9.7% of behavioral activities recorded, Boonratana & Le, 1998a), compared with the colobine species (*Nasalis larvatus*: 2.2%, Boonratana, 1994; *Rhinopithecus bieti*: 6.1%, Kirkpatrick, 1996; *R. bieti* at Samage: 6.7%, Grueter, 2009). Most involves allogrooming, and adult females are the groomers on all occasions. Play, which makes up 2.9%, is observed only in juveniles and infants. Vigilance contributes to 23.3% of total activity (Boonratana & Le, 1998a).

This chapter describes the social organization of *R. avunculus* in terms of demographics (band and unit sizes and composition) and behaviors with respect to agonistic interaction, grooming, sexual behavior, playing, vigilance, and initiation of group movement at Tat Ke and Khau Ca.

4.2. Methods

4.2.1. Study sites

I studied the social organization and behavior of *R. avunculus* at two study sites: Tat Ke Sector, Na Hang NR and Khau Ca HSCA over the course of twenty- four month (see detailed descriptions of the study sites in chapter 3). Over the course of eleven-month study at Tat Ke Sector (between September 2004 and July 2005), only nine contact hours were made. Seven out of which were visible. High human activities and reduced population size are likely to be main explanations for these small contact hours and sample sizes. Few data available on social organization and behavior of *Rhinopithecus avunculus* were therefore obtained. For above reasons, I had to move to another known site of *R. avunculus*: Khau Ca HSCA. A total of 241 contact hours was made during the course of the thirteen-month study at Khau Ca (between September 2005 and August 2006), 195 of which was visual contact. The number of scan observations was 397 observations.

4.2.2. Habituation

Rhinopithecus avunculus at both study sites were not habituated to humans when this study began. I attempted to habituate *R. avunculus* so as to reduce bias in observations. The animals, however, would either flee away immediately or stay still for a long period (from 1 to 2 hours). During encounters, they often displayed some certain behavior such as stopping what they are doing; crouching and looking at observers; and making continuous alarm calls when observers approached to close range. This would cause bias in data as only two activities were recorded. Thus, to collect data without bias, dull colored clothes were worn; observers were often hidden in foliage and remained distance with the animals as long as possible; and observations were often made from

the opposite hills. This allowed observers to have a wider range of view to study animals and study animals to exhibit natural behavior.

4.2.3. Data collection

Group sizes, band sizes, and their composition were estimated based on mean of direct counts and individuals heard and branch movements when the monkeys crossed open areas between canopies, or when a group was feeding or resting in one tree.

Given the species' low population size and rarity, we used both scan and *ad libitum* sampling methods (Altmann, 1974) to obtain information on social behavior. We made attempts to follow the study animals, but full day observations from dawn to dusk were impossible on most occasions because of their shyness to observers, the difficulty of the terrain, and poor visibility. Instead, I chose vantage points on adjacent hill and mountain tops and ridges to make observations at a distance of 30 to 100m. This allowed the observers to see more animals at one time than at close range, and allowed the monkeys to display their normal behavior i.e. without being distracted or influenced by the observers' presence.

All observations were made using Bushnell 10x42 binoculars. Scan samples were recorded during a 2-minute period at every 15 minute intervals. Each observation was recorded three seconds after an individual was sighted so as to reduce bias towards individuals engaged in eye-catching activities (following Boonratana & Le, 1994). An observation refers to one animal recorded during each scan (following Bennett 1983; Boonratana, 1993; Boonratana & Le, 1994). Activity categories used in this study are presented in Table 4.1. *Ad libitum* was used to record events that occurred outside the scan sampling period some rare behavior such as sexual behavior. Data recorded during each scan sample included date, location (name of area if known), weather, location of the group encountered, time, age and sex of observed individual, identity of observed

individual, if known, behavior, age and sex of the individual nearest to the observed individual, the distance from the observed individual to the nearest neighbor, the number of other group members within 2.5 and 5m of the observed animal and height of observed individual above ground.

Age/sex categories used in this study are presented in Table 4.2. Adult males and females were easy to distinguish in the field because of their differences in body size and pelage coloration features. Juvenile and infants of the two sexes, however, were very difficult to distinguish in the field except at close distance (30-40m). For the purposes of scans and data analysis, juvenile males and females were therefore collectively regarded as “juveniles”. Similar methodology was applied for infants.

4.2.4. Data analysis

In each scan, it was possible to see more animals engaging in conspicuous activities (e.g., traveling) than in less conspicuous activities (e.g., resting). To reduce this bias, the number of individuals recorded in each scan was weighted, such that each scan contributed one point to the dataset, irrespective of how many animals were seen during the scan. Weighting involves dividing each observation in a scan by the total number of observations made in that scan. Therefore, the combined weighting for each scan is one (following Kavanagh, 1977; Bennett, 1983; Boonratana, 1993). Further, the percentage of individuals and age/sex classes was calculated by month for monthly values. Monthly values were then averaged to give annual values (following Clutton-Brock, 1977b; Kirkpatrick, 1996).

Table 4.1. Activity categories used in this study (adapted from Boonratana and Le, 1993).

Activity	Definition
Resting	Subject sitting but not engaged in any other activity
Lying	Subject lying down and not engaged in any other activity
Traveling	Any movement between two points. Sub-divided into 1. Travel within the same tree; 2. Travel between trees; 3. Travel on the ground
Grooming	Any scratching or cleaning action using hands, feet or mouth. Sub-divided into 1. Autogroom; 2. Subject allogroom another; 3. Subject being allogroomed
Feeding	Subject manipulating, putting into mouth or masticating food items
Suckling	Subject with nipple of adult females in mouth
Clinging	Subject clinging to another individual with both hands. The subject's weight may or may not be supported by the other individual
Playing	Chasing, wrestling, exploratory and other movements which apparently are not goal-directed. Play can be solitary or social i.e. involving two or more individuals
Mounting	Subject positions itself behind and above another, with ventral-dorsal contact. Sub-divided into 1. Male mounting the female with penile penetration; 2. Female being mounted by the male with penile penetration; 3. Homosexual mounting without penile penetration; 4. heterosexual mounting without penile penetration
Agonistic	Subject delivers or receives act of aggression. Sub-divided into 1. Without physical contact e.g., deliver open-mouth facial threat; 2. with physical contact e.g., grab, lunge or bite.
Vocalisation	Any call produced by subjects. Includes "honk", grunt, bark, cough, squeal and scream.

Table 4.2. Age/sex categories used in this study (adapted from Boonratana and Le, 1993).

Category	Criteria
Adult male	The largest animal of group with robust head and large body. He has pink thick lips and dark coloration above upper lip. Face shape is square-like. The ears have creamy-white tufts. Hair on the back of head and neck is blackish brown. Orange patch on the throat is prominent. There is a blue V-shape on perineum region. Black penis is contrast with large creamy-white testicles. Tail is long with basically dorsal blackish gray and ventrally long white hairs arising from the base to just above white tufted tip.
Adult female	Large animals. Compared to adult male, she has a smaller size and slimmer body. Orange patches on either side of belly and inner thighs are conspicuous. Black nipples are contrast with creamy-white chest hair. There is no a blue V-shape on perineum region. White hairs on the ventral tail are shorter.
Sub-adult male	Male more than two-thirds of full body size of adult male but brown hair on the back of head and neck is not as conspicuous as adult male. Hairs on the tail are shorter and smoother.
Sub-adult female	Female more than two-thirds of full body size of adult female but brown hair on the back of head and neck is not as conspicuous as adult female. Hairs on the tail are shorter and smoother.
Juvenile	Medium-sized animals. Orange patch on the throat is less prominent. Outer limbs are whitish gray, gradually turning black. Hairs on the tail are short and smooth. Tufted tip is not as hirsute as in adults. They are usually observed actively playing.
Infant	Small individuals. The naked facial skin around the eyes and mouth is pale bluish white. Orange patch on the throat is not conspicuous. Back of the head and back are from light grey to grey. Outer limbs are whitish gray. They were observed much playing with other infants or juveniles, but spend most of their time with their mothers.
Newborn	Smallest animals. Pelage is white with grayish white patches on the back of head and back. They were observed clinging their mothers at all time.

4.3. Results

4.3.1. Group size and composition

Tat Ke Sector

Sizes and age/sex composition of bands of *R. avunculus* in Tat Ke Sector are presented in Table 4.3. The highest minimum count for the band at Tat Ke Sector is 17 individuals, but a total estimate of 22 is made, based on evidence of branch movements of about four to five animals traveling behind this band. This estimate is likely to be the entire population of *R. avunculus* at Tat Sector because there was no evidence of the if existence of other bands during the course of the study.

One-male unit sizes ranged from six to eight with an average of seven individuals (Table 4.4). Adult sex ratio was 1:3.5; Adult/immature ratio was 1:0.6; the infant/adult female ratio was 1:0.1. On two occasions, AMUs were observed, consisting of five individuals (two adult males and three juvenile males). These units can be regarded as a single unit since I encountered them on two consecutive days at the same area.

Khau Ca HSCA

Band sizes and their age/sex composition, based on direct counts at Khau Ca Forest, are presented in Table 4.5. The size of the bands ranged from 22 to 81 individuals and appeared to be dependent on the number of associated OMUs and AMUs. The highest minimum count for the band at Khau Ca was 81 individuals in April 2006, and this included seven adult males, 25 adult females, and six newborns. This count may underestimate the band size because some infants clinging to females, and animals traveling in dense foliage, were missed. Our estimate of the size of the band was about 90 individuals. The lowest minimum count for a band was 22 individuals in April 2006, consisting of two adult males, seven adult females, and two newborns.

The sizes and age/sex composition of one-male units of *R. avunculus* are presented in Table 4.6. These Figures are selected from direct counts of independent one-male units during the course of the study. OMU sizes ranged from seven to 15 individuals per group and averaged 11.3. The age/sex ratio of the OMUs was 1 adult male, 3.8 adult females, 1.5 sub-adult females, 2.5 juvenile females and 2 infants. Only one AMU of 7 individuals, comprising one adult male, two sub-adult males and four juvenile males, was observed during the course of the study; the size of this AMU was likely underestimated because it often joined with large bands (several OMUs) for traveling, feeding and resting; group spread was large; and it was very difficult to distinguish between juvenile males and females.

4.3.2. Social organization

The basic social unit of *R. avunculus* at Tat Ke was the one-male unit. It seems likely that the Tat Ke band contained two OMUs (Table 4.4) and one AMU. No solitary individuals were seen during the course of the study.

The basic social unit of *R. avunculus* at Khau Ca was also the OMU. The Khau Ca band contained at least five to six OMUs and one AMU (Table 4.6). It was relatively easy to recognize OMUs of *R. avunculus* when they foraged independently (Figure 4.1), but their distances between them were not clear in most cases, when they associated with one or more other units to form large bands. Independent OMUs of seven to 15 individuals of *R. avunculus* were sometimes encountered, but the AMU was always seen in association with one or more OMUs.

On three occasions, I encountered solitary adult males and sub-adult females. An individual was recorded as a solitary when it was further than 20m from the nearest conspecific (following Boonratana, 1993). On two occasions, lone adult males were

observed traveling about 50 to 70m away from the band, and a subadult female was observed feeding alone once.



Figure 4.1. One-male unit of *R. avunculus* during resting time in Khau Ca.

Table 4.3. The three highest counts of the band and their age/sex composition at Tat Ke.

Date	AM	AF	JM	JF	J?	IF	Newborn	Unknown	Size
13 Nov 2004	3	5	0	0	3	2	0	1	14
22 Nov 2004	4	5	0	0	4	2	0	1	16
20 Feb 2005	2	7	0	0	4	2	0	1	17

AM: Adult male AF: Adult female JM: Juvenile male JF: Juvenile female IF: Infant ? Sex unknown

Table 4.4. Age/sex composition different units of *R. avunculus* at Tat Ke.

Unit ID	AM	AF	JM	JF	J?	IF	Newborn	Unknown	Size
OMU1	1	4	0	0	0	1	0	0	6
OMU2	1	3	0	0	4	0	0	0	8
AMU1	2	0	3	0	0	0	0	0	5

AM: Adult male AF: Adult female JM: Juvenile male JF: Juvenile female IF1: Infant ? Sex unknown

OMU: One-male unit AMU: All-male unit.

Table 4.5. Age/sex composition of the bands of *R. avunculus* at Khau Ca HSCA.

Date	AM	AF	SAM	SAF	JM	JF	J?	IF	Newborn	Unknown	Size
16 Sep 2005	2	12	0	5	0	2	4	4	0	2	31
16 Jan 2006	5	22	2	8	3	3	7	8	0	5	63
23 Mar 2006	4	15	0	8	0	5	4	5	3	3	47
11 Apr 2006	2	7	0	2	1	5	0	3	2	0	22
16 Apr 2006	7	25	4	10	4	2	6	12	6	5	81
15 May 2006	8	26	2	9	3	4	5	14	2	6	79

AM: Adult male AF: Adult female SAM: Sub-adult male SAF: Sub-adult female J?: Juvenile unknown sex
 JM: Juvenile male JF: Juvenile female IF: Infant

Table 4.6. Age/sex composition of the one-male units of *R. avunculus* at Khau Ca HSCA.

Unit ID	Date	AM	AF	SAM	SAF	JM	JF	J?	IF	Newborn	Size
OMU1	13 Sep 2005	1	2	0	1	0	3	0	1	0	8
OMU2	1 Nov 2005	1	5	0	2	0	3	0	2	0	13
OMU3	9 Apr 2006	1	6	0	1	0	3	0	2	2	15
OMU4	17 Apr 2006	1	2	0	2	0	1	0	0	1	7
AMU	16 Apr 2006	1	0	2	0	4	0	0	0	0	7

OMU: One-male unit AM: Adult male AF: Adult female JM: Juvenile male JF: Juvenile female
 ?: Unknown age/sex IF: Infant AMU: All-male unit

Group spread

Estimation of the band spread was quite difficult in the forest because of limited visibility. However, based on limited observations, the members of the band at Tat Ke were apparently spread over 30-50m. OMUs seem to spread over a smaller distance because they often rested and fed in one tree. The average group spread of OMUs and AMUs was 9.4m (ranged 4-15m, n=4).

At Khau Ca, the spatial distribution of *R. avunculus* varied between the bands and OMUs and appeared to be dependent on the number of associations of OMUs and the sizes of the OMUs. Band spread was estimated only when they were active (feeding and traveling time); the spread ranged from 30 (band of 22 individuals) to 200m (band of 81 individuals) (average 73.3m, n=18). For OMUs, it was easier to estimate the spatial distribution of groups because they were often feeding and resting in one or two adjacent trees (Figure 4.1). The average spread of OMUs was 12.6m (n=22, range 4-40 m). The AMU had an average spread of 7.7m (n=3, range 5-12m).

Intra-group associations

No data on intra-group associations were obtained in Tat Ke. Details of intra-group associations of one-male units at Khau Ca are presented in Table 4.7 and results can be summarized as follows:

1. The adult male spent more time than would be expected near to the adult females but less time than expected near to all the other age/sex classes.
2. Adult females spent more time than expected near to the adult males and to infants, but less time than expected to all other age/sex classes.
3. Subadult females spent more time than expected near to the adult females, but less time than expected to all other age/sex classes.

4. Juveniles spent more time than expected near to the adult males, adult females and juveniles, but less time than expected to all other age/sex classes.

5. Infants spent more time than expected near to the adult females and infants, but less time than expected to all other age/sex classes.

Intra-group spacing

Intra-group spacing results at Khau Ca are presented in Figure 4.3a&b, 4.4a&b, and 4.5a&b and can be summarized as follows:

1. The adult male was less than 2m from any other individual for more than 82.4% of the time. Most of that time was spent close to an adult female, especially an adult female that had an infant. Only on three occasions, from *ad libitum* observations, two adult males from different one-male units were observed within 5m in the same tree on three occasions, twice during traveling and once during feeding time, but this proximity was seen in short period of time (less than 2 minutes) because one male had to leave the tree because of chasing by the resident males.

2. Each adult female spent more time within 2m of another individual of the unit than the adult male did (86.1% and 82.4%, respectively), but less of her time between 0 and 1m of another individual of the unit than the adult male did (51.7% and 60.9%, respectively).

3. Each sub-adult female (78.6%) spent less of her time within 2m of another individual of the unit than any other age/sex class did, but a greater proportion of time more than 5m from all other unit members (8.2%).

4. Juveniles and infants spent more than 80% of their time within 2m of another group member. Infants spent the greatest proportion of time less than 2m within other

individuals of the (91.3%). Most of that time they were close to adult females, and sometimes other infants and young juveniles for play.

In summary, one-male units of *R. avunculus* in Khau Ca were cohesive. The members of OMUs spent more than 80% of their time within 2m of another individual except for sub-adult females.



Figure 4.2. One male unit of *R. avunculus* spacing during resting time in Khau Ca.

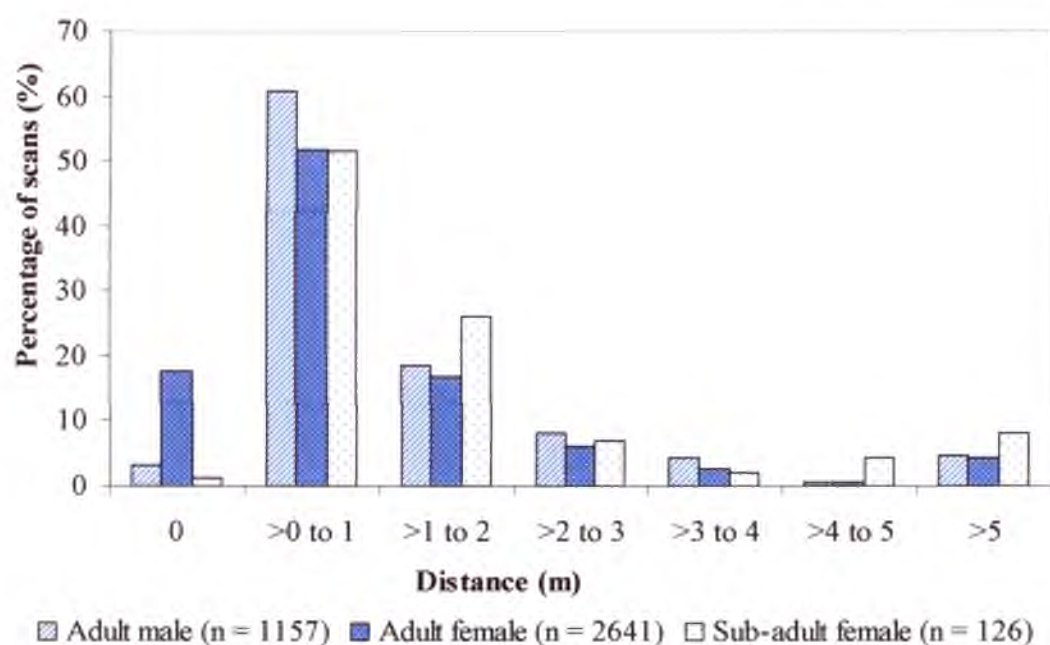


Figure 4.3a. Percentage of time for which the nearest neighbor was within the specified distance of the subject (Weighted data).

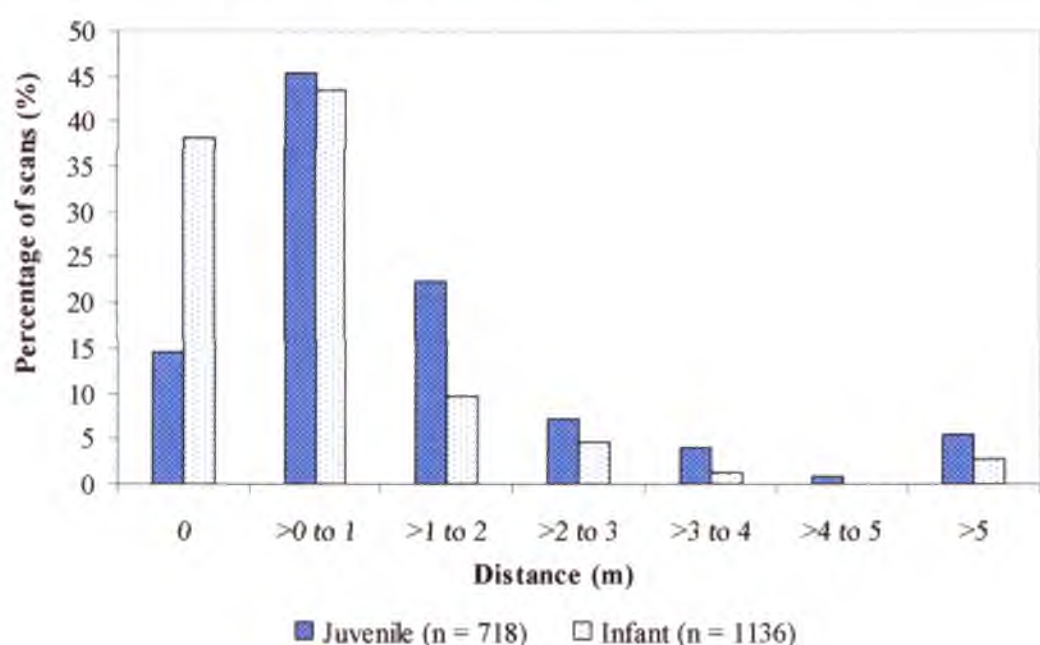


Figure 4.3b. Percentage of time for which the nearest neighbor was within the specified distance of the subject (Weighted data).

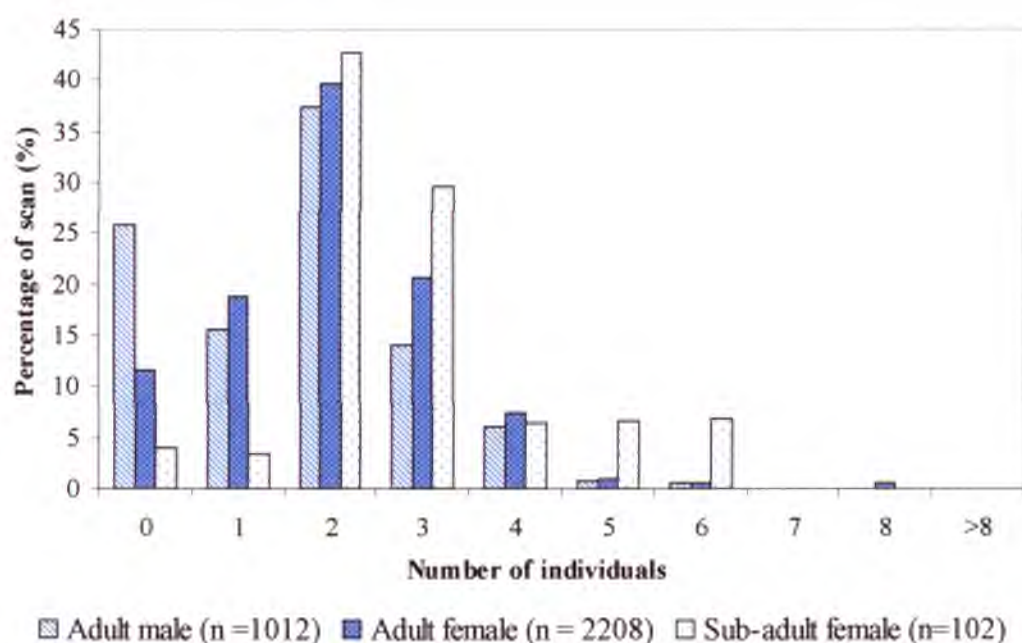


Figure 4.4a. Percentage of time for which different number of individuals were within 2.5m of the subject at Khau Ca (weighted data).

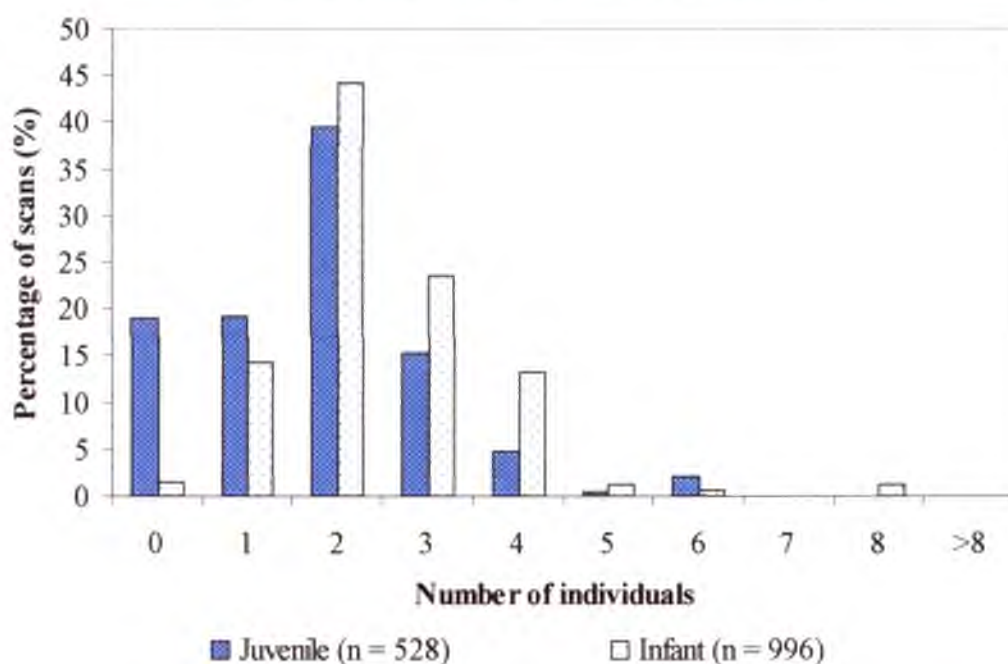


Figure 4.4b. Percentage of time for which different number of individuals were within 2.5m of the subject at Khau Ca (weighted data).

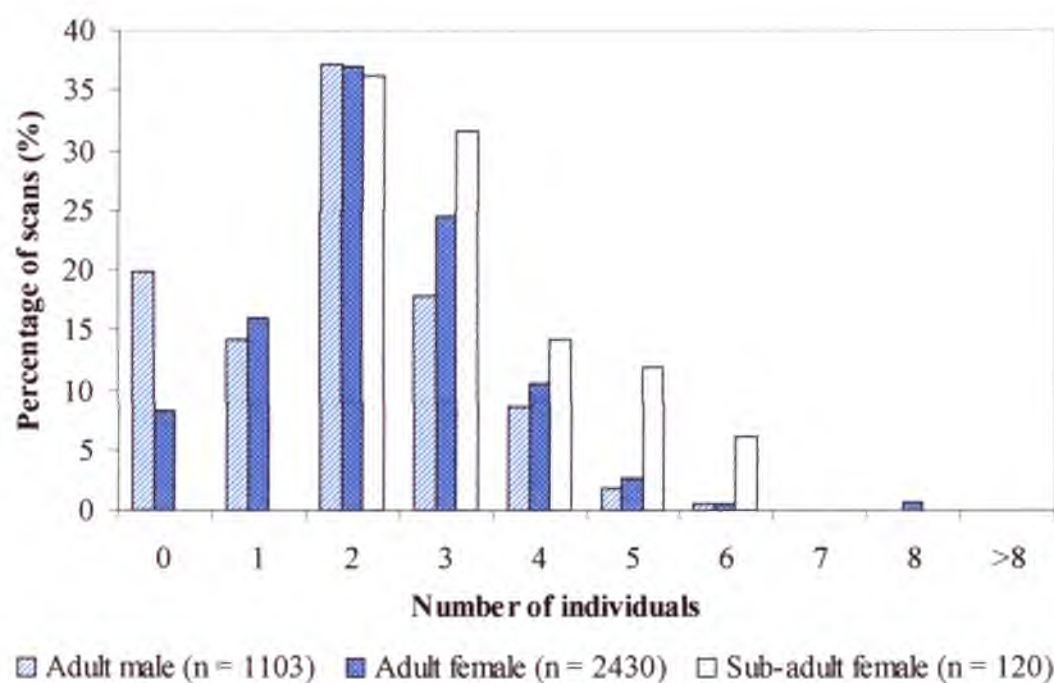


Figure 4.5a. Percentage of time for which different number of individuals were within 5m of the subject at Khau Ca (weighted data).

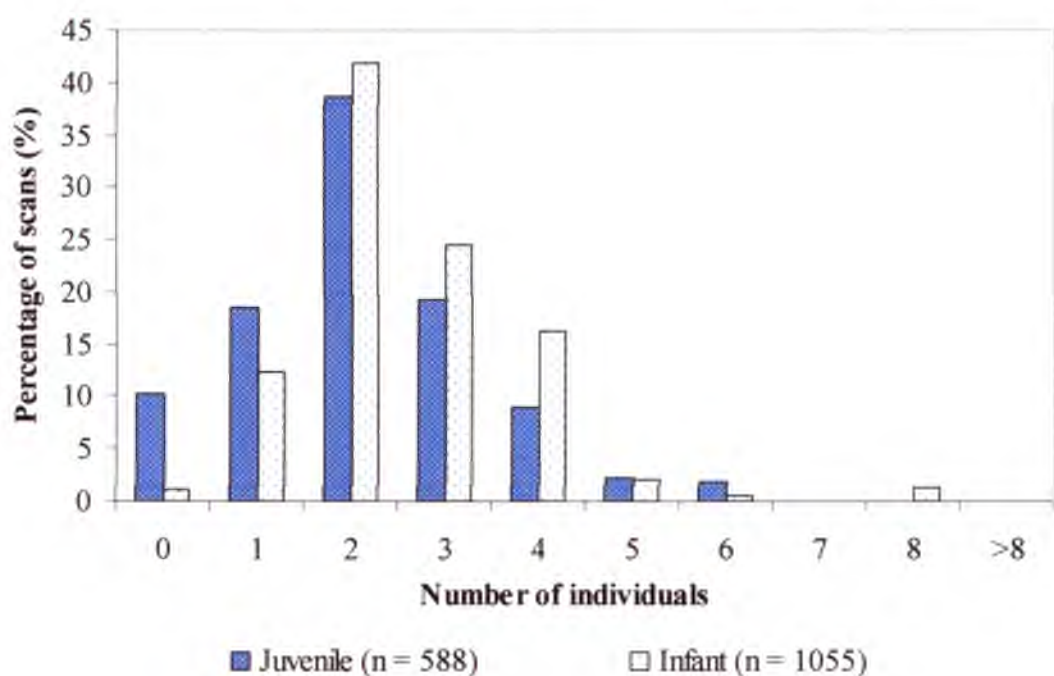


Figure 4.5b. Percentage of time for which different number of individuals was within 5m of the subject at Khau Ca (weighted data).

Table 4.7. Percentage of time for which individuals of different age/sex classes were nearest to the subject at Khau Ca Forest (n= 2263, weighted data).

Subject	AM		AF		SAF		J		IF		n
AM	–		87.5	(38.8)	0.1	(15.3)	7.1	(25.5)	5.3	(20.4)	457
AF	24.8	(10.2)	32.2	(28.6)	2.0	(15.3)	9.3	(25.5)	31.7	(20.4)	1060
SAF	4.8	(10.2)	95.2	(38.8)	0	(5.1)	0	(25.5)	0	(20.4)	39
J	15.6	(10.2)	48.6	(38.8)	0	(15.3)	34.0	(15.3)	1.8	(20.4)	267
IF	3.7	(10.2)	82.6	(38.8)	0	(15.3)	3.3	(25.5)	10.4	(10.2)	440

AM: Adult male AF: Adult female SAF: Sub-adult female J: Juvenile IF: Infant

*Number in parentheses: Expected values derived from the average composition of one-male units throughout the study.

Inter- unit associations

One-male and all-male units at Tat Ke were seen traveling, feeding and resting together on three occasions. The members of the bands were observed traveling in the same path when they crossed open canopy gaps. On three occasions, bands split up into small factions in different directions because of the observer disturbance. Data concerning time scale for fission and fusion, however, were not available because of incomplete full-day follows and small contact hours.

Like Tat Ke site, different OMUs and AMUs of *R. avunculus* at Khau Ca frequently aggregated in large bands ranging from 22 to 81 individuals for traveling, feeding, resting and sleeping. The duration of these associations remained unclear because of incomplete full-day follows, although it appeared to vary between the bands, and to be dependent on the sizes of the bands and frequently on human disturbance. On two occasions, a band of 81 individuals came together for one and half days before they split into at least four smaller units and traveled in different directions in the morning for feeding. On five occasions, a band of 22 individuals split up into two smaller units consequent on observer disturbance after two and three days in aggregation for traveling, feeding and resting.

The movements of the band appeared to be mostly initiated by adult females. I observed that adult females were often the first animals seen leaving the tree in which they had been resting and an adult male was often the last animal. Soft vocalizations "hoo, hoo" were emitted during travel by some members of the one-male units. It was very difficult to identify one-male units during travel, but it seemed to be clearer when they were at rest (see Figure 4.1)

4.3.3. Social behavior

Grooming comprised 5.1% (n= 136) of the total activity time. Of this, grooming dyads accounted for 67.6% (n = 92) of the time and the rest was autogrooming (32.4%, n=44); the former proportion, however, is likely an underestimate because most grooming dyads were taken during resting in dense foliage. All age/sex classes participated in allogrooming (Table 4.8). Adult females groomed and were groomed more time (73.9%, n= 68) than any other age/sex classes. Most of their grooming time was devoted to infants (41.1%, n= 28) and adult males (32.3%, n= 22). Adult males and juveniles (8.7%, n= 8) spent the same amount of time for grooming, but juveniles were groomed less time than adult males (13%, n=12 and 23.9%, n=22, respectively). Adult males and infants were seen being groomed by adult females only. Among the various age/sex classes, Sub-adult females participated in grooming the least time among age/sex classes (2.2%, n=2).

I observed male-male aggression when different units came together. During male-male aggression, one adult male often glared at the other followed by open-mouth threats. On one occasion (noted above), the resident male was seen chasing another male accompanied by loud roar and branch movements when the latter entered the feeding trees of the former one from the other trees. *Ad libitum* observations showed that these sounds were often heard in the late afternoon and early morning at sleeping sites before sleeping and feeding times respectively. Only on one occasion an adult female was observed chasing another female when she approached to the close proximity of an adult male.

Table 4.8. Percents for grooming dyads seen during scan observations at Khau Ca.

		Groomee					Total
		AM	AF	SAF	J	IF	
Groomer	AM	0	8.7	0	0	0	8.7
	AF	23.9	10.9	0	8.7	30.4	73.9
	SAF	0	2.2	0	0	0	2.2
	J	0	4.3	0	4.3	0	8.7
	IF	0	6.5	0	0	0	6.5
	Total	23.9	32.6	0	13.0	30.4	100.0

AM: Adult male AF: Adult female SAF: Sub-adult female
 J: Juvenile IF: Infant

Although I observed infants throughout the course of the study, there appeared to be a birth season in March, April and May of 2006. At least six newborns with white pelage (see Table 4.2 for description) were recorded at the end of March and the middle of April 2006, and another two newborns in May 2006. This number was likely underestimated because the newborn pelage was similar in color to the adult females' belly.

Only three copulations (one in May, 2005 and two in October 2006) were observed, by *ad libitum* sampling, during the course of the study. All copulations appeared to be single mount, and initiated by adult females. Duration of copulations ranged from 18 to 32 seconds (average 24 seconds). Typically, the adult female crouched, with her head down, on the supporting branch, and presented her perineum in a quadrupedal position. The adult male approached her from behind, grasped her hips with his hands, rested his feet on the supporting branch, and mounted her from the rear. This was followed by repeated thrusting movements by the adult male. Both the male and female, on all occasions observed were seen sitting close to each other after dismounting.

On two occasions, alloparental care by juveniles was observed during *ad libitum* observations. On the first occasion, a juvenile took the infant sitting next to an adult female and carried the infant for about ten meter before the adult female followed and took the infant back. On the second occasion, an adult female passed an infant to a juvenile, who carried it away from the adult female while she was sitting and looking the general direction of the juvenile and infant. Then after one minute, the adult female followed the juvenile, took the infant back, and went back to her previous sitting tree.

4.3.4. Other observed behaviors

Playing

Play occupied 3.7% (n= 68) of the total activity time, of which 94.3% (n=64) was social play. Only juveniles and infants were seen playing (Table 4.9). In general, juveniles spent less time playing than infants (41.4, n= 28 and 52%, n= 36, respectively). Subjects appeared to have preferred partners. Juveniles played with other juveniles for 40.1% (n= 28) time, whereas they spent only 6.6% (n= 6) time playing with infants. Similarly, infants played with other infants for 47.6% (n= 30) of the time.

Social play was seen during resting periods, in the early morning and late afternoon after animals woke up, and before resting time. Social play typically comprised two or more animals chased each other within or between trees, accompanied with noisy, conspicuous branch movements, jumping, leaping and sometimes dropping from higher to lower branches. In several cases, animals were observed hanging over the branches with one or two forelimbs, twisting the body around, and playing with each other with their feet.

Table 4.9. Percents for social and self-play of *R. avunculus* at Khau Ca (n = 68, weighted data).

Subject	Social playing		Self-playing		Total
	Juvenile	Infant	Juvenile	Infant	
Juvenile	40.1	6.6	1.3	0	48.0
Infant	0	47.6	0	4.4	52.0
Total	40.1	54.2	1.3	4.4	100.0

Vigilance

Vigilance accounted for 13.6% (n= 218) of the total activity time. An activity was recorded as vigilance when an animal scanned the surroundings, looked at objects more than five meter away, and looked at the observers (following Boonratana, 1993). Observers were included because the monkeys often displayed two particular behaviors when they detected observers they stopped what they were doing, stayed still, looked at the observers, and emitted loud alarm vocalizations “hoochk, hoochk” if observers kept their distance and did not make any movements; and they would flee immediately if the observers approached at close range or if the encounters were sudden.

All age/sex classes were involved in this activity. The proportion of time spent in vigilance, however, was different among them (Figure 4.5). Adult males (50.5%, n= 100) spent the greatest proportion of time in vigilance among age/sex classes, whereas this Figure was only 0.2% in the subadult female. (N.B. low sample size, n=1). For adults alone, adult males spent more time vigilant than adult females (Wilcoxon, $T^+ = 78$, n = 12, p = 0.002).

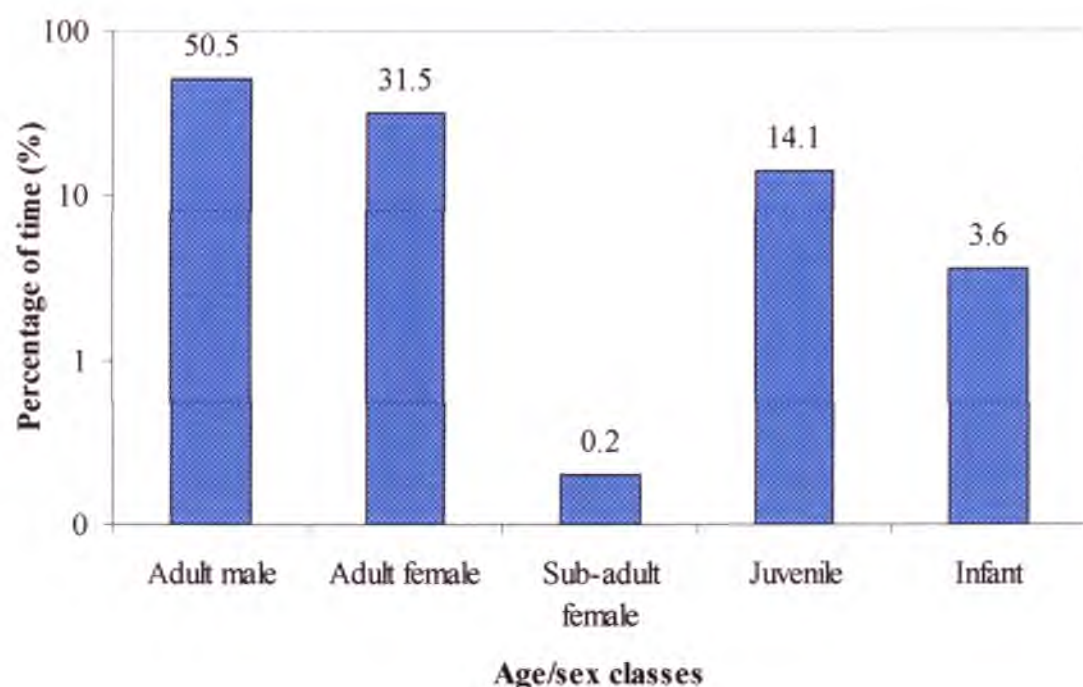


Figure 4.6. Percentage of time spent in vigilance by the different age/sex classes of *R. avunculus* at Khau Ca (n=218).

Members of *R. avunculus* at Khau Ca emitted at least three different types of vocalizations: soft “hoos”, loud and rapid “huchuks”, and rapid “chits”. Firstly, soft “hoo” vocalizations were emitted by a limited number of animals when OMUs were disturbed by the observers and had split up. Secondly, loud “huchuk” vocalizations were emitted whenever the monkeys detected the observers and other threats. Thirdly, rapid “chit” vocalizations were used when they were fleeing from unexpected encounters with observers.

All age/sex classes were seen emitting alarm vocalizations when they detected the observers. *Ad libitum* observations showed that different age/classes emitted different alarm vocalizations of different pitches. Adults of both sexes appeared to emit high-pitched vocalizations, but adult males have higher pitched vocalizations than females do. This sometimes allowed the observers to locate the adult males in the units.

Agonistic interactions made up only 0.4% (n= 5) of the total activity time of *R. avunculus* at Khau Ca. Most (60%) involved male-male aggression between OMUs (see above). On one occasion, I observed an adult male of *R. avunculus* emitted loud roar during an inter-group encounter with a group of *Macaca assamensis* at a resting tree at noon. All age/sex classes appeared to respond aggressively toward observers, except for infants clinging to adult females. Typically, they displayed by crouching, standing on all four limbs or on their hind limbs with their arms holding branches above, and gave open-mouth threats usually accompanied with loud vocalizations “hoochks”.

Resting comprised 31.9% (n= 647) time of the total activity. Of this resting time, 0.4% (n = 28) was rest-huddling. Rest-huddling was recorded when one or more individuals rest closely together while embracing another individual with their arms. All age/sex classes except for infants clinging adult females were seen huddling. The maximum number of individuals participated in huddling was five. During rest-huddling, individuals sat on the long branches, lowered their head on the back of the front individual, and embraced another individual with arms from behind.

Locomotion and terrestriality

R. avunculus exhibited six types of locomotion, including climbing, quadrupedal walking, semi-brachiation, hanging, bipedal movement, leaping or jumping (Figures 4.7; 4.8; 4.9). The monkeys appear to travel within the same tree by climbing, quadrupedal walking and semi-brachiation, bipedal movement and jumping. Hanging, leaping and jumping were used to travel between different trees. Sometimes I observed the monkeys hang from the terminal branches of one tree with one hand and reach out to grasp the terminal of branches of other tree with the other hand.

R. avunculus was for the first time observed traveling, resting and feeding on the ground at Khau Ca (n=6). All age/sex categories exhibited this behavior (Figure 4.10).

Sleeping site

The Tonkin snub-nosed monkey does not appear to have any fixed sleeping sites. Valleys were often used for resting and sleeping. However, I observed that the Tonkin Snub-nosed Monkey often come closer to the ground during resting and sleeping, usually 5 to 10m above the ground. During resting and sleeping, they would sit on the lower branches, frequently hidden within dense foliage and are very quiet (Figure 4.11). This may likely an adaptation to thermo-regulation and it may also be an anti-predator strategy.

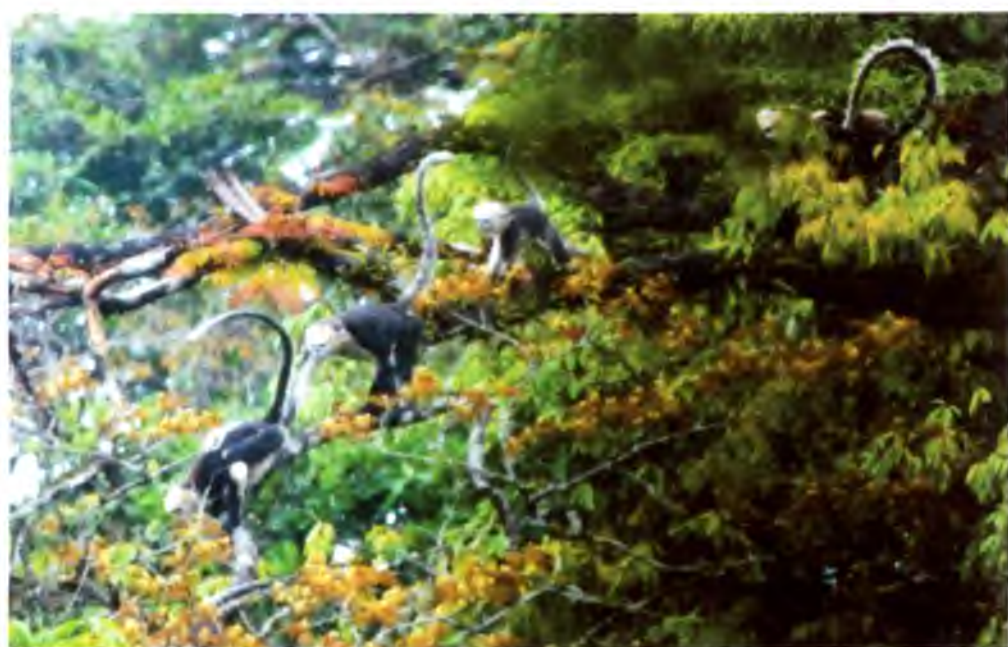


Figure 4.7. *R. avunculus* traveling within tree by quadrupedal walking.



Figure 4.8



Figure 4.9

Figure 4.8 & 4.9. *R. avunculus* exhibited vertical climbing and hanging.

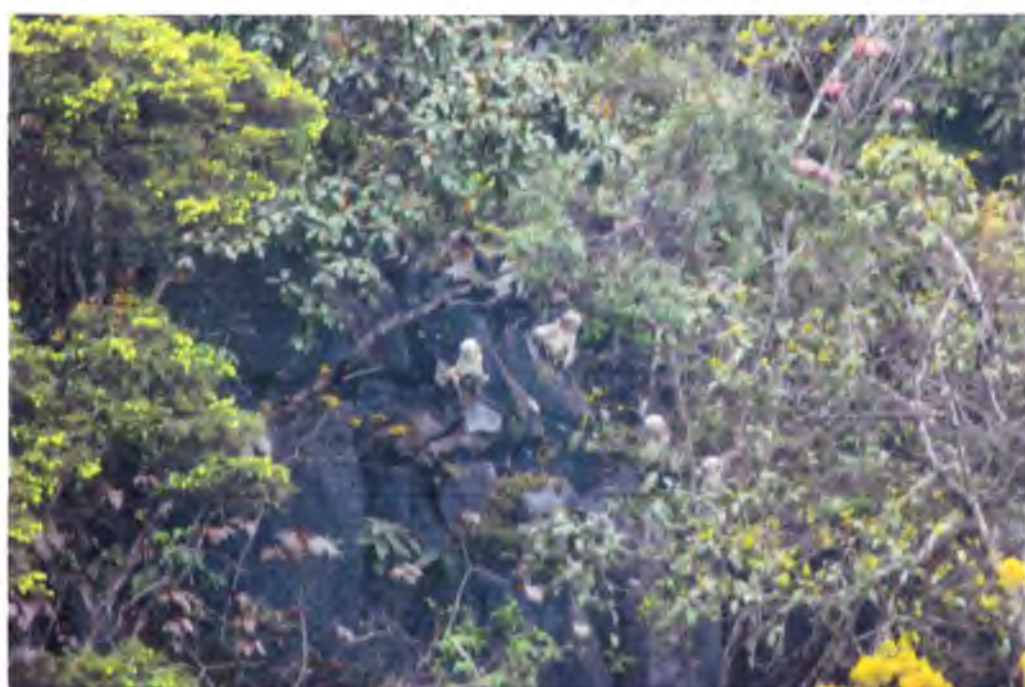


Figure 4.10. *R. avunculus* traveling and resting on the ground at Khau Ca.



Figure 4.11. *R. avunculus* resting on lower branches of the trees.

4.4. Discussion

4.4.1. Social organization

My results indicate that the basic social structure of *R. avunculus* at Tat Ke and Chau Ca is based on OMUs, with extra males forming AMUs. Different OMUs and AMUs frequently come together for feeding, traveling, resting and sleeping, suggesting a secondary level of social organization, the band. A similar finding was made in previous studies of *R. avunculus* at Na Hang NR (Boonratana & Le, 1994; 1998a), and this conclusion is consistent with findings on species of the genus *Rhinopithecus* in China (*R. brelichi*, Bleisch et al., 1993; Bleisch & Xie, 1998; *R. roxellana*, Ren et al., 1998; Tan et al., 2007; Zhang et al., 2006; *R. bieti*, Kirkpatrick, 1996; Kirkpatrick et al., 1998, Table 4.10), as well as some other Asian colobines (*Nasalis larvatus*, Bennett & Sebastian, 1988; Boonratana, 1993; 2002; *Trachypithecus pileatus*, Stanford, 1991). This is, however, in contrast to previous reports of multi-male and multi-female units (Le et al., 2006; Ratajszczak et al., 1990; 1992). Different results may be due to differences in the duration of observation and probably methodological differences. Ratajszczak et al., (1990; 1992), for example, reported based on brief observations and largely local reports. The most likely explanation for these discrepancies is that aggregations of different one-male units and all-male units may lead observers to mistakenly assume that they are seeing a single multi-male, multi-female unit (Boonratana, 1993; 2002; Boonratana & Le, 1994; Grueter, 2009; Yeager, 1990; Zhang et al., 2006).

The size of the band and unit of *R. avunculus* at Tat Ke is considerably smaller than those observed in an earlier study in the same site (Boonratana & Le, 1994; 1998a) (Table 4.10). These differences are likely due to hunting pressure. Hunting pressure can

strongly reduce primate population sizes (Cowlshaw & Dunbar, 2000; Mittermeier, 1987). This may be true for of Tat Ke. Hunting pressure seems to be very high here; team members often encountered groups of hunters in the forest and could hear from 5 to seven gunshots on a daily basis. Based on local reports, at least one adult female and a juvenile were killed in November 2004. Cowlshaw & Dunbar (2000) further suggest that smaller groups are more common in areas of heavy hunting.

Predation is another possible reason for the decreasing group size of *R. avunculus* at Tat Ke. It has been reported that leopard, clouded leopard, Asiatic golden cat, and raptors are all predators of *R. avunculus* (Le, 1973). No attack on *R. avunculus* was witnessed over the course of an 11-month study at Tat Ke, however, and large mammal densities appeared to be very low. Further, if predation does exist and foraging cost is low, group size may actually be larger to decrease predation risk (Chapman & Chapman, 2000; Wrangham, 1987). In contrast, the size of bands and one-male units at Tat Ke is smaller than that found in earlier studies. Predation pressure might therefore not be an influence on unit size at Tat Ke.

Food competition may also be a factor. In an attempt to explain the differences between the size of one-male units of *R. roxellana* at the Qinling and Shennongjia sites, Zhang et al. (2006) suggest that the lower population and even distribution of food resources in Qinling may result in less food competition, thus resulting in the smaller size of one-male units. The tropical forest of *R. avunculus*, however, may offer higher food quality and smaller food patches than at Shennongjia (Li, 2001); moreover, areas with high density of potential food resources tend to have larger groups than areas where food resources were less abundant (Chapman & Chapman, 2000). It seems therefore most likely that the smaller size of one-male units at Tat Ke may result from high hunting pressure, and perhaps low predation risk, rather than food competition.

The Khau Ca band size (81, estimate 90 individuals) is higher than that found in earlier studies (50 to 60 individuals, Le, 2004; Le, 2006; Covert et al., 2008). This is likely to be the entire population of Khau Ca Forest because no other groups of *R. avunculus* were observed in this area during the times of forming such a large band. Forming a large band has been reported in Chinese snub-nosed monkeys: band size is more than 175 individuals at Wuyapiya (*R. bieti*, Kirkpatrick, 1998), about 400 individuals at Samage (*R. bieti* Grueter, 2009), and 430 individuals at Fanjing (*R. brelichi*, Bleisch & Xie, 1998).

Fission and fusion have been reported in all four species of the genus *Rhinopithecus* for which field data are available (Table 4.10). The degree of cohesion of the bands and time scale for fission and fusion appeared has varied across species and sites (Bleisch & Xie, 1998; Kirkpatrick, 1998). Large bands of *R. avunculus* at Khau Ca often split up into smaller bands (22 to 47 individuals) or one-male units (range seven to 16 individuals) in the morning for foraging and traveling, and then coalesce daily in most cases at resting and sleeping sites, suggesting daily fission and fusion. These results are most similar to what was observed in *R. avunculus* at Na Hang NR (Boonratana & Le, 1994; 1998a) and *R. brelichi* at Fanjing (Bleisch et al., 1993; Bleisch & Xie, 1998) but different from those found in *R. bieti* in Wuyapiya (Kirkpatrick, 1996; 1998) and Samage (Grueter, 2009). A possible explanation for these differences is *R. bieti* live in temperate environment, whereas *R. brelichi* and *R. avunculus* lives in subtropical semievergreen forest and tropical forests, respectively. Tropical forest are more heterogeneous in tree species than are the sub-tropical and temperate forests and may support smaller food patches (Kirkpatrick, 1998). Splitting of large bands may allow smaller one-male units to exploit small food patches, thus reducing the cost of large

bands (Bleisch & Xie, 1998; Stevenson et al., 1998). The daily cycle is therefore likely to be influenced by the size of food patches.

Fusion of smaller groupings into the largest band (81 individuals) at Khau Ca was seen in April and May, 2006, corresponding to an abundance of young leaves and flowers, and probably breeding season. This may suggest that *R. avunculus* appear to form the very largest band on seasonal cycle since no such a large band was observed in other seasons during the course of the study. However, it is noted that my study was carried out only a year-round, therefore this suggestion need further investigations for several years. Group size in colobines can be regulated by a number of ecological and social factors, such as food availability, intra and intergroup competition, predators, infanticide risk, and phylogeny (Clutton-Brock & Harvey, 1977; Gillespie & Chapman, 2001; Isbell, 1991; Janson & Goldsmith, 1995; Steenbeek & van Schaik, 2001; Terborgh & Janson 1986; Wrangham et al., 1993); of which the size, density and distribution of food patches are likely most important (Bleisch & Xie, 1998; Chapman & Chapman, 2000; Fimbel et al., 2001). It is suggested that the availability of large food patches may support larger group sizes (Bleisch & Xie, 1998; Chapman & Chapman, 2000; Wrangham, 1987), though an increase in group size will increase intragroup feeding competition, and larger groups have to travel further to search for adequate food supplies (Gillespie & Chapman, 2001; Isbell, 1991; Janson & Goldsmith, 1995). The cost of a large group, however, may be minimized if food patches become larger, more dense, and more evenly distributed in the landscape (Fimbel et al., 2001). Phenology patterns at Khau Ca show that more than 90% of trees in the plots produced young leaves in April and May of 2006, and a distinct peak of flowering (19.73%) was found in April 2006. Young leaves (63.3%) and flowers (36.7%) made up 100% of the total diet of *R. avunculus* in April 2006. Further, young leaves and flowers are richer in nutrition and more digestible (Waterman & Kool, 1994). It is therefore possible that the

availability of high food quality and relative digestibility of young leaves and flowers at Khau Ca in April and May 2006 may allow large bands of *R. avunculus* to forage.

4.4.2. Social behavior

Social grooming has been reported as a “female affair” and at low frequency in colobines (Kirkpatrick, 2007). Males are rarely involved in this behavior (Struhsaker & Leland, 1987; Kirkpatrick, 2007). Grooming patterns in *R. avunculus* appear to be similar to other colobines, with most grooming performed by adult females. The social grooming time (3.1%), however, is higher than the typical pattern of Asian colobines (no more than 2%, Kirkpatrick, 2007), and adult of both sexes were groomers and gromees, suggesting high affiliation between them within OMUs.

Adult males of *R. avunculus* between OMUs are non-affiliative with other males. Males behaved aggressively towards other males during aggregation for traveling and feeding. This aggression appears to be related to the defense of females and attempts to gain access to the females by males (Cheney 1987; Stanford, 1991), rather than to the defense of food patches. Therefore, it does not exhibit territoriality. Home range of OMUs and bands at Khau Ca seem to overlap totally.

My results indicate that juveniles of *R. avunculus* exhibit alloparenting behavior. This behavior has been reported in most colobine species (Grueter, 2009; Kirkpatrick, 2007; McKenna, 1979; Newton & Dunbar, 1994; Yeager & Kool, 2000, Table 4.11), typically involving both juvenile and adult females. Possible functional explanations for this behavior include providing more feeding time for mothers (Poirier, 1968), increasing the probability of an infant’s adoption if its mother should die or become disabled (Lancaster, 1971), improving maternal skills for allomothers by handling infants and thereby enhancing the likelihood of survival of their own future infants (Hrdy, 1977). Without individual identification in adult females, only juveniles provided

allomothering were recorded in *R. avunculus* at Khau Ca in short distance and period, suggesting improving maternal skills for allomothers.

Sexual behavior of *R. avunculus* at Khau Ca appears to be similar to other colobines, especially Asian colobines (Kirkpatrick, 2007; Newton & Dunbar, 1994; Yeager & Kool, 2000). Females initiated the behavior, and the presenting postures are similar to those described for *R. roxellana* (Liang et al., 2000; Ren et al., 1991; Ren et al., 2003) and *R. bieti* (Kirkpatrick, 1996; Liang & Xiao, 2004). Seasonality of birth may exist in *R. avunculus*, as in *R. bieti* (Kirkpatrick, 1996; 1998) and *R. roxellana* (Ren et al., 2003; Zhang et al., 2000). Factors that control birth seasons remain poorly documented. Rudran (1973) and Ziegler et al. (2000) suggested that food quality and availability may regulate birth and breeding seasons of the two species of langurs of the genus *Semnopithecus*: *S. vetulus* and *S. entellus*, and this hypothesis may apply at Khau Ca because the phenology pattern show that most trees in the plots produced young leaves and a flowering peak between March and May 2006.

To date, there has been no information available on the mating season of *R. avunculus*, but in 2005 it would have been in August and September if the gestation length is similar to that of *R. roxellana* (6.5-7 months: Kirkpatrick, 1995; 1996; Davison, 1982; Qi, 1986) and other Asian Colobines (6-7 months: Kirkpatrick, 2007; Struhsaker & Leland, 1987).

The new observations on the colour of the newborn are in contrast to previous reports on *R. avunculus* (Le, 1973; Le, 2003) and differ from the common pattern in most colobine species (Newton & Dunbar, 1994). Le (1973) and Le (2003) described newborns of *R. avunculus* have yellowish and yellowish white pelage, respectively. *Ad libitum* observations show that newborns have a white pelage with grayish white

patches on the back of head and back, resembling the belly and chest pelage of the adult female. These patches gradually turn to grey in infants and black in juveniles and adults. Like other Asian colobines, agonistic interactions are infrequent in *R. avunculus* (Table 4.11). Low levels of agonistic interactions may result from low feeding competition among members of the group. McKenna (1979) proposed that it is because colobines possess a specialized digestive system that permits them to digest leaves which are relatively abundant and evenly distributed, that intra-group feeding competition is reduced. It must, however, be noted that *R. avunculus* also consumes seeds and fruits which are often clumped, scattered and seasonal at site. Current data on *R. avunculus* do not allow to give any assumptions and this question need further investigations in the future. Dominance hierarchies among females within units are not obvious, and on only one occasion was an adult female seen chasing and displacing another. This is similar to what is described for other colobines (Newton & Dunbar, 1994; Struhsaker & Leland, 1987).

Adult males and females in one-male units spent more time than expected near to each other, and the members of one-male units spent more than 80% of their time within 2m of another individual except for subadult females (Figure 4.6), suggesting high cohesiveness between members of the one-male units. This finding is somewhat similar to that found in *Nasalis larvatus* (Boonratana, 1994), but differs from *Presbytis siamensis* (Bennett, 1983).

4.4.3. Other observed behaviors

Vigilance

Vigilance behavior has been hypothesized as functions of predator-detection (Dimond & Lazarus, 1974; Terborgh & Janson, 1986), protection of both mates and paternity and

resource-defense (Baldellou & Henzi, 1992; Rose & Fedigan, 1995), and the location of food (Krebs & Partridge, 1973; Underwood, 1982). Data available on predation and the home range of *R. avunculus* does not appear to support the first and third hypotheses. No attack on *R. avunculus* and resource-defense were witnessed at both sites during the course of the study. However, it is noted that members of OMUs seem to scan around more often when observers were detected. Vigilance may meet the second and fourth hypotheses. It is evident that a male attempted to keep other males away from their mates when they approached close to his group, and both sexes spent more time than expected near to each other. Further, males spent more time in vigilance than females. This may suggest a form of mate protection. Searching for and locating food are likely to be shared by both male and females, but females seem to lead group movement, suggesting a greater role in locating food sources.

Vocalization

Members of *R. avunculus* at Khau Ca emitted at least three different types of vocalizations. Although it is too early to determine the exact functions of these calls, I can make some speculations based on the contexts when these calls were given. Firstly, soft hoo vocalizations emitted by limited number of animals appeared to be used to regroup after the group was disturbed by the observers and had split up, and possibly to maintain group spacing. Secondly, loud huchuk vocalizations were used as alarm calls whenever the monkeys detected the observers and other threats. Thirdly, rapid chit vocalizations were used when they were fleeing way from unexpected encounters with observers.

Rest-huddling

Rest-huddling has been reported in *Rhinopithecus bieti* at Wuyapiya (Kirkpatrick, 1996). However, factors that influence on huddling remain unclear. Given the

observational conditions, few data available on rest-huddling of *R. avunculus* were obtained. Rest-huddling was observed at different time of year April (spring), July (summer), and September 2006 (autumn), suggesting that the correlation between temperature and rest-huddling may probably not exist. Further observations are needed to confirm this prediction and future studies should look at other possible social factors promoting huddling.

Group movement

Group movement in *R. avunculus* appears to be initiated by adult females. Based on *ad libitum* observations, females were seen to have initiated movement out of resting and sleeping trees in most cases, whereas the male was sitting, waiting for the rest of the unit to leave first, and left the sleeping and resting tree last. Similarly, during travel the male was observed sitting on a branch and waiting for the rest of the unit to pass his sitting place. This observation is contrary to Pham's (1993) report that group movement was controlled by the adult male, but similar to that described for *Nasalis larvatus* (Yeager, 1990).

4.4.4. Inter-unit interaction

Social interactions between units seem to be characterized by low rates of aggression between males. Males respond aggressively toward the resident males of other one-male units, suggesting probably the defense of females (Cheney, 1987). Without individually recognizable animals, information on female and male transfers between units is not available. It is, however, possible that male emigration may exist because of the absence of juvenile males in observed one-male units and the presence of at least one adult male and a subadult male in all-males unit or as solitaries. Male dispersal has been reported in *Nasalis larvatus* (Boonratana, 1994; Yeager, 1990) and in *R. roxellana* (Zhang et al., 2006). Females and young juveniles of *R. avunculus* appear to behave friendly toward

those of different one-male units. Females of different units occasionally fed on the same tree and juveniles played together during resting time.

Table 4.10. Band and units sizes for selected previous studies of the members of genus *Rhinopithecus*.

Species	Site	Band structure	Band size estimate	One-male unit size estimate	Fission/fusion of bands (Time scale and possible reasons)	References
<i>R. avunculus</i>	Khau Ca	OMUs, AMUs	Range 22 to 81 Estimate: 90	Range: 7 to 16 Average: 11.3	Yes: Daily cycle and possibly seasonal Human disturbance, food patch size	This study
<i>R. avunculus</i>	Tat Ke	OMUs, AMUs	22	Range: 6 to 8 Average: 7	Yes: unclear Human disturbance	This study
<i>R. avunculus</i>	Khau Ca	MMUs, MFUs	50-60		unspecified	Le (2004); Le et al. (2006)
<i>R. avunculus</i>	Na Hang	OMUs, AMUs	Tat Ke: 80 Ban Bung: 50	Range: 10 to 24 Average: 15.2	Yes: unclear	Boonratana & Le (1994; 1998a)
<i>R. avunculus</i>	Na Hang	MMUs, MFUs	30		Yes: In response to threat	Ratajszczak et al. (1990; 1992)

Table 4.10. Band and units sizes for selected previous studies of the members of genus *Rhinopithecus* (Continued).

Species	Site	Band structure	Band estimate	Band size	One-male unit size estimate	Fission/fusion of bands (Time scale and possible reasons)	References
<i>R. roxellana</i>	Qinling	OMUs	82		Range 5 to 14 Average: 9	Yes: Seasonal	Zhang et al. (2006)
<i>R. roxellana</i>	Shennonhjia	OMUs, AMUs	Range: 95 to 340		Range: 4 to 13 Average: 12	Yes: Unclear	Ren et al. (1998)
<i>R. brelichi</i>	Fanjing	OMUs “family groups” and Bachelor groups	430		Range: 5 to 10 Average: 6.1	Yes: Daily cycle, seasonal Food availability and distribution	Bleisch & Xie, (1998); Bleisch, et al. (1993)
<i>R. bieti</i>	Wuyapiya	MFUs, OMUs, AMUs	175 to 200		Range 10 to 16	Yes: Occasional (n=7) Cycle: 25 hours In response to threat and logistics travel	Kirkpatrick (1996); Kirkpatrick et al. (1998)

Table 4.11. Social behavior for selected studies of Asian Colobines.

Species	Site	Aggressive interactions	Social grooming	Allomothering	Birth season	References
Semnopithecus						
<i>S. dussumieri</i>	Kaukori			Yes	April, May	Dolhinow (1972)
<i>S. ajax</i>	Ramnagar			Yes	Jan-Jun	Borries et al. (2001)
Rhinopithecus						
<i>R. avunculus</i>	Khau Ca	0.4	3.4	By juvenile	Probably Mar, Apr	This study
<i>R. bieti</i>	Wuyapiya		6.1	By juvenile	Probably Mar, Apr	Kirkpatrick (1996)
Nasalis						
<i>N. larvatus</i>	Sukau	0.8	2.8	By adult female and juvenile	Weak	Boonratana (1994)
Presbytis						
<i>P. siamensis</i>	Kuala	low	Rare	Rare		Bennet (1983)
	Lompat					
<i>P. rubicunda</i>	Sepilok	low	Rare	Yes		Davies (1984)
Trachypithecus						
<i>T. johnii</i>	Nilgiri			Yes	May-Jun	Poirier (1970)
<i>T. obscurus</i>	Khao	0.2 to 0.4	8.2 to 9.1	By adult of both sexes		Aggimarangsee (2004)
	Lommuak					

4.5. Summary

The basic social organization is similar to those in the Chinese snub-nosed species. The species lives in one-male units comprising a single full adult male, several adult females, and young, with extra males forming loosely-bonded all-male units. One-male unit sizes ranged from 7 to 15 individuals (averaged 11.3 individuals). The age/sex ratio of the OMUs was 1 adult male, 3.8 adult females, 1.5 sub-adult females, 2.5 juvenile females and 2 infants. The Khau Ca band contained at least 5 to 6 OMUs. They are part of a fission-fusion society, with the different units frequently coming together to sleep, travel and feed. Social behavior of *R. avunculus* appear to follow other Aisan colobine pattern. Agonistic interactions between members in OMU was less (0.4 %). Grooming was most involved in adult females (73.9%). These findings suggest that despite ecological differences *R. avunculus* follow the social organization and behavior patterns of other allopatric snub-nosed species in China.

Chapter 5

Feeding Ecology

5.1. Introduction

Members of the Colobinae exhibit a number of anatomical adaptations associated with leaf-eating. These include sharp crests and high cusps on the molars which allow them to cut leaves; enlarged salivary glands that help to reduce the acidity of the forestomach fluid; and a ruminant or, more accurately, macropod-like stomach with symbiotic microflora that enable them to utilise cellulose and hemicellulose and probably neutralize plant secondary compounds (Chivers & Hladik, 1980; Kay & Davies, 1994).

Recent studies in colobines have found that they are not by any means restricted to leaf-eating. They show great diversity and considerable seasonal changes in their dietary habits. Apart from leaves, colobines are able to digest a variety of food items, including fruits, seeds, flowers, lichens, bark, insects and others. For example, annual diets of *Trachypithecus johnii* at Kakachi consisted of leaves, seeds and fruits, flowers and flower buds, buds, and stem or bark (Oates et al., 1980); *Semnopithecus entellus* in Kanha Tiger Reserve consumed mature leaves, fruits, leaf buds, flowers and flower buds, of young leaves, of insects, and gum (Newton, 1992). Similarly, the Chinese *Rhinopithecus* species feed on a wide variety of plant foods, and even some animal matter: leaves, leaf petioles, fruits and seeds, buds, and insect larvae (*R. brelichi*, Bleisch et al., 1993; Bleisch & Xie, 1998); leaves, fruits, buds, barks, bamboo leaves and lichens (*R. bieti*, Ding & Zhao, 2004; Kirpatrick, 1996; Yang, 2003; Yang & Zhao, 2001); leaves, buds, flowers, fruits, seeds, barks, lichens, and insects (*R. roxellana*, Li, 2001; Li, 2006).

Leaves, flowers, seeds and fruits are often seasonal, and their diets may depend on very few species at a given time of year; food selection has been reported in several cases. For example, *R. brelichi* at Fanjiing favoured from four to five species each season: leaves of *Paranus vaniotii*, leaf buds and leaves of *Ficus* sp., and fruit and seeds of *Dendrobenthamia agustana* (Bleisch & Xie, 1998). Of 23 plant species eaten by *R. roxellana* at Shennongjia, only 10 broadleaf deciduous tree species and lichens on nine tree species are their preferred foods (Li, 2006).

Unlike Chinese snub-nosed monkey species, *R. avunculus* in northern Vietnam live in tropical evergreen broadleaf forest associated with karst limestone hills and mountains. They have been reported to feed on leaves, fruits and seeds (Boonratana & Le, 1998a; Pham, 1993; 1994; Ratajszczak et al., 1990), but the reported proportion of plant parts eaten varies between authors. For example, Ratajszczak et al. (1990) reported that *R. avunculus* is folivorous, primarily consuming leaves. In contrast, based on direct observations (n=34 feeding observations), Boonratana and Le (1994; 1998a) documented that the diet of *R. avunculus* at Na Hang comprised 62% fruits and seeds, and 38% leaves. Similarly, Pham (1994; 2002) suggested that *R. avunculus* rely heavily on fruits rather than leaves: for instance, of 61 food species consumed, 52 species are fruit (63%) (Pham, 2002). These latter figures however are just based on local reports and six stomach examinations. The actual diet, therefore, remains in question. This chapter will describe the feeding ecology of *R. avunculus* with respect to feeding behavior, diet, food selection, seasonal variation in diet, and age/sex differences in feeding.

5.2. Methods

I used scan sampling method to obtain quantitative data on diet (Altmann, 1974). Scan samples were recorded during a 2 minute period at every 15 minutes interval from dawn to dusk (see chapter 4). An animal was recorded feeding if it was manipulating, putting into mouth or masticating food items. Data on feeding collected during scan sample included time, age and sex of observed individual, food item eaten (including species if known), height of observed individual above ground, and the position of animal in the feeding tree.

It was very difficult to estimate the height of feeding animals above the ground in meters because of the dense vegetation, as well as the observational distance. Instead, to determine the level of usage, the tree canopy was divided into three layers: under canopy, middle canopy and upper canopy. Under canopy is the lowest layer of the forest, from the ground to the lower branches, about 0 to 10m in height. Middle canopy is the continuous or closed canopy layer, about 10 to 17m. Upper canopy refers to the emergent layer of the forest, usually over 20m in height. In addition, the crown used by feeding animals was also divided into two parts: inner canopy and periphery. The former refers to larger support branches (closer to the main trunk), and the latter is the terminal feeding branches.

To investigate the degree of selectivity, selection ratios for food species in the diet were calculated by comparing the number of feeding observations of a food species with the relative abundance of the species in terms of stem and basal area as estimated from the tree plots. Two formulae were used to calculate selection ratios: one based on the stem-number of different tree species, and the other on the basal area (following Fashing, 2001).

$$\text{Selection ratio 1} = \frac{\% \text{ of annual feeding time spent feeding on species } i}{\% \text{ of total stem density contribute } d \text{ by species } i}$$

$$\text{Selection ratio 2} = \frac{\% \text{ of annual feeding time spent feeding on species } i}{\% \text{ of total basal area contribute } d \text{ by species } i}$$

5.3. Results

5.3.1. Feeding techniques

Feeding techniques were reported here based on *ad libitum* observations and from video film recordings. Terminology of postures used in this study follows Bergeson (1998). Animals frequently entered feeding branches from the main trunk of the tree. Females seemed to initiate the timing of feeding. During feeding, animals exhibited the following postural patterns, which appeared to vary according to the size and structure of the tree, and distribution of food.

A sitting posture was used when food was immediately in front, on either side, or overhead of the animals. Feeding animals picked and carried food to or pulled branches to the mouth with one or both hands while sitting on the supporting branch or branches (Figures 5.1 & 5.2).

A suspensory posture was used most often when feeding in terminal branches. Individuals hung on the branches overhead with one arm and picked food items with the free hand, while the feet were under tension towards supporting branches or hung free (Figure 5.3)

A combination of sitting and suspension was the most common posture utilized when feeding on all food items. Feeding animals hung on an overhead branch with one arm, and picked and carried food to the mouth with the free hand while sitting on the supporting branch or branches (Figure 5.4).

On several occasions, bipedal and quadrupedal standing positions were observed. Feeding animals stood bipedally to reach up and pull down feeding branches overhead with one hand, and the other free hand picked food and brought it to the mouth. Quadrupedal postures were seen only when the animals fed on fruits. Animals stood tripedally with the free hand picking and carrying fruits to the mouth.

When feeding on fruits, *R. avunculus* used one or two hands to pick the fruits off from branches one by one and bring them to the mouth. The size of fruits consumed mostly ranged between 0.3 and 1.5cm in diameter (n=10), the exception being the larger fruits of liana species that resemble pods of the legume family. In the former case, the animals hold the fruit in one hand, and eat the whole fruit (e.g., *Bridelia monoica*), or seeds, discarding the epicarp (e.g., *Celtis sinensis*), or a part of the fruit while discarding the rest (e.g., *Diplospora viridiflora*). In the latter case, fruits were held in one or two hands and broken along one side with the teeth before eating the seeds inside.

Leaves and flowers were collected either by picking them and bringing to the mouth one at a time, or by pulling the branches to the mouth and biting off directly with the teeth (Figure 5.4). One or two hands were used to pick and carry food to the mouth.

5.3.2. Feeding heights and sites

Feeding trees were generally of medium to large size in diameter at breast height that could support several individuals or whole units. The animals spent 82% (n= 329) of their feeding time in the middle canopy, 12% (n= 48) in the upper canopy, and 6% (n=24) in the under canopy. The proportion of feeding time spent in the under canopy and on the ground was likely underestimated because of obstacles to the line of view. Feeding animals often fed in or near the periphery of tree crowns, and were distributed evenly in the feeding tree, and it was rare to see two adults sitting in close proximity on one feeding branch. Frequent use of the periphery of tree crowns may relate to the

distribution of food. Young leaves and fruits were the main food items in the diet (see section 5.3.3), and these were densest in the finest branches.



Figure 5.1. Adult male sitting and eating young leaves of *Diospyros choboensis*.

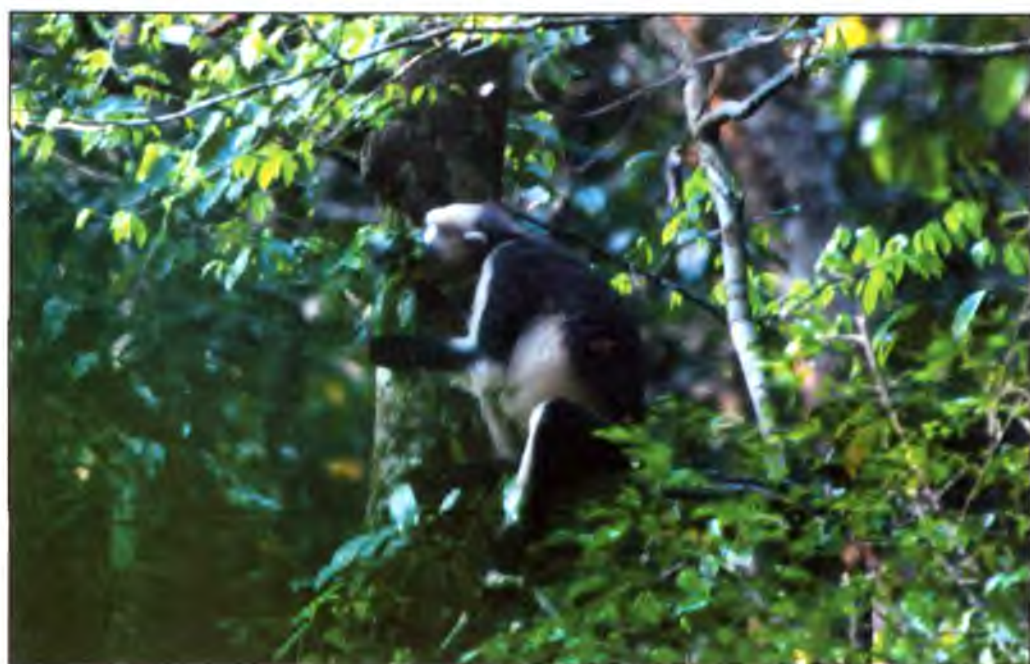


Figure 5.2. Adult female sitting, pulling the branch to the mouth with both hands, and eating young leaves of *Diospyros choboensis*.



Figure 5.3. Adult female hanging and feeding on ripe fruit of *Celtis sinensis*.



Figure 5.4. Adult females hanging and sitting/hanging eating whole ripe fruits of *Celtis sinensis*.

5.3.3. Diurnal patterns of feeding

Rhinopithecus avunculus spent 14.7% (n= 401) of their total activity time in feeding, and fed throughout the day. The distribution of feeding observations over the day during the course of the study is shown in Figure 5.5. It was found that the monkeys began feeding at 6.00h, approximately 30 minutes to 1 hour after dawn, and ended at 18.00h, about 30 minutes before dusk. This however, may change accordingly to seasons. The monkeys appears to start feeding earlier in summer than winter. There were two peak periods of feeding time during the day. The first peak period was found in the morning from 7.00h to 10.00h, accounting for ca. 34% of the total daily feeding observations. The second one was between 14.00h and 16.00h in the afternoon, accounting for ca. 36% of the total daily feeding observations.

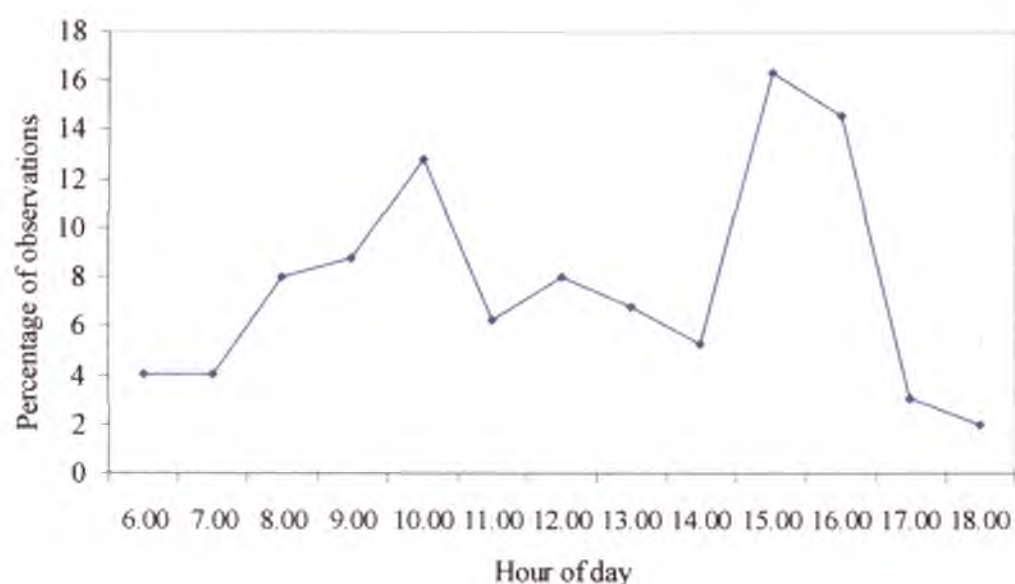


Figure 5.5. Diurnal variation in the percentage of feeding time of *R. avunculus* at Khau Ca (n = 401).

5.3.4. Diet

Rhinopithecus avunculus were observed feeding on variety of food types: young leaves, mature leaves, flowers and flower buds, ripe fruits and unripe fruits, seeds of ripe and unripe fruits, bark and young stems. The proportion of feeding time on different items at Khau Ca during scan observations is presented in Table 5.1.

Young leaves appeared to be important food items, accounting for about 46.2% (n= 142) of the total feeding time, whereas mature leaves were only 6.9% (n= 12). Portions of young and mature leaves which were eaten included part of the blade (e.g., *Camellia sasanqua*, *Machilus bonii*), or the petiole (e.g., *Premana balansae*, *Congea sp*), or whole young leaves (e.g., *Diospyros choboensis* and, *Diospyros pilosula*).

Fruits contributed 24% (n= 79) of the total feeding time. Animals seemed to spend more time feeding on ripe fruits than unripe fruits (13.8%, n=66 and 11.2%, n= 72, respectively). In contrast, seeds of unripe fruits (4.7%, n= 12) were consumed more than those of ripe fruits (2.5%, n= 14). Fruits were eaten either whole (e.g. *Bridelia monoica*, *Berchemia floribunda*), or just the seeds by breaking open fruits with the teeth, eating the seeds (e.g. *Celtis sinensis*, *Schefflera delavayi*).

Flowers made up 11.2% (n= 70) of the total feeding time. Animals were seen eating whole flowers and flower parts of *Diospyros choboensis*, *Diospyros pilosula*, and *Acer chapaense*. In most flowering species consumed, flowers and flower buds were quite difficult to distinguish from a distance because of their small size (e.g. *Acer chapaense*, *Diospyros choboensis*). Furthermore, the animals generally fed on both flowers and flower buds at the same time. For the purposes of scan and data analysis, flowers and flower buds were treated as “flowers”.

On several occasions, young leaves and mature leaves, ripe and unripe fruits could not be distinguished with certainty, and these were labeled as undetermined items (2%, n=10). Bark and young stems of *Cryptocarya* sp, *Trevesia palmata*, *Schefflera delavayi* were seen being eaten by adults of both sexes during *ad libitum* observations. Young stems were broken off from a branch by one or two hands, or bitten off by the teeth, and chewed.

5.3.5. Food selection

Ad libitum and scan sampling recorded *R. avunculus* feeding on 50 different plant species, of which 46 were tree species, two liana species, and two orchid species (Table 5.2). Of these, 40 were identified at the species level, seven at the genus level, and there were one unknown tree species and two unknown liana species. This enumeration was likely underestimated because during traveling the monkeys appeared to feed on various items of liana species and some tree species that could not be ascertained from observations.

Tree species consumed accounted for 33.1% (n= 46) of the total species identified in plot samples in Khau Ca (see section 3.3.5.2, chapter 3). The monkeys did not, however, appear to pick foods randomly. Out of the 29 commonest species of tree in Khau Ca (see Table 3.6, section 3.3.5.2, chapter 3), only 6 were eaten, accounting for 26% of feeding observations, and 15.4% and 23.2% of the total stem and basal area in the plots sampled, respectively (Table 5.3). Several trees fed extensively were not among the commonest species of tree (e.g. *Diospyros choboensis*, *Syzygium* sp., *Sarcosperma laurinum*).

Some species appeared to be utilised more heavily than others. Six out of 23 food species recorded during scan observations were eaten more than 4%, and these six made up 71% of the total feeding time (Table 5.1). *Diospyros choboensis* was the top food

species, accounting for 27.5% of the total diet. This was followed by *Garcinia fagraeoides* (23%), a common tree in the study area.

There appeared to be favoured food parts in the case of some tree species. Out of 50 species consumed, in 6 they were seen feeding on all three phytophases (leaves, flowers, and fruits, in species such as *Diospyros choboensis*, *Trevesia palmate*, *Schefflera delavayi*). Two phytophases, leaves and flowers, were used from eight species, leaves and fruits from six, and flowers and fruits from five (Table 5.2).

The study animals appeared to spend more time feeding on specific plant parts of some species than others (Table 5.1). Young leaves of *Diospyros choboensis*, *Garcinia fagraeoides*, *Syzygium sp.*, and *Quercus acutissima* made up more than 37.9% of the total feeding records. Among these, *Diospyros choboensis* was the top item in the diet, accounting for 19.1% of the total feeding records; the animals also spent the largest proportion of time feeding on flowers of this species (7.9%). Fruits of *Garcinia fagraeoides* were eaten much more than others, accounting for 52.6% of the total fruit feeding records.

The selection ratios for food items and species are shown in Table 5.4 and 5.5. Only 12 out of 23 food species obtained during scan observations were calculated because some species did not occur in the botanical plots (e.g., *Castanopsis tonkinensis*, *Choerospondias axillaris*, *Sarcosperma laurium*), and some species were lianas. *R. avunculus* were highly selective in their choice of foods and fed mainly from trees which were quite rare and low in terms of both the number of stems and basal areas. *Diospyros choboensis* ranked sixty-second in terms of stem-number, but was the species most selected for in the diet. Using a selection ratio based on basal area, *Syzygium sp.* was the most selected species, though its rank was one hundred and sixth in the plots sampled. In contrast, *Machilus bonii*, a very common tree in terms of basal area and

stem-number, appeared to be avoided, and selection ratios based on both stem and basal area were only 0.1.

Similar calculations were used for food items. Selection ratios for food items from Tables 5.4 and 5.5 suggest a strong preference for certain items. Young leaves apparently were the items most selected, followed by flowers and unripe fruits. Relatively high selection ratios for some food items of some species may be related to their availability. Tables 5.6 and 5.7 compare selection ratios for food items of highly synchronized production species with their availability as derived from monthly phenological sampling. The results suggest that food items were strongly selected for when they were available. For example, flowers of *Acer chapaense*, *Diospyros choboensis*, and *Ormosia pinnata*, exploited heavily, were available for just a short period, between March and April 2006. Similarly, unripe fruits of *Schefflera delavayi* were much eaten when they were available, in November 2005.

5.3.6. Monthly variation in feeding

The proportion of different items in the diet from September 2005 to September 2006 is shown in Figure 5.6. Only 12 months of data on the diet were analyzed because there were no feeding records for June 2006. The results show that there was considerable variation in the proportion of different plant parts eaten throughout the study period. The absence of some food items in some months was likely either because they were not consumed, or because they were not seen during scan observations in those months. In the latter case, data on monthly variation could be biased when they were compared with other possible influencing factors (see below).

The amount of young leaves consumed was generally high in most months and reached a peak (100%) in February and May 2006. The fluctuations of young leaves eaten between months appeared to be related to the amount of other items consumed each month. The relationships between young leaves and other items were compared, using a

Spearman rank correlation coefficient. There was a significant negative correlation between young leaves and fruits in the diet ($r_s = -0.81$, $n=12$, $p < 0.01$). A similar correlation was found in the case of seeds ($r_s = -0.69$, $n = 12$, $p < 0.05$). The consumption of young leaves, however, was not related to that of flowers ($r_s = 0.12$, $n = 12$, $p > 0.05$); further, young leaves were consumed more than flowers when both were available at the same time, suggesting preferential selection of young leaves over flowers.

Data on synchrony of phenology among trees in the plots sampled indicate that changes in the proportion of different plant parts in the diet were not significantly correlated with changes in the availability of these parts in the forest (Figure 5.7a,b&c). The Spearman rank correlation coefficient (r_s) ranged between 0.49 and 0.57 (Table 5.8).

Taking seasonal changes in the availability of food items into consideration, the proportion of food items in the diet seemed to vary according to these changes (Figure 7a,b&c). During the spring (February-March 2006, the late months of the dry season), the monkeys fed heavily on young leaves and flowers of *Diospyros choboensis*, *Acer chapaense* and *Ormosia pinnata* when they were abundant. In the summer (May-September 2006, corresponding to the wet season), the amount of young leaves consumed decreased. From October to January (2005 and 2006), corresponding to autumn and winter, fruits and seeds contributed a large proportion to the diet; fruits and seeds of some tree species (e.g. *Schefflera delavayi*, *Celtis sinensis*) and lianas were used extensively. In the late months of the winter season, they exploited, in addition, mature leaves of *Syzygium zeylanicum*, *Syzygium sp.* and *Premna balanceae*.

Table 5.1. Percent time feeding on specific food items by *R. avunculus* at Khau Ca (continued).

Species	Family	YL	ML	FL	RF	UF	SRF	SUF	UI	Total
<i>Choerospondias axillaris</i>	Anacardiaceae	0.7								0.7
<i>Sandoricum kontape</i>	Meliaceae			0.7						0.7
<i>Syzygium zeylanicum</i>	Myrtaceae	0.4								0.4
<i>Ilex macrocarpa</i>	Aquifoliaceae		0.3					0.0		0.3
<i>Limacia sp</i>	Annonaceae		2.6						1.2	3.8
Liana 1					1.8					1.8
Liana 2								3.9		3.9
Total		46.2	6.9	12.2	11.2	13.8	2.5	4.7	2.4	

YL: Young leaves ML: Mature leaves FL/FLB: Flowers and flower buds RF: Ripe fruits UF: Unripe fruits SRF: Seeds of ripe fruits
 SUF: Seeds of unripe fruits UI: Undetermined items

Table 5.2. List of food plants and plant parts eaten by *R. avunculus* at Khau Ca.

Species	Family	YL	ML	FL/FLB	RF	UF	SRF	SUF	Bark	Stem	UI
<i>Acer tonkinensis</i>	Aceraceae			+							
<i>Acer chapaense</i>	Aceraceae	+		+							
<i>Choerospondias axillaris</i>	Anacardiaceae	+									
<i>Alphonsea tonkinensis</i>	Annonaceae	+									
<i>Limacia sp</i>	Annonaceae		+								
<i>Polyalthia sp</i>	Annonaceae	+		+							
<i>Ilex purpurea</i>	Aquifoliaceae	+									
<i>Ilex sp</i>	Aquifoliaceae	+	+								Leaves
<i>Ilex macrocarpa</i>	Aquifoliaceae		+								
<i>Trevesia palmate</i>	Araliaceae	+				+		+		+	
<i>Schefflera delavayi</i>	Araliaceae	+		+		+		+		+	
<i>Garcinia fagraeoides</i>	Clusiaceae	+		+		+					Fruits
<i>Garcinia tinctoria</i>	Clusiaceae	+		+		+					
<i>Diospyros choboensis</i>	Ebenaceae	+		+							
<i>Diospyros pilosula</i>	Ebenaceae	+		+							
<i>Bridelia monoica</i>	Euphorbiaceae				+						
<i>Bowringia callicarpa</i>	Fabaceae			+							
<i>Ormosia sp</i>	Fabaceae							+			

Table 5.2. List of food plants and plant parts eaten by *R. avunculus* at Khau Ca (continued).

Species	Family	YL	ML	FL/FLB	RF	UF	SRF	SUF	Bark	Stem	UI
<i>Castanopsis tonkinensis</i>	Fagaceae			+							
<i>Quercus acutissima</i>	Fagaceae	+									
<i>Castanopsis chinensis</i>	Fagaceae	+									
<i>Anna submontana</i>	Gesneriaceae	+									
<i>Machilus bonii</i>	Lauraceae	+									
<i>Cryptocarya sp</i>	Lauraceae								+	+	
<i>Sandoricum kontape</i>	Meliaceae			+							
<i>Toona sinensis</i>	Meliaceae	+									
<i>Diplospora viridiflora</i>	Menispermaceae					+					
<i>Ardisia ramondiaeformis</i>	Myrsinaceae			+							
<i>Ardisia quinqueгона</i>	Myrsinaceae	+									
<i>Ardisia crispa</i>	Myrsinaceae	+									
<i>Syzygium sp</i>	Myrtaceae	+									
<i>Syzygium zeylanicum</i>	Myrtaceae	+	+								
<i>Syzygium wightianum</i>	Myrtaceae	+	+								
<i>Bulbophyllum pectinatum</i>	Orchidaceae	+								+	
<i>Tropidia curculigoides</i>	Orchidaceae	+								+	
<i>Berchemia floribunda</i>	Rhamnaceae					+					

Table 5.2. List of food plants and plant parts eaten by *R. avunculus* at Khau Ca (continued).

Species	Family	YL	ML	FL/FLB	RF	UF	SRF	SUF	Bark	Stem	UI
<i>Rubus moluccana</i>	Rosaceae	+									
<i>Pavetta tonkinensis</i>	Rubiaceae	+									
<i>Gardenia sootepesis</i>	Rubiaceae	+		+							
<i>Sinosideroxylon wightianum</i>	Sapotaceae	+									
<i>Sarcosperma laurium</i>	Sapotaceae	+	+								
<i>Camellia sasamqua</i>	Theaceae	+									
<i>Congea sp</i>	Verbenaceae		+								
<i>Premna balansae</i>	Verbenaceae	+									
<i>Premna flavescens</i>	Verbenaceae		+								
<i>Tetrastigma gaudichaudianum</i>	Vitaceae				+	+					
<i>Celtis sinensis</i>	Ulmaceae						+				
Liana 1					+						
Liana 2								+			
Unknown					+						+

YL: Young leaves ML: Mature leaves FL/FLB: Flowers and flower buds RF: Ripe fruits UF: Unripe fruits SRF: Seeds of ripe fruits
 SUF: Seeds of unripe fruits UI: Undetermined items.

Table 5.3. Six commonest tree species eaten by *R. avunculus* at Khau Ca.

Species	Family	No. of stems	% stems	% Basal area	Feeding occasions
<i>Machilus bonii</i>	Lauraceae	33	6.45	12.27	3
<i>Gardenia sootepesis</i>	Rubiaceae	14	2.37	1.49	1
<i>Celtis sinensis</i>	Ulmaceae	10	1.95	4.40	14
<i>Garcinia fagraeoides</i>	Clusiaceae	8	1.56	0.81	84
<i>Diospyros pilosula</i>	Ebenaceae	7	1.37	2.39	1
<i>Syzygium zeylanicum</i>	Myrtaceae	7	1.37	1.87	3

Table 5.4. Selection ratios for food items and species consumed by *R. avunculus*, based on time budget relative to density of stems.

Species	Family	Selection ratio based on stem								Total	Rank	% Diet
		YL	ML	FL	RF	UF	SRF	SUF	UDI			
<i>Acer chapaense</i>	Aceraceae			3.0						3.0	(57)	1.2
<i>Celtis sinensis</i>	Ulmaceae						1.3			1.3	(11)	2.5
<i>Diospyros choboensis</i>	Ebenaceae	48.9		20.4					1.2	70.5	(62)	27.5
<i>Diospyros pilosula</i>	Ebenaceae		0.7							0.7	(15)	0.9
<i>Garcinia fagraeoides</i>	Clusiaceae	5.8			2.1	6.4		0.5		14.8	(12)	23.0
<i>Machilus bonii</i>	Lauraceae	0.1								0.1	(2)	0.7
<i>Ormosia pinnata</i>	Fabaceae	0.6		1.6						2.2	(24)	2.2
<i>Quercus acutissima</i>	Fagaceae	10.6								10.6	(67)	4.1
<i>Schefflera delavayi</i>	Araliaceae					4.0				4.0	(41)	2.4
<i>Sinosideroxylon wightianum</i>	Sapotaceae	2.1								2.1	(22)	2.5
<i>Syzygium sp</i>	Myrtaceae	28.7								28.7	(115)	5.7
<i>Syzygium zeylanicum</i>	Myrtaceae	0.3								0.3	(17)	0.4

Figures in parentheses show the rank of species in terms of stem-number in the plot sampled

YL: Young leaves ML: Mature leaves FL/FLB: Flowers and flower buds RF: Ripe fruits UF: Unripe fruits
 SRF: Seeds of ripe fruits SUF: Seeds of unripe fruits UI: Undetermined items

Table 5.5. Selection ratio based on basal area of *R. avunculus* for food items and species during scan observations

Species	Family	Selection ratio based on basal area								Total	Rank	% Diet
		YL	ML	FL	RF	UF	SRF	SUF	UDI			
<i>Acer chapaense</i>	Aceraceae			13.2						13.2	(88)	1.2
<i>Celtis sinensis</i>	Ulmaceae							0.6		0.6	(5)	2.5
<i>Diospyros choboensis</i>	Ebenaceae	83.0		34.5					2.1	119.6	(71)	27.5
<i>Diospyros pilosula</i>	Ebenaceae		0.4							0.4	(11)	0.9
<i>Garcinia fagraeoides</i>	Clusiaceae	11.1			4.1	12.3		1.0		28.4	(31)	23.0
<i>Machilus bonii</i>	Lauraceae	0.1								0.1	(1)	0.7
<i>Ormosia pinnata</i>	Fabaceae	4.2		11.2						15.4	(78)	2.2
<i>Quercus acutissima</i>	Fagaceae	5.9								5.9	(34)	4.1
<i>Schefflera delavayi</i>	Araliaceae					47.1				47.1	(106)	2.4
<i>Sinosideroxylon wightianum</i>	Sapotaceae	1.4								1.4	(14)	2.5
<i>Syzygium sp</i>	Myrtaceae	287.0								287.0	(134)	5.7
<i>Syzygium zeylanicum</i>	Myrtaceae	0.2								0.2	(12)	0.4

Figures in parentheses show the rank of species in terms of basal area in the plot sampled

YL: Young leaves ML: Mature leaves FL/FLB: Flowers and flower buds RF: Ripe fruits UF: Unripe fruits
 SRF: Seeds of ripe fruits SUF: Seeds of unripe fruits UI: Undetermined items

Table 5.6. A comparison of selection ratios for food items of highly synchronized species based on stem with their availability

Species	Family	Selection ratios based on stem						Month (s) available
		YL	FL	RF	UF	SRF	SUF	
<i>Acer chapaense</i>	Aceraceae		4.6					Mar.'06
<i>Celtis sinensis</i>	Ulmaceae					1.9		Oct.'05
<i>Diospyros choboensis</i>	Ebenaceae	47.2	31.0					Mar.'06-Apr.'06
<i>Garcinia fagraeoides</i>	Clusiaceae			3.3	9.7		0.6	Sep.'06
<i>Ormosia pinnata</i>	Fabaceae		2.4					Apr.'06
<i>Schefflera delavayi</i>	Araliaceae				6.1			Nov.'05
<i>Syzygium sp</i>	Myrtaceae	43.5						Nov.'05-Jan.'06

Table 5.7. A comparison of selection ratios for food items of highly synchronized species based on basal area with their availability.

Species	Family	Selection ratios based on basal area						Month (s) available
		YL	FL	RF	UF	SRF	SUF	
<i>Acer chapaense</i>	Aceraceae		20.0					Mar.'06
<i>Celtis sinensis</i>	Ulmaceae					0.9		Oct.'05
<i>Diospyros choboensis</i>	Ebenaceae	80.0	52.6					Mar.'06-Apr.'06
<i>Garcinia fagraeoides</i>	Clusiaceae			6.3	18.6		1.2	Sep.'06
<i>Ormosia pinnata</i>	Fabaceae		17.1					Apr.'06
<i>Schefflera delavayi</i>	Araliaceae				72.0			Nov.'05
<i>Syzygium sp</i>	Myrtaceae	435.0						Nov.'05-Jan.'06

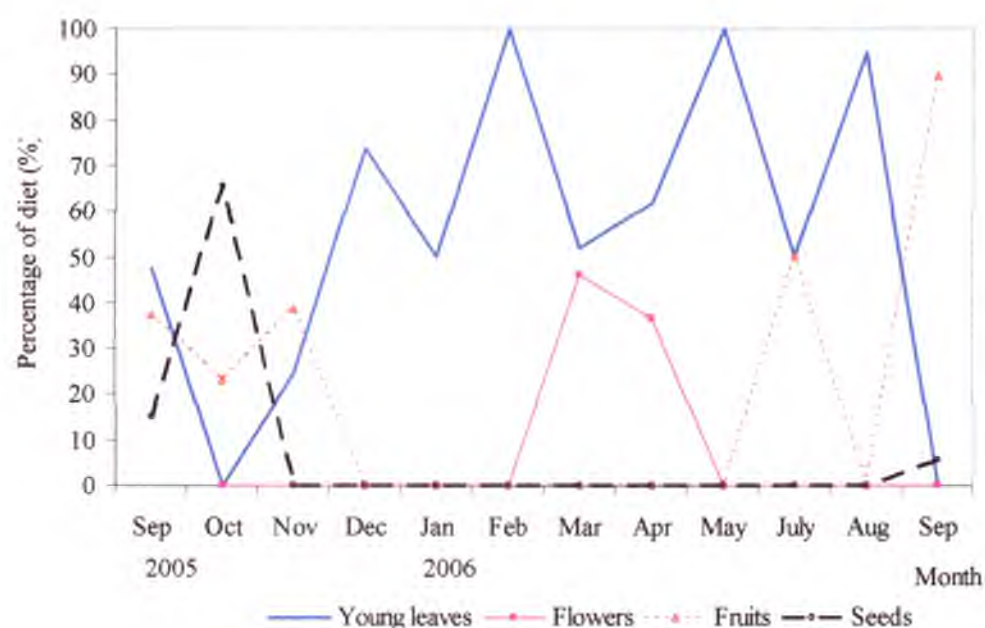


Figure 5.6. Monthly variation in plant parts eaten by *R. avunculus* at Khau Ca (N = 326).

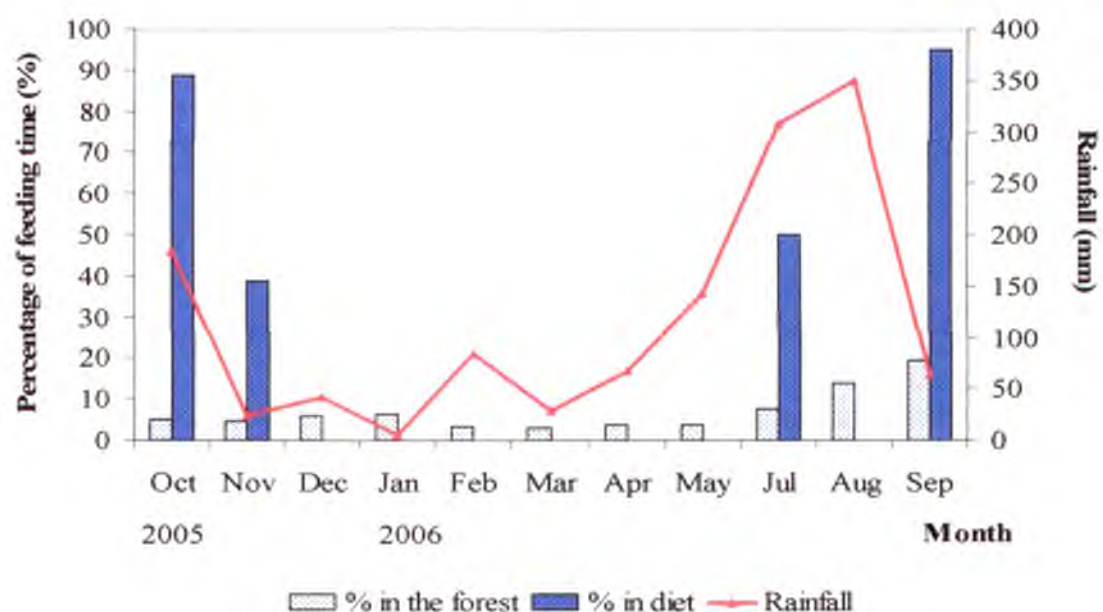


Figure 5.7a. Monthly variation in young leaves in the diet, compared to that in the forest and to rainfall.

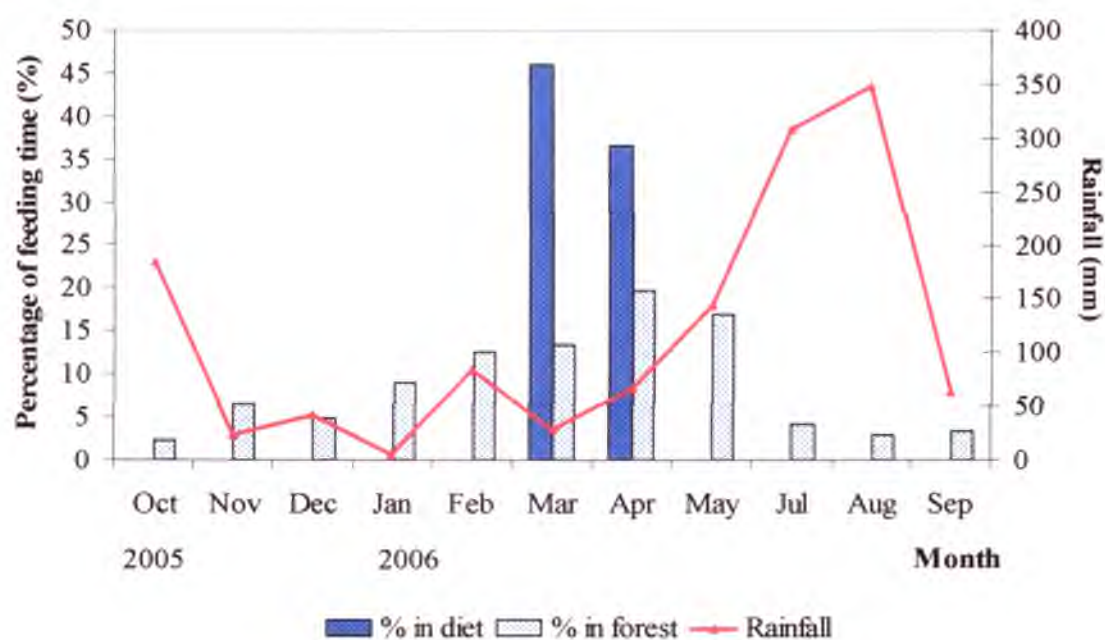


Figure 5.7b. Monthly variation in fruits and seeds in the diet, compared to that in the forest and to rainfall.

5.3.7. Age/Sex variation in feeding

The proportion of feeding time by different age/sex classes is presented in Table 5.9. Subadult females were excluded from these analysis because of sample size limitations. Different age/sex classes did not spend the same amount of time feeding; adult females spent proportionately the greatest time feeding, whereas infants fed for the least time (apart from suckling). For adults alone, adult females spent more than twice as much time feeding as did the adult male.

Table 5.8. Results of Spearman rank correlations between proportion of different plant parts in the diet of *R. avunculus* and synchrony of phenology among trees in the plots sampled.

Variables (in the diet and in the forest)	r_s	p
Young leaves vs. young leaves	0.49	p>0.05
Flowers vs. flowers	0.57	p>0.05
Fruits & seeds vs. fruits & seeds	0.53	p>0.05

Table 5.9. Percent time spent feeding by different age/sex classes of *R. avunculus* at Khau Ca (N=401, weighted data).

Age/Sex	% time feeding	n
Adult female	64.6	258
Adult male	23.0	84
Infant	2.0	10
Juvenile	9.0	44
Sub-adult female	1.4	5

5.4. Discussion

5.4.1. Dietary diversity

Asian colobines exhibit the diversity of diets that allows them to live in diverse habitats and to cope with seasonality in those habitats (Kirkpatrick, 1999; 2007; Table 5.11). *R. avunculus* in Khau Ca fed on 50 food species and a variety of food items including young leaves, mature leaves, flowers and flower buds, ripe fruits and unripe fruits, seeds of ripe and unripe fruits, and young stems.

R. avunculus in the present study harvest more than one and half times as many food species as reported by Le (2006), at the same site (50 and 32, respectively, Table 5.10) and the same number or less than reported for other sites (50 and 84, respectively, Pham, 1993a&b; 1994; 2002, Table 5.10; Appendix 3). However, few food species in my study are in common with previous reports (see Appendix 3). The present study shares only two and five food species with those of Pham (1993a & b; 1994; 2002) and Le (2006), respectively. These differences may result from differences in botanical composition between sites, as well as from different methodologies. The list of food species in Pham (1993a&b; 1994; 2002) was collected from four sites including Na Hang and Chiem Hoa, Tuyen Quang Province, Cho Don, Bac Kan Province, and Luc Yen, Yen Bai Province. Data available on botanical composition do not permit comparisons for all sites, but my results demonstrated that Tat Ke was richer in species than Khau Ca (151 and 136 species, respectively, see chapter 3). Further, it is evident that there was intra-specific variation in feeding strategy as a result of different habitat characteristics (as in the case of *R. bieti*: Grueter et al., 2009). Hence, even taking account of the fact that different methodologies may also influence the results, the feeding strategy of *R. avunculus* is likely to adapt to the botanical characteristics of the different forest environments in which they live. The current list of food species is

based on my direct observations in the field, whereas Pham's (1993a&b; 1994; 2002) results were based on a combination of information from local informants, some field observations, and seven stomach examinations.

5.4.2. Folivore versus frugivore

Prior to this study the question of folivory versus frugivory in *R. avunculus* remained unclear. Previous work reported that the langurs consume more fruits than leaves (Boonratana & Le, 1994; 1998a; Pham, 1993a; Le, 2006, Table 5.10). My data did not support these observations. The monkeys in the present study fed primarily on young leaves, which accounted for 46% of the feeding time. In addition, a large proportion of time was spent eating fruits and seeds (24% and 7%, respectively), concentrated at times when they were available. These discrepancies may be due to differences in the timing and period of study, the number of feeding observations, habitat characteristics, and differences in methodology between studies (Table 5). For example, Boonratana and Le (1994; 1998a) carried out their 6-month study at Na Hang between September 1993 and February 1994, corresponding to the cold and dry season. My phenological data over eleven months in Tat Ke suggested that this period corresponds to the fruiting season with a peak occurring in the early part of the dry season (November 2004, see section 3.2.6, chapter 3); given that the monkeys appear to exploit more fruits when they are available (Figure 5.6 and see below), it is likely that the proportion of fruit in their feeding observations would be somewhat inflated. Another possible explanation for this difference is that there are differences in the number of feeding observations obtained between studies: the proportion of food items in the diet in Boonratana and Le's (1994; 1998a) study was calculated based on only 34 feeding observations from scan and spot samples, whereas the proportion in my study was based on 326 feeding observations. The different calculation methods for proportion of food items between

studies may also affect results. Pham (1993a) and Le (2006) calculated the proportion of food items based on food species composition rather than scan feeding observations, so the results are not truly comparable with those of the current study, quite apart from the fact that the food list obtained by Pham (1993a) was not based primarily on direct observations. It can therefore be assumed that *R. avunculus* eats primarily foliage, with additional food types when available.

5.4.3. Food selection

My results show that the consumption of food trees and food items was not random. The langurs appeared to feed more heavily on items of some species than others; these findings are comparable with those on several other colobines (*Presbytis femoralis*: Bennett, 1983; *R. bieti*: Grueter, 2009; *R. roxellana*: Li, 2006). The selection ratios suggest that *R. avunculus* were highly selective in their choice of foods and fed mainly from trees which were quite rare and low in terms of both the number of stems and basal area. For example, *Diospyros choboensis* and *Syzygium sp* have low number of stems and basal area compare to other tree species, but were the species most selected in the diet. Strong selectivity for uncommon species has been reported in *R. bieti* at Samage (Grueter et al., 2009), *Presbytis rubicunda* on Sandakan Peninsula (Davies & Bennett, 1988), *Procolobus verus* in Sierra Leone (Oates, 1988). Preference for uncommon species may be related to nutritional quality. The monkeys select for tree species that have higher protein and fewer digestion-inhibitory compounds (Davies & Bennett, 1988; McKey et al., 1981; Waterman et al., 1988). Data from plant chemistry analysis have not been available for *R. avunculus* yet, so I can only assume that the langurs follow the pattern of food selection in colobines.

Selection ratios for food items indicate that young leaves are the most favoured food, followed by flowers and unripe fruits. Relatively high selection ratios for some food

items of some species may be related to their abundance and availability (see Tables 5.6; 5.7 and discussed below) as well as nutritional quality. The distribution of nutrients and defense compounds may vary throughout plant parts (Waterman & Kool, 1994). Compared with mature leaves, young leaves, flowers, and fruits have a higher content of protein and lower levels of fiber and toxic secondary compounds, so that they are more nutritious and digestible (Milton, 1979; 1980; Oates et al., 1980; Waterman, 1984). These items, however, are found seasonally at the study site, and the monkeys ate them when abundant and available.

5.4.4. Seasonal variation in diet

My results indicate that there was dietary variation throughout the study period as a result of seasonal changes in availability of food items, as with many other primates (Dasilva, 1994; Guo et al., 2007; Li, 2006; Pinto & Setz, 2004; Stanford, 1991; Wallace, 2005). There was a moderate correlation ($r = 0.49 - 0.57$) between the proportion of different plant parts in the diet and their availability in the forest, suggesting that the monkeys were feeding more on items that were available at the time. This, however, might not reflect a true correlation for the following reasons. Firstly, only 23 identified food species of tree were recorded during feeding scan samples, accounting for 14% of the total trees sampled, whereas the monkeys fed on at least 46 food species of tree from both *ad libitum* and scan observations. Further, most foods were from some uncommon species of trees. The availability of food items of these species may therefore reflect close changes in the proportion of different plant parts in the diet of rather than overall phenological patterns in the forest. Lastly, the disproportion and incomplete nature of feeding scans between months might influence these variations.

The amount of young leaves consumed by the langurs was generally high in most months, reaching a peak (100%) in February and May 2006 when most trees in the forest produced new leaves. Heavy reliance on young leaves in *R. avunculus* is understandable (see above). It may be expected to be a preferred food item (Grueter, 2009; Waterman & Kool, 1994), costing the langurs less time and energy to locate them (Li, 2006), and as a member of the Colobinae they possess a number of anatomical adaptations associated with leaf-eating (Chivers & Hladik, 1980; Kay & Davies, 1994). *R. avunculus* is of relatively large body size (see Table 2.1., chapter 2), and for this reason they could be expected to eat more leaves according to Clutton-Brock & Harvey's model (1977), although Yeager (1989) found that within the Colobinae there is no positive linear relationship between body size and folivory.

My results also indicate that consumption of fruits (both unripe and ripe) and seeds increased significantly during late summer and early winter, resulting in a decrease in the amount of new leaf consumption in these months. Fruits and seeds are commonly exploited by other colobines when available (Bennett, 1983; Oates, 1988; Stanford, 1991; Yeager, 1989); they can be high quality food items in terms of nutrient content and digestibility (Davies & Bennett, 1988; Mckey, 1981; Waterman, 1984), but on a seasonal basis (Oates, 1988). *Ad libitum* observations suggested that the three sympatric cercopithecines (*Macaca arctoides*, *M. assamensis* and *M. mulatta*) also harvested fruits of tree species that are used by the langurs. A seed-eating strategy during late winter may therefore reduce inter-specific competition (Stanford, 1991).

In the late months of winter, *R. avunculus* exploited, in addition, mature leaves of *Syzygium zeylanicum*, *Syzygium sp.* and *Premna balansae*, suggesting that they were increasing dietary diversity during period of food scarcity. These findings are similar to those of Bennett (1983), Grueter (2009), and Yeager (1989). Compared with young leaves, fruits and seeds, mature leaves are poorer in nutrient quality, and primates tend

to eat them only during periods of food stress (Grueter, 2009; Stanford, 1991; Yeager, 1989). Supplemental consumption of mature foliage may serve several purposes: increasing dietary diversity may compensate nutrient levels in the diet (Stanford, 1991), and by eating a nutrient-poor item but one with a wide temporal and spatial distribution as such mature leaves may save them time and energy in searching for food during a period of food scarcity (Dasilva, 1994; Oates, 1987; Yeager, 1989).

5.4.5. Sex differences in feeding

My data indicate that there was a marked difference in time spent feeding between the adult male and female. Adult females spent more than twice as much time feeding as did the adult male, suggesting that larger male body weight does not influence the amount of time feeding. Sex differences in time allocated to feeding have been reported in primates (Boinski, 1988; Ciani & Chiarelli, 1988; Clutton-Brock, 1977; Gautier-Hion, 1980; Harrison, 1983), perhaps related to the energy requirements of pregnancy and lactation in females (Clutton-Brock, 1977). In my observations, males have dominant access to areas of maximal food availability and they feed faster than females, thus they could feed for shorter periods, and less often, as inferred by Clutton-Brock (1977).

Table 5.10. Percent food items in the diet of *R. avunculus* from current and previous studies

Site	Study period	#CH	Plant part eaten											#spp	References	
			YL	ML	LB	P	FL	FB	FR	RF	UF	S	O			
Khau Ca	Sep 05-Sep 06	241	46	6			12		24				7		50	This study
Khau Ca	Dec 04-May 06	?	11				8		28	22			3			Le et al. (2007)
Khau Ca	Dec 04-May 06	?	11			26			21	24			8	11	32	Le (2006) ¹
Khau Ca	Since 2004	?	10	5			10			25	15		5	30	18	Wright et al. (2006) ²
Na Hang	Sep 93-Feb 94	122	38						47				15			Boonratana & Le (1994;1998a) ³
Na Hang	Mar 1992	?			37				63						61	Pham (1993) ⁴
Cho Don	Sep, 1989	?														
Luc Yen	Apr, May 1984	?														

#CH: Number of contact hour YL: young leaves ML: Mature leaves LB: Leave buds P: Petiole FL: Flower FR: Fruit RF: Ripe fruit UF: Unripe fruit S: Seed O: others #spp: Number of food species in the diet ?: Unspecified

¹Le (2006): Percentages of food items were calculated from food species composition

²Wright et al. (2006): Percentages of food items were calculated from food species composition

³Boonratana & Le: Percentages of food items were calculated from scan feeding observations

⁴Pham Nhat (1993): Study was carried out at three sites: Na Hang, Cho Don, Luc Yen. Percentage of food items was calculated from food species composition.

Table 5.11. Diet in selected Asian colobines

Species	Site	Habitat	L	YL/L B	M L	P	Fl	F/S	F	UF	S	Li	S/ B	In	O/ U	#spp	References
<i>Semnopithecus dussumieri</i>	Kanha	Moist deciduous forest		14	35		9	24						3	1	60	Newton (1992)
<i>S. priam</i>	Polonnaruwa	Semi-deciduous tropical forest	48	27	21		7	45								23	Hladik (1977)
<i>Semnopithecus vetulus</i>	Polonnaruwa	Semi-deciduous tropical forest	60	20	40		12	28								12	Hladik (1977)
<i>Semnopithecus johnii</i>	Kakachi	Evergreen forest		25	20	6	9	25					1		7	102	Oates et al. (1980)
<i>Presbytis rubicunda</i>	Sepilok	Dipterocarp forest		36	1		11	17			30				1	103	Davies (1984)
<i>Presbytis siamensis</i>	Kuala Lompat	Dipterocarp forest		28	3	5	11	49	10		25					87	Bennet (1983)
<i>Trachypithecus obscurus</i>	Khau Lommuak	Evergreen forest		34	2		24		18		0.5		0.4		0.2	29	Aggimaran gsee (2004)
<i>Rhinopithecus roxellana</i>	Shennongjia	Conifer/broadleaf forest		34	3		1	15				43	1			23	Yiming (2006)
<i>Rhinopithecus roxellana</i>	Qinling	Conifer/broadleaf forest	24	4				29				29	11		2	84	Guo et al. (2007)
<i>Rhinopithecus bieti</i>	Wuyapiya	Conifer forest	6								0.1	86			8		Kirkpatrick (1996)

Table 5.11. Diet in Asian Colobines (Continued)

Species	Site	Habitat	L	YL/LB	M L	P	Fl	F/S	F	UF	S	Li	S/ B	In	O/ U	#spp	References
<i>R. brelichi</i>	Fanjingshan	Temperate broadleaf forest	78				10	9					1		2		Bleisch et al. (1993) Bleisch & Xie (1998)
<i>Nasalis larvatus</i>	Tanjung Puting	Peat swamp	52	41			3		40					<1	5	55	Yeager (1989)
	Sukau	Peat swamp		73	0.3		8		8		2				8	33	Boonratana (1994)

L: Leaves; YL/LB: Young and mature leaves; ML: Mature leaves; P: Petioles; FL: Flowers; F/S: Fruit/Seeds; UF: Unripe fruits; S: Seeds; Li: Lichen; In: Insect; S/B: Shoot/Bark; O/U: Others/Unidentified; #spp: Number of food species in the diet.

5.5. Summary

Tonkin snub-nosed monkeys use different techniques to harvest food items. A combination of sitting and suspension was the most common posture utilized when feeding on all food items. Food items were picked and brought to the mouth mostly by one or both of the animal's hands, but were occasionally picked directly with lips and teeth. The langurs generally chose feeding trees ranging from medium to large size, which could support individuals or whole units. They use the middle canopy (10-17m, 82%) most when feeding, followed by the upper canopy (>20m, 12%) and under canopy (<10m, 6%). They started feeding at 6.00h and ended at 18.00h. There were two peak periods of feeding time during the day: in the morning from 7.00 to 10.00h, accounting for ca. 34% of the total daily feeding observations, and between 14.00 and 16.00h in the afternoon, accounting for ca. 36% of the total daily feeding observations. *R. avunculus* feed on 50 food species (46 species of plants, two species of liana, and two species of orchids). The annual feeding time budget comprises young leaves (46.2%), ripe fruits (13.8%), unripe fruits and flowers (11.2%), seeds (7.2%), mature leaves (6.9%), and undetermined items (2%). Food species were selected from uncommon trees in terms of both the number of stems and basal areas in the forest. There were seasonal variations in the diet of the langurs, corresponding to the availability of food items. Young leaves and fruits appear to be preferred food items because they were strongly selected when available. Males spent less time feeding than did females.

Chapter 6

Population size, distribution and conservation status of

Rhinopithecus avunculus in Vietnam

6.1. Introduction

The Tonkin snub-nosed monkey (*Rhinopithecus avunculus*) is a critically endangered primate (IUCN, 2010), endemic to Vietnam. As noted earlier, *R. avunculus*, unlike Chinese snub-nosed monkeys, live in tropical forests (mixed broadleaf and bamboo forests), at relatively low elevations (Le & Boonratana, 2006). Its current range is limited to the fragmented forest patches associated with limestone hills, and is still dramatically reducing in size (Boonratana and Le, 1994; 1998b; Le & Boonratana, 2006; Nadler et al., 2003; Pham, 2002; Ratajszczak et al., 1990; 1992). At the present time it is found only at Quan Ba and Khau Ca, Ha Giang Provinces (Le, 2004), and Cham Chu and Na Hang NR, Tuyen Quang Provinces (Dong, 2007).

Total population estimates have remained unreliable. There have been few studies up to now to document its population size, whether at each known site or in Vietnam as a whole (Cao & Pham, 1995; Boonratana & Le, 1994; Nadler et al., 2003; Le, 2004), and such reports as exist are largely based on interview information and short surveys. One of the aims of this study is to determine the population size at each site and to give an estimate of the total population size for Vietnam.

Hunting and habitat destruction are major threats to the survival of *Rhinopithecus avunculus* throughout the range (Boonratana & Le, 1994; 1998b; Cao & Pham, 1995; Dong & Boonratana, 2006; Dong et al., 2006; Le et al., 2000; Le & Boonratana, 2006;

Long & Le, 2001; Nadler et al., 2003); details on how these threats affect the species and its habitat at some sites have not been published.

This chapter will present the trends in population size and distribution as well as conservation status of *R. avunculus* in 6 protected areas in northern Vietnam between 2004 and 2010. Recommendations for future action towards conservation and management of the species and its habitat will also be provided.

6.2. Method

6.2.1. Study areas

I carried out surveys at six known sites of occurrence of Tonkin snub-nosed monkeys in the north eastern region of Vietnam (Figure 6.1) between 2004 and 2010: Na Hang NR and Cham Chu NR in Tuyen Quang Province, Chau Ca HSCA in Ha Giang Province, Nam Xuan Lac HSCA and Ba Be NP in Bac Kan Province, and Than Sa-Phuong Hoang NR in Thai Nguyen Province. The Tat Ke Sector of Na Hang NR and the Chau Ca HSCA are treated in detail in chapter 3. The following is a brief description of the study sites of Cham Chu NR, Ba Be NP and Nam Xuan Lac HSCA area and Than Sa-Phuong Hoang NR.

Cham Chu NR

Cham Chu NR is located in Chiem Hoa and Ham Yen Districts, in Tuyen Quang Province, located between 22°09' - 22°20'N and 104°95' - 105 °08'E (Long & Le, 2001). The reserve covers an area of 58,187ha and is divided into three management zones: strict protection, reforestation and administration areas, respectively measuring 17,904ha, 40,283ha and 1.5ha. The topography of the reserve can be categorized into three levels: low lying areas with gentle slopes, steep sided mountainous terrain, and undulating mid-altitude hills. The highest mountain in the area is Cham Chu peak

(1,587m), followed by Pu Loan (1,154m) and Khau Vuong (1,218m) (Le et al., 2000; Long & Le, 2001).

There are two marked seasons in this area, the dry season from October to April and the rainy season from May to September (Le et al., 2000). The mean temperature is 22.9°C and the mean precipitation is 1,661 mm (Long & Le, 2001). The areas surveyed comprise mainly evergreen forest associated with limestone hills and mountains. In addition, there is some mixed semi-evergreen broadleaf and bamboo forest. It has been reported that the reserve contains 42 mammal species, 127 bird species, 38 reptile species, and 15 amphibian species, including two globally threatened primates (Le et al., 2000). The presence of the endemic and critically endangered Tonkin snub-nosed monkey *R. avunculus* and of Francois' langur *Trachypithecus francoisi* has vital implications for long-term conservation and management (Le et al., 2000; Long & Le, 2001).

There are several local communities living in and around the reserve, comprising mainly Tay, Dao, Nung, H'mong, Cao Lan, La Chi, Hoa and Kinh. They cultivate rice as a main crop and others such as corn, orange and cassava, and raise some domestic animals such as buffaloes, cows and goats. Different groups have different agricultural land use strategies and hunting methods which result in various degrees of threats and impacts on the reserve as well as difficulties in making effective management and conservation plan.

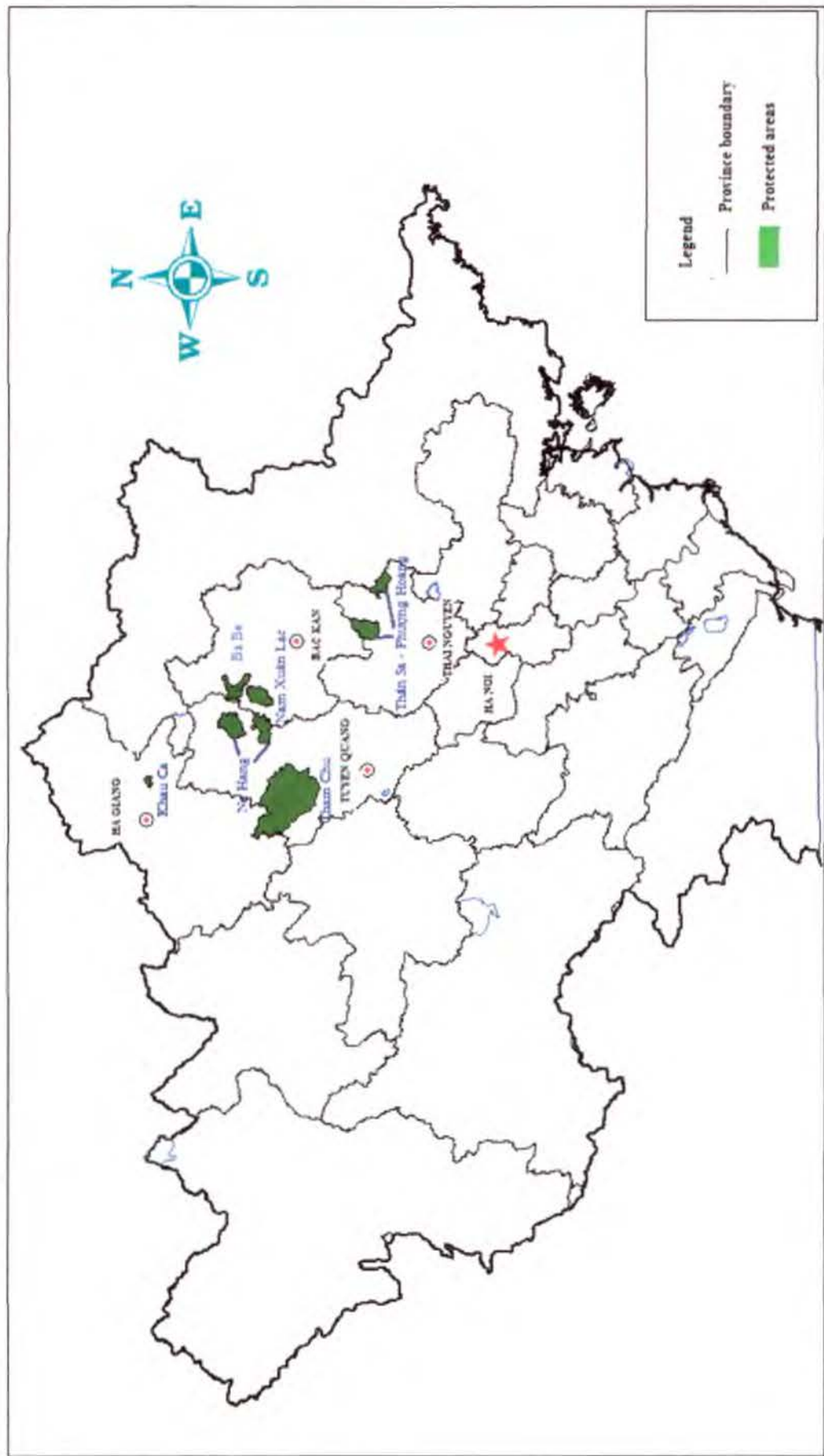


Figure 6.1. Map of areas surveyed.

Ba Be NP

Ba Be NP is located in the Ba Be District of Bac Kan Province (22°21' - 22°29'N by 105°34' - 105°42'E, Figure 6.1). The NP covers an area of 7,608ha, with about 85% of the area still with forest cover. The NP is divided into three functional zones, comprising a strict protection area of 3,226ha, a forest rehabilitation area of 4,082ha, and an administration area and lake surface of 300ha (Bac Kan Provincial People's Committee [PPC], 2001; Bui, 2003).

Steep limestone hills and valleys characterize the topography of the NP. The elevation ranges between 150 and 1,121m asl, with the highest peak Cang Lo at 1,121m asl. Many limestone caves are found along the steep cliffs, with Puong Cave at 300m in length being the largest. Ba Be NP falls within the microclimate of the northeast region of Vietnam, with four distinct seasons (spring, summer, autumn, and winter) and influenced by the cold and dry north-east winds during the dry season (from October to March). The mean monthly minimum and maximum temperatures were recorded at 22°C and 39°C respectively. The mean annual humidity was reported at 83%, and the mean annual rainfall was recorded as 1,378mm (Bui, 2003).

There are three main types of forest in Ba Be NP: evergreen forests associated with limestone hills and mountains, lowland evergreen forests, and bamboo forests. Limestone associated with forests occupy most parts of the park and feature thick vegetative cover, while evergreen forests are distributed on low earthen hills covered with a thicker soil layer. Species of lowland forests are more diverse than those found on limestone mountains (Hill et al., 1997). Flora comprises about 603 vascular plant species belonging to 137 families (Bui, 2003). Dominant tree species include *Bleekrodea tonkinensis* (Moraceae), an important element of the lower canopy, and

Burriodendron hsienmu (Timaliaceae), common in upper canopy forests (Trai et al., 2004). The fauna of the NP is reported to comprise 65 mammal species, 214 bird species, 46 reptile and amphibian species, and 87 fish species (Bui, 2003; Pham, 2003). The presence of the two critically endangered and endangered primates, *Rhinopithecus avunculus* and *T. francoisi*, has given the park great importance as a national and international conservation area.

Ethnic minority groups within the Ba Be NP Landscape include Tay, Nung, Dao and H'mong. These groups have lived for many years in villages located in the buffer zone, and in limestone mountain valleys or along the lake border. Paddy cultivation is a major economic activity of these groups, but land for agriculture is insufficient and many of them have to rely on hunting and illegal forest extractions to support themselves. Each group has its own cultural characteristics. The Tay people usually live in wooden stilt houses and maintain their livelihood through fishing or weaving, while the H'mong people rely heavily on upland crop cultivation and hunting (Bac Kan PPC, 2001).

Nam Xuan Lac HSCA

Nam Xuan Lac HSCA (22°17'-22°19'N by 105°28'-105°33'E) is located in Xuan Lac Commune, in Cho Don District of Bac Kan Province. The total area of Nam Xuan Lac HSCA is 1,788ha, comprising a strict protection area of 1,646ha, a forest rehabilitation area of 142ha (Bac Kan Provincial Forest Protection Department [PFPD], 2003), and a buffer zone covering an area of 7,508ha.

Steep limestone hills and valleys are the main features of the topography. The elevation ranges between 400m and 1,159m, with the highest peak Tam Sao at 1,159m (Bac Kan PFPD, 2003). There are many peaks reaching elevations to about 1,000m. Additionally, the north-western region of the HSCA is typical of Nui Dat, with elevations ranging from 400 to 600m. The mean temperature is 21.1°C, and the mean monthly minimum

and maximum temperatures have been recorded at 13.5°C in July and 26.7°C in January. The mean annual humidity is 82%. Mean annual rainfall is 1,153mm. Most of the rains fall within April and October (Bac Kan PFPD, 2003).

Of its 1,788ha, 1,646ha (92.06%) is primary forest, 32ha (1.80%) is medium forest, 70ha (3.90%) is degraded forest, and 40ha (2.24%) is regrowth forest after shifting cultivation (Bac Kan PFPD, 2003). Most of the evergreen forest associated with limestone hills remains intact or slightly disturbed. Main plant families in Nam Xuan Lac HSCA are Tiliaceae, Fabaceae, Lauraceae, Clusiaceae, Araliaceae, Verbenaceae, Moraceae, Aceraceae, and Elaeocarpaceae. The dominant species in the forest are *Burretiodendron hsienmu* and *Zenia insignis*. *Pinus fenzeliana* is distributed in the peaks of the limestone mountains.

Thirty four mammal species, 156 bird species, 19 reptile species, and 14 amphibian species have been recorded in Nam Xuan Lac. Among these, 11 species are listed in the IUCN Red List and 16 species in the Vietnam Red Book (Bac Kan PFPD, 2003). Notably, the presence of several globally critically endangered and endangered species such as *Rhinopithecus avunculus*, *Trachypithecus francoisi* and the White-eared Night Heron (*Gorsachius magnificus*) within the reserve has been mentioned in previous documents (Bac Kan PFPD & Vietnam Conservation Fund, 2009; Bac Kan PFPD & Ministry of Agriculture and Rural Development, 2004; Bac Kan PFPD, 2003).

Several ethnic minority groups including H'mong, Tay, Dao, and Nung live in the surrounding areas of Nam Xuan Lac HSCA. Rice paddy cultivation is a major economic activity of these groups. Additionally, many families have corn fields on hill slopes. Income is low, and they have to rely on exploiting natural resources, especially forest, for additional income. H'mong people usually have insufficient land for upland crop

cultivation. They are also renowned for wildlife hunting habits and skills (Bac Kan PFPD, 2003).

Than Sa Phuong Hoang NR

Than Sa Phuong Hoang NR is located in Thai Nguyen Province, between 21°45'12" -21° 56'30" N and 105°51'05" - 106°08'38"E. It covers an area of 17,639ha, comprising a 6,310ha strict protection area, a 11,226ha forest rehabilitation area and 103ha administration area (Thai Nguyen PPC, 2008). The topography in the NR is characterized by rugged and steep limestone hills, contributing to one third of the reserve. Average elevation is about 700m.

There are two marked seasons in the year. The rainy season lasts from May to October, and the dry season is from October to April. The mean annual rainfall is from 2,000 to 2,500mm. The mean temperature is 21.5°C, and the mean monthly minimum and maximum temperatures have been recorded at 13.2°C in July and 34°C in January. There are several temporary and permanent streams inside the Reserve.

There are three main forest types in the Reserve: evergreen forests associated with limestone hills and mountains, evergreen forests, and mixed semi-evergreen broadleaf. Flora comprises about 1011 species of vascular plants belonging to 142 families (Thai Nguyen PPC, 2008). Dominant tree species include *Bleekrodea tonkinensis* (Moraceae), an important element of the lower canopy, and *Burretiodendron hsienmu* (Timaliaceae), common in upper canopy forests. 56 mammal species, 117 bird species, 39 reptile and amphibian species, and 83 fish species have been recorded in the NR (Thai Nguyen PPC, 2008). The presence of critically endangered and endangered primates, *R. avunculus* and *T. francoisi*, has given the reserve, like others in this area, great importance as a national and international conservation area. (Dong, 2010; Thai Nguyen PPC, 2008)

Ethnic minority groups in the Nam Xuan Lac HSCA comprise Tay, Nung, Dao and H'mong. Paddy cultivation is a major economic activity of these groups, but varies not enough land for agriculture and many of them have to rely on hunting and illegal forest extraction to support their livelihood (Thai Nguyen PPC, 2008).

6.2.2 Data collection

Due to the rarity of the species and difficulty of the terrain, I used a combination of methods to obtain data on distribution and population size. These included interviews, line transects, reconnaissance and total counts (White & Edwards, 2000). A range of local people, from villagers, hunters and patrollers to NP staff, were interviewed before the surveys took place. The key informants were those who had seen *R. avunculus* in recent times. The purpose of the interviews was to collect general information on the species in the proposed survey areas. Verbal reports, however, were used with care and only added to the dataset after further verification in the field. Pictures of the species were also used during the interviews to avoid confusion about local names of certain species (see Rabinowitz, 1999).

Existing trails and line-transects were combined to determine the presence/absence and population size of *R. avunculus* in the areas studied (White & Edwards, 2000). Given the small populations, opportunistic census was used to count the total the number of animals in groups as encountered. More effort was paid to the resting and sleeping sites early in the morning and late in the afternoon, since this permitted observers the best visibility, so as to obtain a good count of a whole group of monkeys. Further, the presence/absence of *R. avunculus* was also obtained from both direct and indirect evidence (see Ross & Reeve, 2003):

- Direct observation of live animals
- Indirect observation of characteristic signs (feeding signs and vocalizations, etc.)
- Observation of animals captured or killed

- Reports from local communities

I walked along existing trails and transect lines beginning at 0630-0700h and ending at 1730-1800h at an average speed of about 1-1.5 km/h. For each group sighting I recorded time, number of individuals seen, estimated number of individuals, GPS location, activities, and habitat.

I used Margoluis & Salafsky's (2001) method called "Threats Reduction Assessment (TRA)" to assess threats encountering along the transects within study sites. This method was developed to measure conservation success in reducing threats to protected areas and to species within protected areas. To provide a measure of the relative abundance of the two threats, encounter rate per kilometer walked was calculated for all signs of human activity. The TRA method ranks each threat for three criteria: AREA, INTENSITY, and URGENCY, defined as follows:

AREA: The portion of habitats in the site that the threat will affect. Will it affect all of the habitats at the site or just a small part?

INTENSITY: The impact or severity of destruction caused by the threat. Within the overall area, will the threat completely destroy the habitat(s) or will it cause only minor changes?

URGENCY: The immediacy of the threat. Is it a current threat? Will it occur only 25 years from now?

Data on population size and distribution as well as threats were analyzed with the aid of software (Excel, SPSS and MapInfo).

6.3. Results

6.3.1. Population size and distribution

Population sizes and distribution of *R. avunculus* were obtained from a total of 5,529 working hours (549 working days) covering an area of 300km². Of that, about 82% working hours covering 135km² were devoted to two main study sites: Tat Ke Sector of

Na Hang NR, and Khau Ca habitat and species conservation area (Table 6.1). This made of a total of 250 observational hours.

Sightings of *R. avunculus* were made only in Tat Ke Sector (Na Hang NR) and in Khau Ca HSCA. For the remaining sites, information on population size and distribution were derived from local informants (Table 6.2). The total estimated population size for all sites studied is 150 individuals. Population sizes in all sites are small, ranging from 6 to 22 individuals, except for Khau Ca HSCA (90 individuals). In some areas the populations appear to be extirpated, such as Ba Be NP and Nam Xuan Lac HSCA. Detailed data on the population size and distribution of *R. avunculus* at six sites are presented in Table 6.2 and Figure 6.2 and given below.

Tat Ke Sector, Na Hang NR

R. avunculus groups were seen only six times in the reserve over 245 working days in Tat Ke Sector. Group sizes range from 5-17 individuals (see Table 4.3, section 4.3.1, Chapter 4). The highest minimum count for the band was 17 individuals, although estimated to be 22. This estimate is based branch movements possibly made by about four to five animals traveling behind this band. This estimate is likely to be the entire population in Tat Ke Sector, as there was no evidence of the existence of any other groups or bands during the course of the study.

R. avunculus were encountered more frequently at some locations than in other known locations in Tat Ke Sector; most frequently in the Khau Tep, Lung Khao and Tat Tra areas (Figure 6.3). These areas share some common features, predominantly being that they were remote and difficult to access by humans. All habitats where I saw the *R. avunculus* are within evergreen forests associated with limestone hills.

Cham Chu NR

No direct or indirect observations of *R. avunculus* were made during 43 working days in the reserve. All information on the species' past and current population and distribution was collected from interviews (Table 6.3; Figure 6.4). Based on this information, the population size in Cham Chu appears to be between eight and 12 individuals.

Local people from Khuon Pong village saw a group of eight *R. avunculus* in Khau Vuong (105°07'E/22°22'N) area near the village in May 2005. In August 2005, a member of staff of Chiem Hoa Forest Enterprise bought an adult male of *R. avunculus* weighing about 12kg from a H'Mong hunter, who had killed it between Khau Sang and U Tum areas, but he did not know the size of the group from which he had killed it. In April 2005, local people from Ha Lang Commune bought two live individuals (one adult female and an infant) from a hunter of Ban Hiep Village. The adult female died after two days, and the infant died of diarrhea within two weeks after it was fed with condensed milk (Ma Van Binh, pers. comm., 2006). In September 2004 a hunter of Tan An commune encountered a group of approximately 12 individuals (with at least one adult male, two adult females with two clinging infants, and seven other individuals of unknown age/sex) at the bottom of Khau Sang mountain (105°08'E/22°23'N). In 2003, an adult male was killed by a Tay hunter from Ban Hiep village in Khau Sang area. According to Hoang Duc Tai from Nam Luong village, Phu Luu commune, an individual was killed in the Quan Tien area in 2001; the meat was eaten, the bone was used for making a traditional medicinal balm locally known as "Cao", and the skin was used for decoration. "Cao" is typically mixed with drinking alcohol or warm water and drunk to bring down fever and for treating aching joints and muscles.

According to Ma Cong Linh (Pers. comm., April 2006), two individuals weighing about 3kg (probably juveniles) were captured at Dan Khao in 1999, and were raised for 5 months in captivity, after which they were sold to people in Chiem Hoa for 60,000

Vietnamese dong (ca. US\$3.5) per individual. He also added that a solitary large individual was encountered in the Nam Luong area in October 2005.

Khau Ca HSCA

A total of 241 contact hours was recorded during the course of a thirteen-month study at Khau Ca HSCA, out of which 195 hours were visual. This accounted for 2397 scan observations. Band sizes and their age/sex composition based on “good counts” at Khau Ca HSCA are presented in Table 4.5 (see section 4.3.1., chapter 4). The size of the bands ranged from 22 to 81 individuals, and appeared to be dependent on the number of one-male units in travelling or resting in association with one another. The highest minimum count for a band at Khau Ca was 81 individuals in April 2006. The estimated size of the population in Khau Ca was about 90 individuals (Table 6.1). This count may likely be an underestimate of the the band size because some infants clinging to the adult females and individuals traveling under dense foliage were missed. All counts were made when the bands crossed open canopy gaps. *R. avunculus* in Khau Ca appears to use most parts of the reserve. They used 25 quadrats within the study area year-round, covering an area of 625ha (Figure 6.5).

Ba Be NP

No direct or indirect observations of *R. avunculus* were made in the reserve during 21 working days covering an area of 47km² in the park (Table 6.1). According to local informants, the species has not been seen for years, and they believed that no populations remain in this area. It can be assumed that *R. avunculus* is locally extinct in the park.

Nam Xuan Lac HSCA

No *R. avunculus* was observed during 12 working days covering an area of 14km² in the HSCA although all possible areas of occurrence were exhaustively searched (Table 6.1).

Local people however confirmed the past and recent occurrence of the species in the area. Interview information on the past distribution and group sizes of *R. avunculus* in the areas surveyed is presented in Table 6.4 and Figure 6.6

According to respondents, groups of *R. avunculus* were sometimes seen in Lung Li and Lung Luong areas between 1998 and 1999. In 2004, a hunter from Na Village saw a group of about 20 animals in Lung Li area (Luong Van Tuyen, pers. comm., 2010). As reported by the same hunter, an adult female (ca. 7kg) was shot out of a group of five to six animals in Lung Luong area in 2005. The animal was brought to the hunter's house, and the meat used for food and the bone used for making the traditional medicine "Cao". The most recent encounter of *R. avunculus* by local people was in October 2009 in Dau Cap area near the Bo Man and Tam Tinh areas, according to Hoang Van Pao, (Pers. comm., 2010), who also noted that the chance of encountering the species in the forest is low since they appear to travel in relatively small groups and remains very quiet when they detect the presence of humans, very likely a behavioral adaptation to the high hunting pressure in this area.

Local people also reported the possibility of groups travelling back and forth between Nam Xuan Lac HSCA and the Ban Bung Sector of Na Hang NR: when one area is disturbed by human activities, they would move to the other site through connecting corridors. This may be one of the reasons why team members did not see any *R. avunculus* during the survey.

Than Sa Phuong Hoang NR

I did not observe any *R. avunculus* during 28 working days covering an area of 40km² in the reserve (Table 6.1). Local people, however, reported that they saw a group of about 20 individuals in the Dan Deng and Co Poc areas in 2008, and believed that the group is still existing there (Figure 6.7). This information, however, came to me they

few months after the field surveys; future work should search these areas for their presence and to estimate the population size.

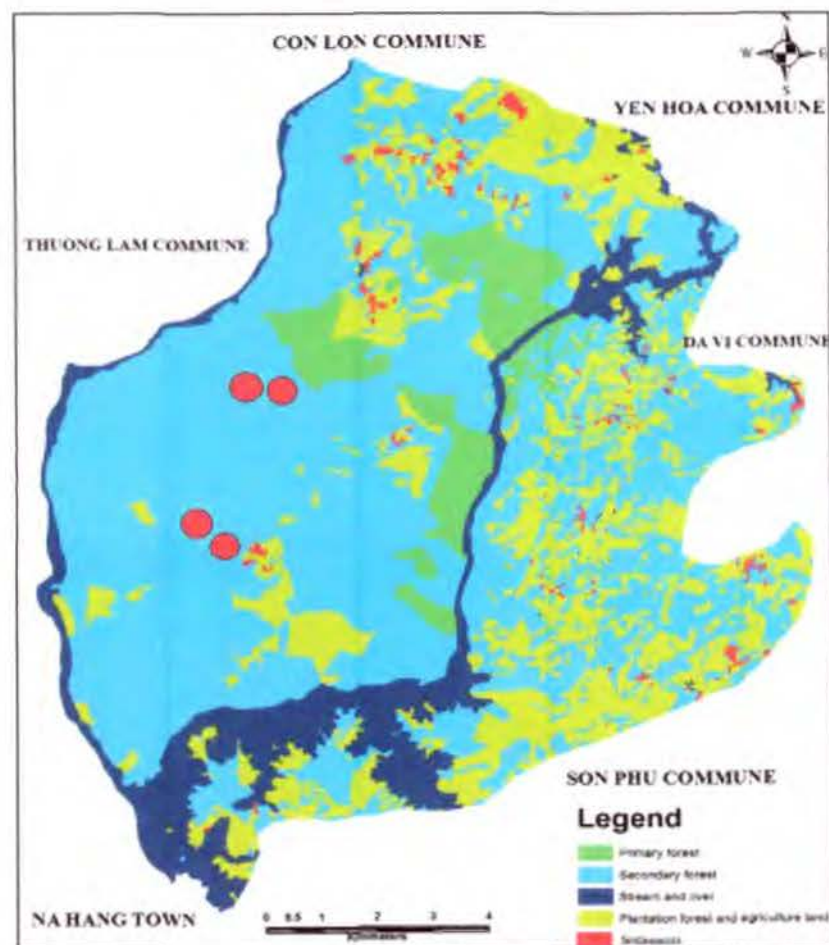
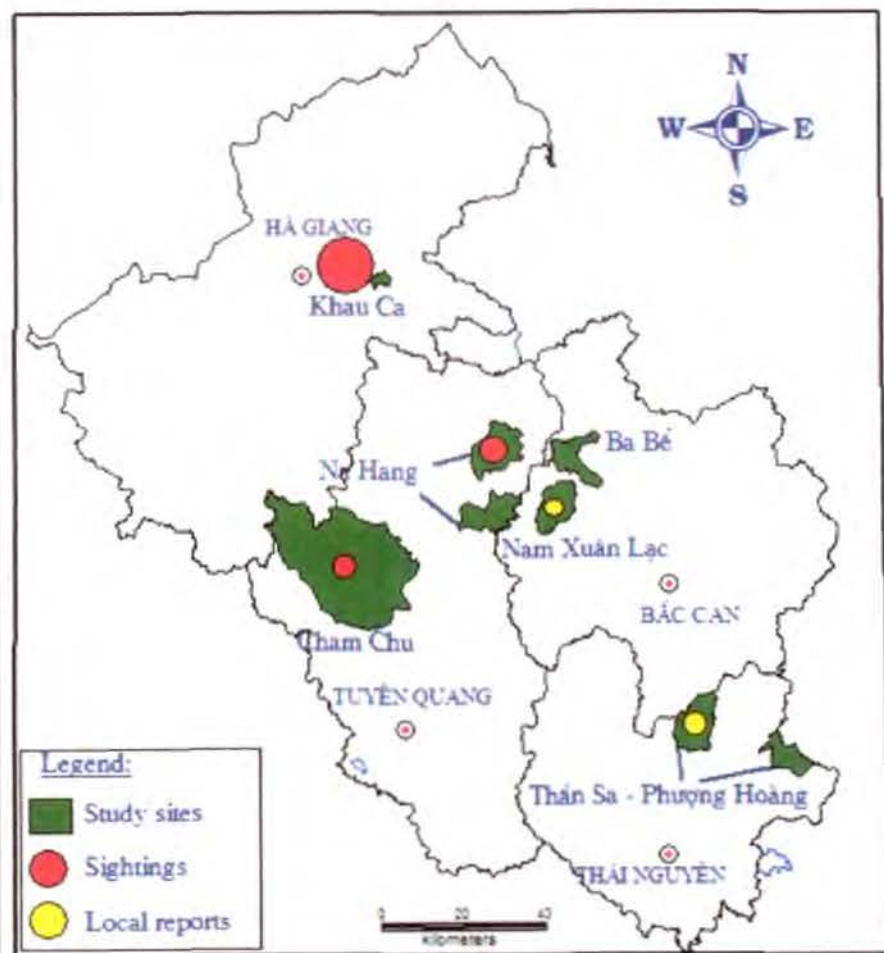


Figure 6.2. Map of areas surveyed for *R. avunculus* in the region of Hà Giang, Tuyên Quang, and Thái Nguyên provinces. Figure 6.3. Locations of *R. avunculus* sightings in Tat Ke.

(Note: The larger circles depict higher population sizes).

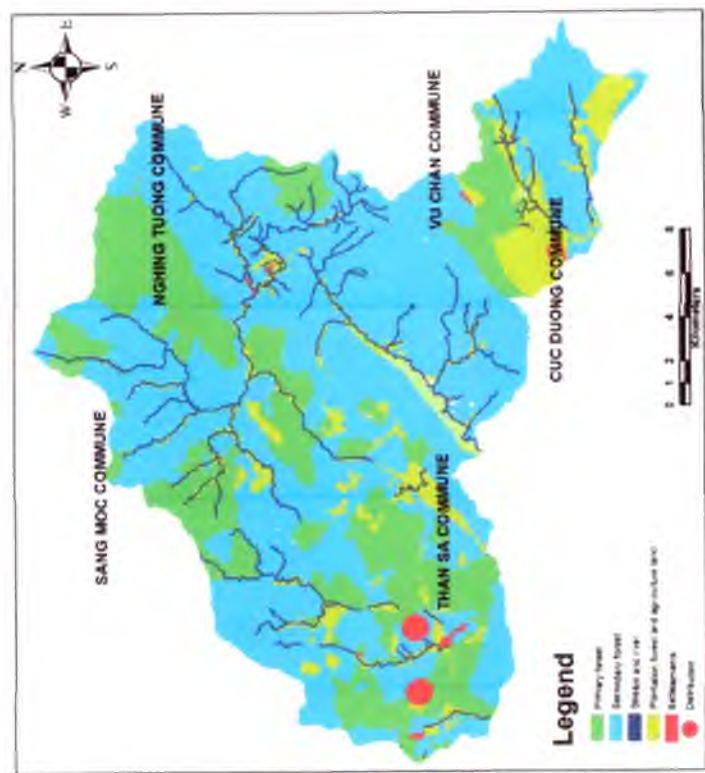
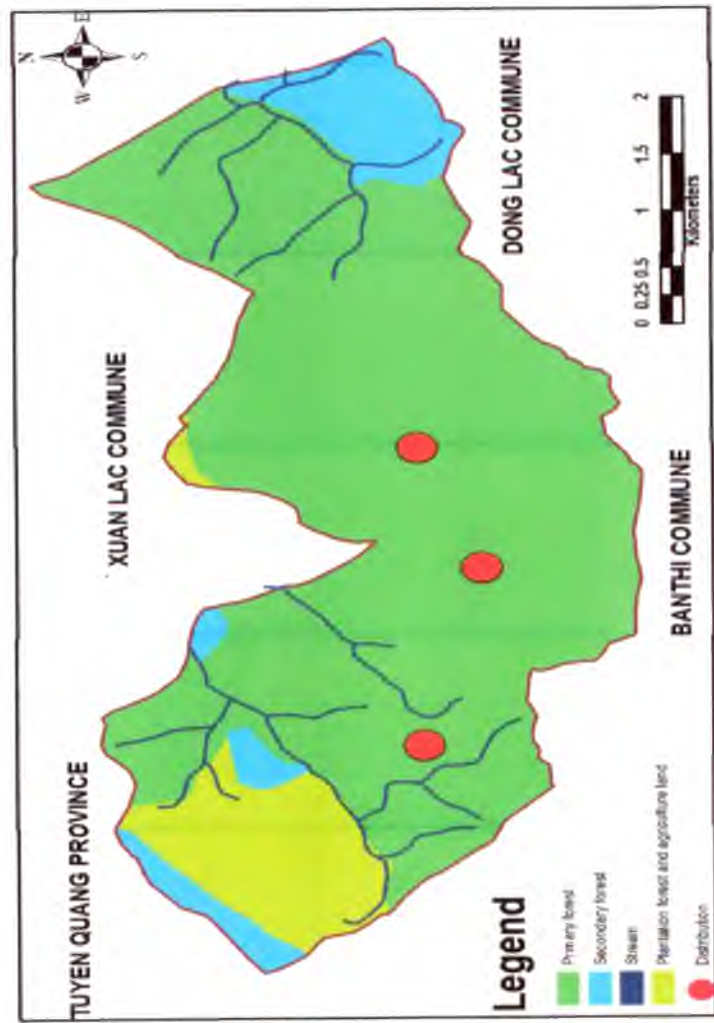


Figure 6.6. A distribution map of *R. avuncula* in Tuyen Quang Province. Figure 6.7. A distribution map of *R. avuncula* in Sa-Phuong Hoang NR.

Table 6.1. Number of working days and areas covered in six sites surveyed.

Sites	Provinces	Area (km²)	Forest types	Working days (days)	Areas covered (Km²)	Working hours (Hours)
Tat Ke, Na Hang NR	Tuyen Quang	125	Evergreen forest	245	125	2450
Cham Chu NR	Tuyen Quang	581.87	Evergreen forest	43	64	363
Khau Ca HSCA	Ha Giang	10	Evergreen forest	200	10	2100
Ba Be NP	Bac Kan	76.08	Evergreen forest	21	47	216
Nam Xuan Lac HSCA	Bac Kan	17.88	Evergreen forest	12	14	150
Than Sa-Phuong Hoang NR	Thai Nguyen	176.39	Evergreen forest	28	40	250

Table 6.2. Population sizes of *R. avunculus* at six sites surveyed.

Sites	No. of individuals seen	Estimated individuals	No. of Habitats	Observation hours
Tat Ke, Na Hang NR	17	22	Evergreen forests	9
Cham Chu NR	0	8-12*	Evergreen forests	0
Khau Ca HSCA	81	90	Evergreen forests	241
Ba Be NP	0	0	Evergreen forests	0
Nam Xuan Lac HSCA	0	4-6*	Evergreen forests	0
Than Sa-Phuong Hoang NR	0	20*	Evergreen forests	0

*Information collected from local informants

Table 6.3. Interview information on group size and distribution of *R. avunculus* in Cham Chu NR.

Date	No. of individuals seen	Sites	Locations (VN2000)	References
August 2005	1	Khau Sang U Tum	105 ⁰ 09'E/22 ⁰ 21' N 105 ⁰ 08'E/22 ⁰ 23' N	Ma Dinh Uoc, Khuon Pong Village
May 2005	8	Khau Vuong	105 ⁰ 07'E/22 ⁰ 22' N	Ma Van Dong, Khuon Pong Village
April 2005	2	Khau Sang U Tum	105 ⁰ 09'E/22 ⁰ 21' N 105 ⁰ 08'E/22 ⁰ 23' N	Hoang Van Su, Khuon Pong Village
September 2004	12	Khau Sang	105 ⁰ 09' E/22 ⁰ 21'N	Linh Mong Duyen, Tan An Village
2003	1	Khau Sang	105 ⁰ 09' E/22 ⁰ 21'N	
2001	1	Quan Tien	105 ⁰ 08' E/22 ⁰ 21'N	Hoang Duc Tai, Nam Luong Village
1999	2	Dan Khao	105 ⁰ 14' E/22 ⁰ 19'N	Ma Cong Linh, Nam Luong Village

Table 6.4. Interview information on group sizes and distribution of *R. avunculus* in Nam Xuan Lac HSCA.

Date	Sites	Locations (VN2000)	Group sizes	Evidences	References
1998-1999	Lung Li	105 ⁰ 66' E/22 ⁰ 23'N	?	Sighting	Triệu Hữu Hòa, Triệu Hữu Hiến and Triệu Văn Sâm, Nà Dạ Village
Sep 2004	Lung Li	105 ⁰ 66' E/22 ⁰ 23'N	Ca. 20	Sighting	Lương Văn Tuyển, Nà Dạ Village
Jun 2005	Lung Luong	105 ⁰ 68' E/22 ⁰ 24'N	5-6	Sighting	Lương Văn Tuyển, Nà Dạ Village
Oct 2009	Đầu Cap	105 ⁰ 58' E/22 ⁰ 45'N	4-6	Sighting, vocalization	Hoàng Văn Pào, Bó Mẩn Village

(?) Unknown

6.3.2. Conservation issues

Threats

Hunting and habitat destruction were identified as main threats to *R. avunculus* and its habitat. Hunting signs included hunters encountered, gunshots heard, hunting dogs, extinguished campfires, temporary hunting shelters, hunting trails. Habitat destruction included tree-cutting, stacked timber, logging huts, fire wood and non-timber forest product collection, livestock grazing and cutting trees for grazing. In general, these signs were found in all sites surveyed, although there are differences in the intensity of threats and impacts to each site (Appendix 3 and Table 6.5).

Hunting

Hunting signs were seen in all sites studied. Predominant signs of hunting in all forests were those related above, although hunting dogs were recorded only in Na Hang NR and Ba Be NP.

The relative intensity of hunting sign in forest studied is shown in Figures 6.8 to 6.13. The larger circles in the maps mean that the encounter rates of hunting signs are more intensive. Cham Chu and Na Hang sites have higher levels of hunting sign than others. On a daily basis, I could hear between three and 10 gun shots, and groups of hunters were encountered several times in these areas, while signs of active hunting trails were more common than those of other sites; this may be why population sizes of *R. avunculus* have been declining in these areas. Khau Ca area has the lowest level of hunting among sites studied; I did not see any sign of hunting in this area during the course of the study.

Hunters typically comprise Tay, Dao and H'mong people from the villages in and around the protected areas. Different groups may have different hunting strategies. Tay and Dao people often go hunting alone and spend a night or a maximum of two to three days in the forest. In contrast, H'mong hunters often go hunting in groups of two or more persons and spend longer periods in the forest than any other groups of hunters (often one to two weeks). *R. avunculus* was mainly hunted using homemade guns. According to the hunters, this is because these monkeys often occupy the canopy level, so other hunting tools are ineffective. Hunting seems to be conducted throughout the year, but the main hunting season is between November and January corresponding to their time available post-harvest.

Hunting signs were generally found in the more remote and difficult (terrain-wise) areas, that hold better quality forest habitat, and are more remote from established ranger stations and less regularly patrolled by the rangers. The relative intensity of hunting signs observed in survey areas is presented in Figures 6.8 to 6.13. The Figures show that all sites studied share common features. The signs of hunting increased with increased distance from forest edges, except for Khau Ca. This is likely to be because, firstly, hunters dare not hunt around forest edges where they face higher risks of being caught by rangers, and, secondly, according to local reports, most large mammals are now forced to live in remote and difficult areas.

R. avunculus is not a target species, according to hunters. They believe that their meat is not "good tasting" compared to that of other wildlife, but due to the shortage of other wildlife they would hunt it when encountered. The number killed between 1999 and 2005 in Cham Chu NR (six individuals) is evidence for this. The meat fried with ginger would be used for family consumption, and bones would be used for making "Cao" (Van Du, pers.comm., Jan, 2006), which can be either used for domestic family

medicinal purposes or sold in local markets and to traders (Ma Dinh Uoc, pers.comm., 2006).

Habitat destruction

Habitat destruction was observed in some parts of the forests studied and had an impact on the forest integrity. Among the types of habitat destruction, illegal logging was identified as the most serious threat since it takes place inside the known langur habitats.

The encounter rates of illegal logging at six areas surveyed are shown in Figures 6.8 to 6.13. The Figure shows that Ba Be NP, Nam Xuan Lac HSCA and Than Sa-Phuong Hoang NR areas appeared to have higher levels of illegal logging than other sites.

Trees cut for timber and stacked timber boards were encountered along existing trails in the forests, despite this activity being illegal within the protected areas. Much of the felling was undertaken with the use of chainsaws rather than with traditional pit sawing methods. The use of chainsaws allows users to harvest timber more quickly and with less manpower, reducing the potential of attracting the rangers' attention. Further, illegal logging often takes place at night or in the early morning and is very difficult to control since only a small number of rangers are available on site. The trees cut are often large and valuable timber species such as Tong Du (*Toona sinensis*) and Nghien (*Burretiodendron hsienmu*), which are of interest to loggers since they are valuable house building and furniture making materials.

Non-timber forest product collection activities were recorded in all forests studied. Local people collect a variety of products in the forest ranging from roots, barks, shoots, rattan and fruits of certain trees and lianas. These products were used for domestic

family medicinal purposes or sold in local markets and to traders. Bamboo shoot collection is a good example of this activity; this occurs between June and September in the Na Hang, Cham Chu, and Ba Be areas where there are several patches of bamboo forests. This activity is also illegal in the protected areas and is having a detrimental impact on the forest integrity in this area. Collectors harvested fresh bamboo shoots and often dried the vast majority of product inside the forest. Dried bamboo shoot products are then transported out of the forest and sold to traders or in local markets, attracting a local value of VND 35,000-80,000/kg equal to US\$2-5/kg (Per. obs., 2005; 2009). Each adult villager in Tat Ke Sector Na Hang NR, on average, earns from four to five million Vietnam dong (equivalent to US\$250-310) per season (H.T. Dong, pers. obs., 2005). Collectors are local people living in and surrounding the protected areas.

Livestock grazing and cutting trees for grazing are also having an impact on the habitats of the species and wildlife in general. It is clear that this activity is far less widespread than hunting and illegal logging. Livestock grazing often takes place at abandoned cultivations and lower elevation sites in the forest. In most cases, the trees cut for grazing are *Streblus brenieri*.

Firewood collection activities are also traditional and cultural customs of ethnic minority groups in protected areas. This activity is often carried out by women who collect firewood for family consumption and takes place at the edges of the forests not far from the villages, so may have a minor impact on the forest integrity in all protected areas.

Mining and dam construction are ongoing threats in Na Hang, Nam Xuan Lac and Chau Ca. Mining exploitation is still in operation in some areas adjoining or surrounding *R. avunculus* habitats. Gold mining was seen on Pac Van and Gam Rivers bordering Na Hang NR. Mining for zinc and aluminum based in Lung Vay area, Minh Son Commune

(about two kilometers away from the Khau Ca HSCA), cause a number of very loud explosions to be heard every day at noon and in the late afternoon. These activities result in a number of negative impacts on *R. avunculus* populations and habitats, including forest clearance and noise pollution. Further, the presence of miners and workers appears to increase demand for wildlife products. Post assessment of the impact of dam construction in Na Hang NR on the population of *R. avunculus* has not as yet been conducted but, based on my observations, this activity increased noise pollution and the accessibility of the reserve to human activities. It also caused flooding in a large area in Tat Ke Sector.

Threat analysis

The details of the threats for each site are presented in appendix 4.1; 4.2; 4.3; 4.4; 4.5; 4.6. Ranking of threats to each study area is summarized in Table 6.5. The higher the number the greater the impact, extent, and urgency of the threat. The values in the Table cannot be used to compare the seriousness of threats and impacts between sites, since the Figures were calculated based on the number of threats and threats that occur at each site. For instance, a value of 1 in Na Hang NR (gunshots heard) is not equivalent to a value of 1 in Ba Be NP (felling trees for timber).

Threats to each site were scored and ranked. While ranking the threats at surveyed areas, the highest number is assigned to the threat that affects the greatest area, while the lowest number (always #1), is assigned to the threat that affects the smallest area. In other words, the highest number is assigned to the highest and most urgent threat and thereafter continued down on the ranking sequence to that of #1 for the least urgent. After the ranking of threats on each criterion, three rankings (AREA + INTENSITY + URGENCY) are added across the columns to arrive at a total ranking. Threats with the highest total scores in the rankings sequence are the ones that are assessed as having the greatest impact on the forest integrity and contained species.

Table 6.5. Ranking of threats to each sites studied. The higher the number the greater the impact, extent and urgency of the threat.

Sites	Na Hang	Cham Chu	Khau Ca	Ba Be	Nam Xuan Lac	Thansa -Phuong Hoang
Threats						
Hunting						
Hunters encountered	2	4		8	1	7
Gunshots heard	1	2		5	3	7
Fire camps and hunting huts	6	3		6	6	5
Hunting trails	2	1		3	2	
Dogs	9			11		
Habitat destruction						
Felling trees for timber	4	5		1	5	1
Stacked timber boards	6	7		2	7	2
Campsites for logging	13	8		6	9	4
Used trails for transporting logs	9	6		4	8	3
Livestock grazing and cutting trees for grazing fodder	12	10	3	10	11	
Mining	14		1		10	
Dam construction	11					
Fire wood collection				13		
NTFP collection						
Bamboo shoot collection		9		11		9
Plant medicinal collection			2	9	4	
Orchid						
Rattan						6

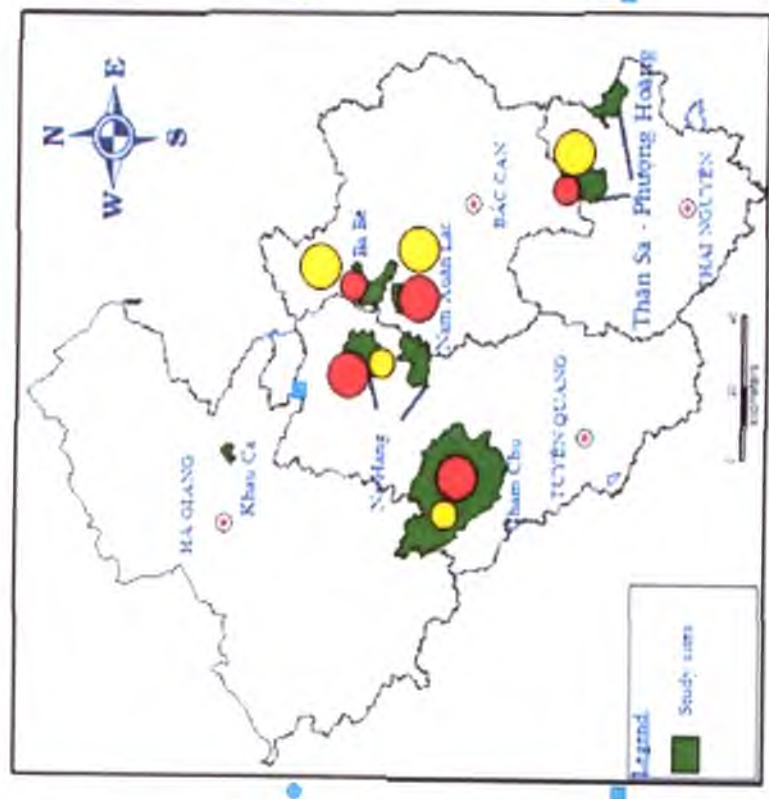


Figure 6.8. Hunting and destruction signs in each site surveyed (larger circles indicate higher encounter rate. Red circles: hunting; Yellow circles: habitat destruction).

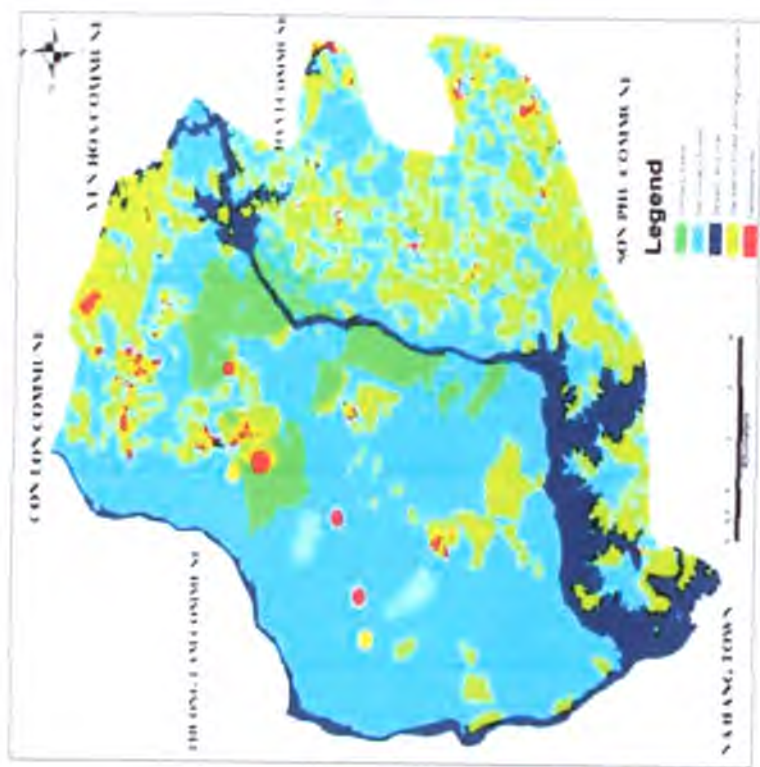


Figure 6.9. Hunting and destruction signs in Na Hang NR (larger circles indicate higher encounter rate. Red circles: hunting; Yellow circles: Habitat destruction).

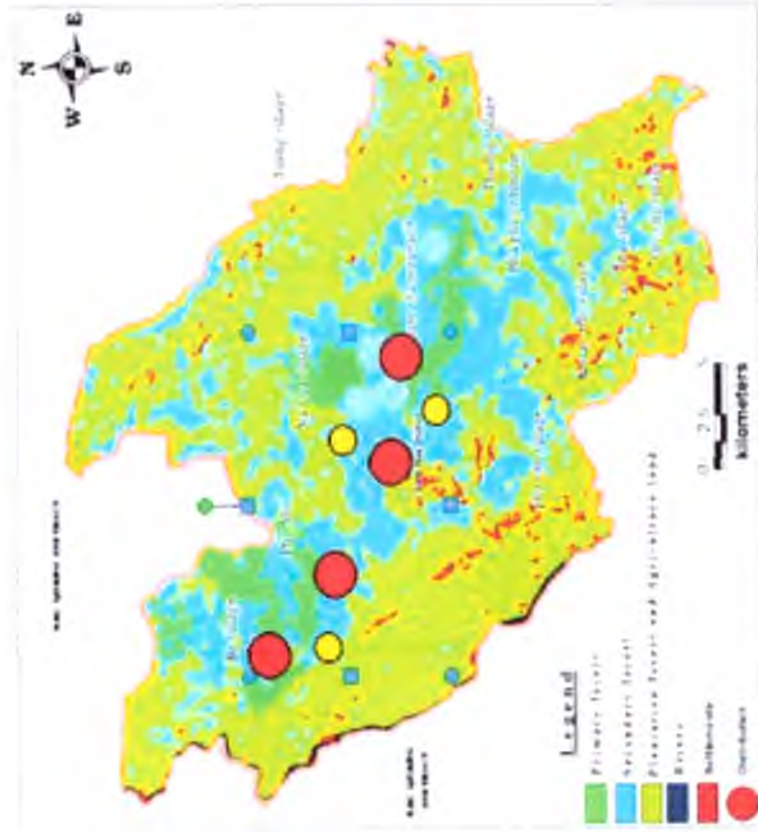


Figure 6.10. Hunting and destruction signs in Cham Chu NR
 (larger circles indicate higher encounter rate. Red circles: hunting; Yellow circles: Habitat destruction).

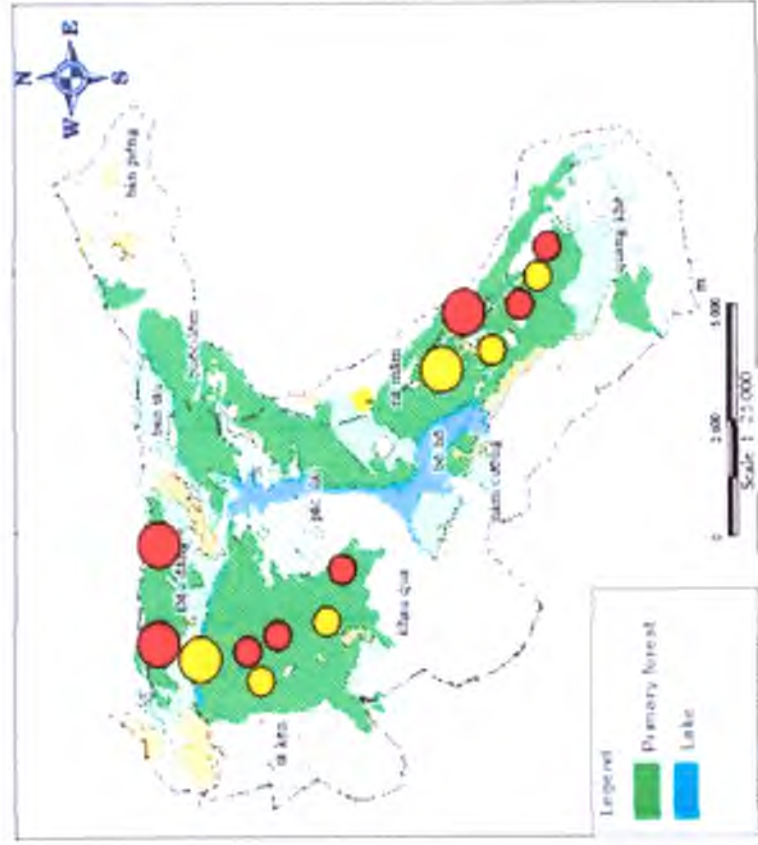


Figure 6.11. Hunting and habitat destruction signs in Ba Be NP
 (larger circles indicate higher encounter rate. Red circles: hunting; Yellow circles: habitat destruction).

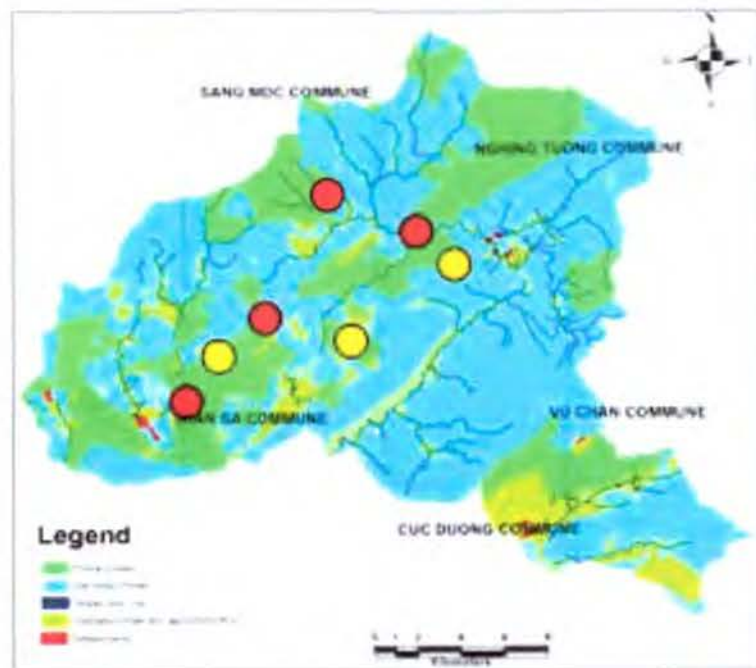


Figure 6.12. Hunting and destruction signs in Than Sa Phuung Hoang NR (larger circles indicate higher encounter rate. Red circles: hunting; Yellow circles: Habitat destruction).

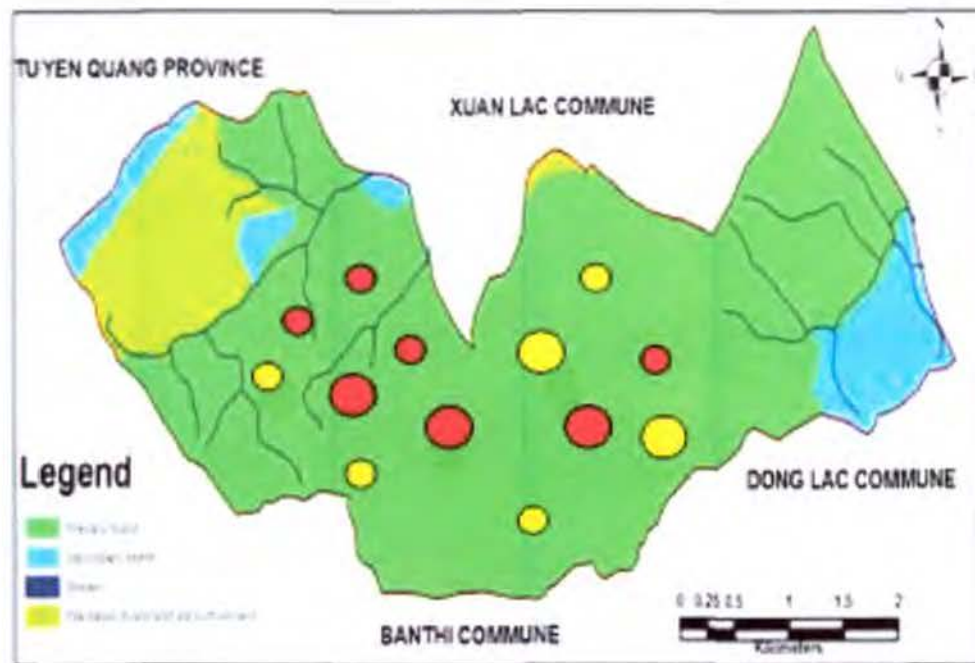


Figure 6.13. Hunting and destruction signs in Nam Xuan Lac (larger circles indicate higher encounter rate. Red circles: hunting; Yellow circles: Habitat destruction).

6.4. Discussion

6.4.1. The evidence of decline in populations of *R. avunculus* in Vietnam

My results suggest that *R. avunculus* populations are decreasing in size in most of the sites surveyed, the only exception being Khau Ca. This gives a downward trend in total population in Vietnam over the 15 years for which data are available, reducing to 200 individuals between 1995 and 2010 (Table 6.7). It is noted that Tung Vai Forest, Ha Giang Province is the newly discovered distribution area (Le & Covert 2010). The total population estimated for Vietnam is ca. 215 individuals (Table 6.6).

The population size in the Tat Ke Sector (Na Hang NR) proved to be smaller than we originally expected. Since Boonratana and Le's study (1994), the current population size has reduced by ca. 60 individuals (Table 6.6), most likely due to severe hunting pressure. Similar to the Na Hang situation, the current population size in Cham Chu NR (8-12 individuals) is considerably lower than that in the early report by Long and Le (2001) in the same area (70 individuals). This decline can also be attributed to hunting.

Data on population sizes in Nam Xuan Lac HSCA and Than Sa-Phuong Hoang NR also support the above statement, although they are solely based on local information, so may not reflect the true population sizes. It is evident that hunting and illegal logging activities are high, and no sightings were made during the course of the studies in these areas. The extirpation of *R. avunculus* at Ba Be NP is very likely as there have been neither sightings nor reports of the species during and prior the survey, and local people interviewed are unanimous in their belief that the species no longer exists in the NP.

In Khau Ca HSCA, the current population size of *R. avunculus* is higher than that initially estimated by Le (2004), but corresponds with his later observations (100 individuals, Le & Covert, 2010). There are some possible explanations for these

differences. First, the population may have grown over the past 4 years. Secondly, the 2004 study was conducted in a rather short period of time. Lastly, there may be differences in methods of population size estimation between studies.

Given the small populations, difficult terrain and large study sites, my study efforts in Nam Xuan Lac HSCA, Than Sa-Phuong Hoang NR, and Cham Chu NR might not have been enough to cover the whole area and detect such populations. Future research should plan for a longer time and focus on possible occurrence areas as reported by local informants (see section 6.3.1., this chapter). Nevertheless, information on current population sizes will be important for making an urgent conservation action plan for this critically endangered species.

6.4.2. Threats

My results indicate that hunting is a major threat to *R. avunculus* populations in all survey sites, causing population declines and local extinction in Ba Be NP. Hunting is common in the known sites and had the greatest impact on their populations (Boonratana & Le, 1994; Le, 2004; Long & Le, 2002). Hunting also poses a serious risk of extinction for a considerable number of the world's primate populations (Mittermeier, 1987; Mittermeier & Cheney, 1987) and may be the key threat for rare species restricted to small areas of protected habitat (Bleisch & Zhang, 2004). As far as the present species is concerned, data on the number killed are not available for all sites, but hunting is clearly a main cause of population decline all sites studied. Le (2004) reported that ca. 20 individuals have been killed in Du Gia NR since 1990. The smaller population sizes in Tat Ke Sector (Na Hang NR) and Cham Chu NR compared to previous reports result from high hunting pressure in these areas. Hunting can influence not only population size but population structure and the behavior of individuals within populations, and that densities of primates tend to be lowest where hunting intensity is

greatest (Cowlshaw & Dunbar, 2000), and this may explain the low frequency of encounter in Tat Ke and the lack of sightings in Cham Chu, Than Sa-Phuong Hoang, Ba Be and Nam Xuan Lac, areas where hunting activities are relatively high.

Guns are the main means of hunting *R. avunculus* in the study sites, and this is common in many protected areas in Vietnam (Dang & Nguyen, 1999; Le, 2004; Nadler et al., 2003; Pham, 2002). Surveys by Boonratana and Le (1994) in the vicinity of Na Hang NR estimated that every household owned at least one gun and probably had more than one. Although gun confiscation and conservation programs have been carried out in the range of *R. avunculus*, and successful prevention of hunting has been reported (Le, 2003), it is evident that the use of guns is still widespread and common. On a daily basis, I would hear between five and seven gun shots in Tat Ke Sector in Na Hang NR (Dong, 2007) and from three to ten gun shots in Cham Chu NR (Dong et al., 2006). Further, groups of two to five hunters, and both old and recent huts, were encountered during surveys (Dong, 2007). It seems, therefore, that law enforcement has not been effective enough to control the use of guns in the areas studied.

Although *R. avunculus* is not the target of the hunters they would kill them whenever encountered. This echoes previous reports (Boonratana and Le, 1994; 1998b; Dong et al., 2006). The meat used for family consumption and the bones are made into traditional medicine as is common for other primates (Dong, 2009; Li et al., 2007; Nadler et al., 2003; Nguyen et al., 2006); this latter product and other body parts such as liver are sold at the market (Dong et al., 2006) or body parts traded to China (Boonratana and Le, 1994; 1998b).

My results also indicate that habitat destruction is another threat to the survival of primate species in the sites studied, and this is an important factor contributing to the decline in all Vietnam primates (Bleisch & Zhang, 2004; Nadler et al., 2003), and the

world's primate populations as a whole (Mittermeier & Cheney, 1987). The forms of habitat destruction identified in all study areas (logging, subsistence farming, grazing, firewood collection and NTFP collection) are common in other forested areas (Dong, 2009; Mittermeier & Cheney, 1987; Nadler et al., 2003). Habitat destruction can lead to forest loss, fragmentation and modification, therefore influencing primate population viability (Cowlshaw & Dunbar, 2000; Kirkpatrick, 1995), home ranges, and species extinction risk (Cowlshaw & Dunbar, 2000).

Illegal logging is the main factor causing habitat degradation and fragmentation in most study areas as has been mentioned in previous reports (Le & Boonratana, 2006; Nadler et al., 2003; Pham, 2002; Ratajszczak et al., 1990), influencing the behavior and activities of primates. Logging is known to alter activity patterns and thus densities of primates, as documented by Johns (1986) and Plumptre et al. (2003); the density of chimpanzees in logged forest is often lower than in mature forest (Plumptre & Reynolds, 1994), and studies of *Hylobates lar* and *Presbytis femoralis* have observed that they spend more time resting and less time feeding and travelling following logging and the consequent reduction in the availability of their preferred and more nutritious foods (Johns, 1986).

Another major concern for *R. avunculus* in Na Hang NR is the construction of a dam that began in 2002. First, the human population of Na Hang was increased by 8,500 workers, resulting in increased demand for wildlife and other forest products (Le & Boonratana, 2006; Nadler et al., 2003, Mittermeier et al., 2006). Wild meat became available at Na Hang Town, most being consumed by workers (H.T. Dong, pers. obs., 2004-2006). Second, some parts of Na Hang NR along the Gam and Pac Van Rivers, about 220 hectares, have been or will be flooded by Na Hang Hydropower Plant (Le & Boonratana, 2006; Nadler, et al., 2003). Last, dam and road construction increase the

accessibility of the reserve to human activities as well as generating noise that may have a negative impact on the population dynamics of *R. avunculus* and other wildlife, affecting breeding patterns and causing the animals to avoid preferred feeding areas (Nadler et al., 2003).

My results identified the threats and how they impact on the *R. avunculus* populations in the sites studied. Future research should look at how effective managers are in tackling the major problems they are facing while conserving the values of a protected area. Nevertheless, the data will have important implications for conservation of the species and its habitat. Understanding the threats and their rankings to each area studied will be a critical step for setting conservation priorities and preventing future population decline and extinctions.

Table 6.6. Population sizes of *R. avunculus* in Vietnam reported between 1995 and 2010.

Sites	Year	Estimated no. of individuals	References
Vietnam	1995	350	Cao & Pham (1995)
	2003	307	Nadler et al. (2003)
	2004	250 -260	Le (2004)
	2006	250	Le & Boonratana (2006)
	2004-2010	150	Current study

Table 6.7 A comparison of current and past *R. avunculus* population sizes between sites studied/surveyed.

No.	Sites	Current study		Previous studies/surveys		References
		Year	No. of IDs	Year	No. of IDs	
1	Tat Ke Sector, Na Hang NR ¹	2005	17 (22) ³	1993	72 (80)	Dong (2007); Boonratana & Le (1994)
2	Cham Chu NR	2006	8-12	2001	70	Dong (2006); Long & Le (2001)
3	Khau Ca HSCA ²	2005	81 (90)	2004	55-60	Dong (2007); Le (2004); Le (2010)
				2009	100	
4	Ba Be NP	2009	0			Dong (2009)
5	Nam Xuan Lac HSCA	2010	4-6	1999	18-20	Bezuijen & Trinh (2003); Dong and Vu (2010);
				2002	4-5	Nguyen & Nguyen (1999)
6	Than Sa-Phuong Hoang NR	2010	20		?	Dong (2010)

¹NR: NR; ²HSCA: Species and Habitat conservation area; ³The number in parenthesis indicate estimated number of individuals

? Unknow

IDs: Individuals

6.5. Summary

Surveys of population sizes, distribution, and conservation status were conducted in six protected areas in northern Vietnam between 2004 and 2010. The six sites studied have much in common in terms of topography, forest types, climate and hydrology, and local people's ethnicity and means of subsistence. Due to the rarity of the species and difficult terrain, a number of methods (interviews, transects, reconnaissance and total counts) were used to collect data on population size, distribution and threats. Threat reduction assessment (TRA) method is used to assess intensity of the threats to the species and its habitat. Population size and distribution were obtained from a total of 5,529 working hours (549 working days) covering an area of 300km². Of that, about 82% working hours covering 135km² were devoted to two main study sites: Tat Ke Sector, Na Hang NR, and Khau Ca HSCA, making a total of 250 observational hours.

Population sizes of *R. avunculus* in all sites studied are smaller than originally expected (ranging from 6 to 22 individuals) except for Khau Ca area (90 individuals); the species was sighted only in Tat Ke and Khau Ca. The Ba Be population is a likely local extinction. Current population size estimated for all sites studied (215 individuals) is smaller than that of previous studies, exhibiting a severe decline in the Vietnam and global population of *R. avunculus*. The distribution of *R. avunculus* appears to be restricted to remote and difficult areas that are hard to access by humans, very likely due to hunting pressure and habitat destruction.

Hunting and habitat destruction are the main threats to the species and its habitat. Indicators of hunting took the form of hunters encountered, gunshots heard, dogs, camp fires, hunting huts, and hunting trails. Indicators of habitat destruction includes cutting trees, stacked timber, logging huts, firewood and non-timber forest product collection, livestock grazing and cutting trees for grazing. Hunting poses the most serious threat in

all study areas. The use of guns is still widespread and common among local people living in and around protected areas, although it is illegal. Illegal logging is still widespread in Ba Be, Nam Xuan Lac, and Than Sa Phuong Hoang areas. This results in habitat degradation and fragmentation, influencing the density, behavior and activities of *R. avunculus*.

Chapter 7

Conclusion and recommendations

7.1. Introduction

This is the first long-term study on ecology and behavior of *Rhinopithecus avunculus* conducted in Vietnam. The study has described the botanical structure; monitored and compared the phenology of the study sites, and assessed seasonal changes in food availability; provided data on the population size, the social organization and behavior, and the feeding ecology of *R. avunculus* in relation to the botany and phenology of the habitat; assessed current and potential threats to the species and its natural habitat. This chapter will summarize main findings and make recommendations for future conservation and research.

7.2. Conclusion

Tat Ke and Khau Ca are relatively similar in botanical structure and species composition as well as phenological patterns (see chapter 3). The main forest type here is evergreen forests associated with limestone hills. Phenological patterns at both sites were characterized by high production of young leaves throughout the year and seasonality of flowers and fruits. Rainfall correlated with the production of young leaves, flowers and fruits.

The social organization of *R. avunculus* follows the typical patterns of other colobines in that the basic structure is one-male unit (see chapter 4). OMUs and AMUs frequently aggregated in large bands for traveling, feeding, resting and sleeping. These findings support Boonratana and Le's (1993) observations but contrast with previous reports of multi-male and multi-female units (Le et al., 2006; Ratajszczak et al., 1990; 1992).

Different results may be due to differences in the duration of observation and probably methodological differences. Previous reports based on brief observations and largely local reports. *R. avunculus* also show fission and fusion that found in other Chinese species and *Nasalis larvatus* (see chapter 1;2;4). Daily and seasonal fission and fusion may result from the size of food patches, the abundance and availability of high food quality, and human disturbance at Khau Ca. Members of *R. avunculus* within OMU have high cohesiveness as a result of close social distance.

Social and agonistic interactions within and between units are infrequent, as with many colobines. Males respond aggressively toward the resident males of other one-male units, suggesting probably the defense of females. Social grooming of *R. avunculus* is dominated by adult females, typical for colobines. Males are rarely involved in this behavior. Adult of both sexes were groomers and groomees, suggesting high affiliation between them within OMUs. Adult males of *R. avunculus* between OMUs are non-affiliative with other males. Males behaved aggressively towards other males during aggregation for traveling and feeding. This aggression appears to be related to the defending of females as well as attempts to gain access to the females by males. My results also indicate that juveniles of *R. avunculus* exhibit alloparenting behavior that has been reported in most colobine species

Sexual behavior of *R. avunculus* at Khau Ca appears to be similar to other colobines, especially Aisan colobines (see chapter 4). Females initiated the behavior, and the presentation of postures are similar to those described for *R. roxellana* and *R. bieti* (see chapter 4). Seasonality of birth may exist in *R. avunculus* since I observed more newborns in March and April. This is similar to *R. bieti* at Wuyapiya and *R. roxellana* in captivity (see chapter 2). Food quality and availability might probably be factors that regulate birth and breeding season of *R. avunculus* because the phenology pattern show

that most trees in the plots produced young leaves and a flowering peak between March and May 2006, which are preferred food items (see chapter 5).

This is the first time the study documented the new observations on the colour of the newborn (see chapter 4). These findings are in contrast to previous reports on *R. avunculus* (Le, 1973; Le, 2003) and differ from the common pattern in most colobine species (Newton & Dunbar, 1994).

Other new observations on behavior documented the first time in this study include group movement, vigilance, vocalizations, rest-huddling, and terrestriality (see chapter 4). The results show that group movement in *R. avunculus* appears to be initiated by adult females. Males spent more time on vigilance than females, suggesting a form of mate protection. Searching for and locating food are likely to be shared by both male and females, but females seem to lead group movement, suggesting a greater role in locating food sources. Members of *R. avunculus* at Khau Ca emitted at least three different types of vocalizations. Possible functions of these calls were given in chapter 4. *R. avunculus* was the first time observed traveling, resting and feeding on the ground at Khau Ca Forest. All age/sex categories exhibited this behavior.

R. avunculus is folivore and frugivore. They fed on a diversity of plant parts with emphasis on young leaves, suggesting a preferred food item. This is inconsistent with previous reports (see chapter 5). The monkeys at Khau Ca did not randomly select food trees and food items. The selection ratios suggest that *R. avunculus* were highly selective in their choice of foods and fed mainly from trees which were quite rare and low in terms of both the number of stems and basal area. Strong selectivity for uncommon species has been reported in several colobines (see chapter 5) and may be related to nutritional quality, abundance and availability of food items. Data on plant chemistry analysis has not been available for *R. avunculus* yet, so I can only assume that the monkeys follow the pattern of food selection in colobines.

Diet of *R. avunculus* at Khau Ca varied according to seasonal changes in availability of food items, as with many other primates (see chapter 5). The correlation between the proportion of different plant parts in the diet and their availability in the forest suggests that the monkeys were feeding more on items that were available at the time. The monkeys harvested young leaves throughout the year, decrease in the amount of new leaf consumption during late summer and early winter when fruits and seed are available, and increase dietary diversity during period of food scarcity by eating mature leaves (see chapter 5). Sex differences in feeding may be related to the energy requirements of pregnancy and lactation in females.

The total population estimated for Vietnam is ca. 215 individuals. Population sizes are decreasing in most of the sites surveyed, the only exception being Khau Ca. This results from high hunting pressure and habitat destruction (see chapter 6). Immediate conservation measures need to be taken to protect small remaining populations of *R. avunculus* before they become locally extinct as in Ba Be NP.

7.3. Recommendations for conservation

The conservation of the remaining populations of *R. avunculus* in Vietnam will be a challenge, however, not insurmountable with conservation actions targeting the threats listed in Tables 6.5. Actions required to reduce the impacts of these threats will form the basis of a strategic action plan for conservation of the *R. avunculus* populations in Vietnam. The following recommendations should be taken into consideration.

7.3.1. Conducting additional surveys and locating remaining populations of *R.*

***avunculus* in Vietnam**

Management and conservation of *R. avunculus* and its habitat in Vietnam face a number of issues in which lack of data available on status and distribution is one of the important ones. Therefore, conducting additional surveys and locating remaining populations of *R. avunculus* in Vietnam will be a baseline for creating prioritizes for conservation actions in coming years. Additional surveys on the population status of *R. avunculus* should be conducted across possible occurrence sites. Priorities will be given for Kim Hy NR, Bac Kan Province, Bac Me and Phong Quang NRs, Ha Giang Province, and Tan Phuong, Yen Bai Province. Detailed distribution and critical habitat maps of *R. avunculus* in their known sites should also be available for management and conservation.

7.3.2. Suppression of hunting of *R. avunculus* in the areas surveyed

Hunting has been recognized as a major threat to the *R. avunculus* populations in Vietnam (see chapter 6). Shotguns were the main method for hunting *R. avunculus* across their known sites. Most hunters were from villages from in and around Protected Areas. Hunting signs were often found in remote and difficult areas. Therefore, to reduce hunting pressure on the species the following conservation actions should be taken into consideration.

- 1) Implement gun confiscation or buy-back programs in identified villages with regular law enforcement patrols;
- 2) Conduct programs that target hunters living in identified villages to provide alternative livelihood options;

- 3) Commence or expand frequency of patrols in remote and difficult areas where *R. avunculus* and large mammals are present and tend to be higher in density;
- 4) Conduct targeted awareness raising and conservation education programs in prioritized villages living in and around protected Areas.
- 5) Recruit and train local people to join patrol and monitoring programs of *R. avunculus*.

7.3.3. Improving protection of critical *R. avunculus* habitat

My results indicate that habitat destruction was a ongoing threat to critical *R. avunculus* habitat (evergreen forests associated with limestone hills) and had an impact on the forest integrity. This may result from lack of manpower for protected Area Ranger patrols to patrol the entire forest, forests surveyed easily accessed from many directions, lack of awareness raising programs, and zoning planning. To improve protection of critical *R. avunculus* habitat, I strongly recommend the following conservation actions:

- 1) Limit human access to forests especially in identified critical habitat areas by strengthening law enforcement in the protected Areas including community-based initiatives, establishing patrol trails and conducting regular patrols in known areas of critical habitat of *R. avunculus*
- 2) Identify what resources people harvest from the forest and either look for alternatives or provide opportunities to develop them outside the forest on their own land.
- 3) Develop plantation programs either outside or in rehabilitation Zones within the Protected Areas that act to provide alternative sources of highly desirable resources to reduce pressure for timber, non-timber forest products and firewood from the protected Areas.
- 4) Develop zoning plans for livestock grazing to identify where livestock can graze.
- 5) Implement alternative fodder/food and animal shelter activities to reduce necessity to graze livestock in Protected Areas forest areas.

6) Develop critical habitat restoration and rehabilitation programs, especially in Khuu Ca HSCA. Selection for plantation trees should refer to the list of important food species and species composition of the forests identified.

7.3.4. Establishment of a long-term monitoring program

One of the aims of a monitoring program is to provide up-to-date information on changes in population size or threats to the target species that help managers and conservationists give prioritized actions to undertake. However, data available on changes in population sizes of the species as well as current threats at all sites have been insufficient and unsystematic. This is probably due to lack of long-term monitoring programs of *R. avunculus* in the protected Areas, lack of manpower and trained people to develop and implement the program, and lack of funding available for conducting these activities. Actions suggested are as follows:

- 1) Develop a monitoring program protocol for both species and habitat at known sites of *R. avunculus* including professional and local input.
- 2) Recruit and train local people and Protected Area Rangers ready to participate in these activities
- 3) Develop a fund raising program that can secure long-term monitoring activities

7.3.5. Increase public awareness for *R. avunculus* conservation

Raising awareness is an important issue of conservation activities. Hunting, shifting cultivation and grazing cattle is a tradition of ethnic communities particularly H'mong and Dao. Therefore, law enforcement and improvement of habitat protection themselves do not appear to be effectively enough for management and conservation if it is lack of local support and involvement in *R. avunculus* conservation initiatives. Conservation actions should develop wildlife education program to discourage hunting by local

people in the Protected Areas; develop awareness materials (posters, radio programs, documentary) about *R. avunculus* in all sites and broadcast it on National and local television and radio; recruit and involve local people in conservation programs to make positive use of their local knowledge and instill a sense of pride in the iconic species within their villages; and develop a special education program for schools located in villages both inside and outside the sites of *R. avunculus*.

7.3.6. Conduct long-term research on *R. avunculus* ecology and behavior

Research play an important role in providing useful information input towards any ongoing management and conservation action plans for the species. Further, The presence of researchers at sites may reduce human activities in areas studied. Research on behavior and ecology of *R. avunculus* has been carried out at only two sites: Chau Ca and Tat Ke until now. Therefore, it needs to develop a appropriate policy that encourage students and researchers to get involved in long-term research programs. This require develop funding sources available for relevant research and train students, Protected Area staff and local people to involve in these activities.

7.4. Recommendations for future research

The present study has elucidated many aspects of the ecology and behavior of *R. avunculus* in Chau Ca and Tat Ke. The results collected lay the foundation for future research. However, there have been many research questions remained unanswered. Suggested research questions for future research are presented as follow:

Where are suitable sites to study the ecology and behavior of *R. avunculus* in Vietnam? Selection of a suitable site for long-term study is a concern of researchers, especially for *R. avunculus*. I had an experience on Tat Ke site with a small contact hour and scanty data collected because of small population size and the shyness of human presence of the species (see chapter 4). I strongly recommended that Chau Ca HSCA is the most

suitable site to study ecology and behavior of *R. avunculus*. One, however, must be aware that *R. avunculus* population in Khau Ca is unhabituated and the topography is rather difficult (see chapter 3;4). Well-prepared methodology and physical prior to study therefore are recommended.

What are the factors that caused fission and fusion in *R. avunculus*? The monkeys in the present study show fission and fusion societies as possibly a result of the size of food patches, the abundance and availability of high food quality, and human disturbance (see chapter 4). Other colobines such as *N. larvatus* and *Rhinopithecus* species in China also exhibited this behavior and a number of possible causes also suggested (see chapter 2). Therefore, in order to understand detailed causation of this behavior, future research should relook at and investigate all possible factors suggested in this study and by other authors.

How many types of vocalizations does *R. avunculus* use and what are the exact functions of vocalizations in a given context? Until now my study has been recognized at least 3 different types of vocalizations and the functions of these were speculated only based on given contexts (see chapter 4). Vocal analysis has not been done yet. To better understand these kinds of questions, future research should re-determine types of vocalizations used by *R. avunculus* and examine their functions by using high quality recording sound.

How do the monkeys select food species and plant parts? In the present study I found that *R. avunculus* were highly selective in their choice of food species and food items (see chapter 5). However, why the monkeys select those trees and plant part as food remains unclear. To deeper understand this mechanism, chemical analysis of tree species and plant parts eaten and not eaten by *R. avunculus* should be conducted.

What is carrying capacity of Khau Ca forest? It is clear that Khau Ca holds the largest population of *R. avunculus* in Vietnam, but the area is the smallest among the known sites of the species (see chapter 6). Further, Khau Ca population tend to increase in size over time. Study of carrying capacity of Khau Ca forest, therefore, would provide useful information on relationship between population size of *R. avunculus* and ability to support of the habitats available and more importantly for making conservation decisions in Khau Ca such as habitat expansion programs for the species.

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Appendix 1: Tree species and their proportions in the botanical plots at Tat Ke Sector.

Family	Latin name	No. of stems	% of stems	Basal area (cm ²)	% of total basal area of plots
Actinidiaceae	<i>Saurauia tristyla</i> DC	13	2.12	4582.83	1.21
Anacardiaceae	<i>Allospodias lakonensis</i> Pierre	1	0.16	795.77	0.21
	<i>Drimycarpus racemosus</i> (Roxb.) Hook.f. ex Marchand	8	1.31	2434.25	0.65
	<i>Mangifera longipes</i> Griff.	1	0.16	82.51	0.02
	<i>Toxicodendron succedaneum</i> (L.) Kuntze	1	0.16	240.72	0.06
Annonaceae	<i>Annona</i> sp1	1	0.16	55.46	0.01
	<i>Miliusa filipes</i> Merr. & Chun	17	2.78	11863.55	3.14
	<i>Polyalthia cerasoides</i> (Roxb.) Benth. & Hook. f. ex Bedd	1	0.16	233.77	0.06
	<i>Polyalthia</i> sp1	1	0.16	62.39	0.02
Apocynaceae	<i>Kitabalia macrophylla</i> (Pierre)Woodson	22	3.59	2786.07	0.74
	<i>Kitabalia microphylla</i> (Pitard)Woodson	3	0.49	194.61	0.05
Aquifoliaceae	<i>Ilex crenata</i> Thunb.	2	0.33	97.47	0.03
	<i>Ilex cinerea</i> Champ. ex Benth.	1	0.16	225.22	0.06
Araliaceae	<i>Heteropanax fragrans</i> (Roxb.) Seem.	1	0.16	88.77	0.02
	<i>Schefflera heptaphylla</i> (L.) Frodin	2	0.33	239.00	0.06
	<i>Trevesia palmata</i> (Roxb. ex Lindl.) Vis.	6	0.98	1370.23	0.36

Appendix 1: Tree species and their proportions in the botanical plots at Tat Ke Sector (continued).

Family	Latin name	No. of stems	% of stems	Basal area (cm ²)	% of total basal area of plots
Asteraceae	<i>Vernonia arborea</i> Buch.-Ham. ex Buch.-Ham.	1	0.16	524.69	0.14
Bigoniaceae	<i>Fernandoa brilletii</i> (Dop) Steenis	1	0.16	104.86	0.03
	<i>Rhadernachera boniana</i> P.Dop.	1	0.16	63.73	0.02
Burseraceae	<i>Canarium album</i> (Lour.) DC.	1	0.16	43.57	0.01
Caesalpiniaceae	<i>Saraca dives</i> Pierre	3	0.49	248.72	0.07
Clusiaceae	<i>Garcinia bonii</i> Pit.	5	0.82	590.72	0.16
	<i>Garcinia cowa</i> Roxb. ex Choisy	1	0.16	29.34	0.01
	<i>Garcinia fagraeoides</i> A.Chev.	6	0.98	2025.54	0.54
	<i>Garcinia lanceifolia</i> Roxb.	2	0.33	195.93	0.05
	<i>Garcinia oblongifolia</i> Champ. ex Benth.	3	0.49	1043.76	0.28
Daphniphyllaceae	<i>Daphniphyllum calycinum</i> Benth.	2	0.33	186.13	0.05
Dilleniaceae	<i>Dillenia indica</i> L.	1	0.16	761.14	0.20
Ebenaceae	<i>Diospyros choboensis</i> Lecomte	2	0.33	147.01	0.04
	<i>Diospyros eriantha</i> Champ. ex Benth.	2	0.33	312.68	0.08
	<i>Diospyros pillosella</i> Wall	1	0.16	66.46	0.02

Appendix 1: Tree species and their proportions in the botanical plots at Tat Ke Sector (continued).

Family	Latin name	No. of stems	% of stems	Basal area (cm ²)	% of total basal area of plots
Elaeocarpaceae	<i>Diospyros pilosula</i> (A.DC.) Wall. ex Hiern	1	0.16	44.32	0.01
	<i>Diospyros susarticulata</i> Lecomte	35	5.72	32249.79	8.55
	<i>Elaeocarpus balansae</i> D.C.	2	0.33	990.81	0.26
	<i>Elaeocarpus griffithii</i> (Wight) A Gray	2	0.33	725.23	0.19
Euphorbiaceae	<i>Elaeocarpus hainanensis</i> Oliv	1	0.16	35.09	0.01
	<i>Antidesma japonicum</i> var. <i>japonicum</i>	2	0.33	969.93	0.26
	<i>Antidesma fordii</i> Hemsl.	1	0.16	35.09	0.01
	<i>Antidesma montanum</i> Blume	4	0.65	958.83	0.25
	<i>Antidesma tonkinense</i> Gagnep.	5	0.82	848.71	0.22
	<i>Aprosa myrocalyx</i> Hassk	2	0.33	1827.76	0.48
	<i>Baccaurea ramiflora</i> Lour.	1	0.16	74.51	0.02
	<i>Bischofia javanica</i> Blume	3	0.49	10655.99	2.82
	<i>Cleistanthus monoicus</i> (Lour.) Müll.Arg.	2	0.33	421.93	0.11
	<i>Bridelia glauca</i> Blume	3	0.49	2181.34	0.58
	<i>Bridelia parvifolia</i> Kuntze	1	0.16	264.02	0.07
	<i>Chaetocarpus castanocarpus</i> (Roxb.) Thwaites	5	0.82	2272.98	0.60
	<i>Cleistanthus oblongifolius</i> (Roxb.) Müll.Arg.	1	0.16	382.17	0.10
	<i>Croton</i> sp	1	0.16	260.36	0.07
	<i>Croton tiglium</i> L.	2	0.33	145.89	0.04
	<i>Croton yunnanensis</i> W.W.Sm.	1	0.16	64.64	0.02
	<i>Deutzianthus tonkinensis</i> Gagnep.	1	0.16	61.50	0.02

Appendix 1: Tree species and their proportions in the botanical plots at Tat Ke Sector (continued).

Family	Latin name	No. of stems	% of stems	Basal area (cm ²)	% of total basal area of plots
	<i>Glochidion heyneanum</i> (Wight & Arn.) Wight	2	0.33	238.85	0.06
	<i>Mallotus japonicus</i> (L.f.) Müll.Arg.	1	0.16	194.98	0.05
	<i>Mercurialis leiocarpa</i> Siebold et Zucc	3	0.49	379.82	0.10
	<i>Vernicia montana</i> Lour.	1	0.16	1180.55	0.31
Fabaceae					
	<i>Ormosia balansae</i> Drake	1	0.16	359.36	0.10
	<i>Ormosia pinnata</i> (Lour.) Merr.	1	0.16	157.58	0.04
	<i>Castanopsis fordii</i> Hance	2	0.33	1572.71	0.42
	<i>Lithocarpus henryi</i> (Seemen) Rehder & E.H.Wilson	3	0.49	1188.93	0.32
Flacoutiaceae					
	<i>Flacourtia ramontchi</i> L'Hér.	2	0.33	616.44	0.16
Icacinaceae					
	<i>Gomphandra mollis</i> Merr.	2	0.33	74.26	0.02
Iteaceae					
	<i>Itea chinensis</i> Hook.et Arn.	1	0.16	82.51	0.02
Juglandaceae					
	<i>Cayra tonkinesis</i> Lec	2	0.33	519.95	0.14
	<i>Engelhardia roxburghiana</i> Wall.	1	0.16	68.32	0.02
	<i>Engelhardtia roxburghiana</i> Lindl.	1	0.16	30.88	0.01
Kygelariaceae					
	<i>Hydnocarpus hainanensis</i> (Merr.) Sleumer	15	2.45	4550.05	1.21
Lauraceae					
	<i>Beilchmiedia percoriaceae</i> Allen	3	0.49	4608.62	1.22

Appendix 1: Tree species and their proportions in the botanical plots at Tat Ke Sector (continued).

Family	Latin name	No. of stems	% of stems	Basal area (cm ²)	% of total basal area of plots
	<i>Beilschmiedia balansae</i> Lecomte	4	0.65	906.39	0.24
	<i>Beilschmiedia laevis</i> C.K.Allen	1	0.16	58.01	0.02
	<i>Carydaphnopsis tonkinensis</i> (H.Lec.) Airy-Shaw	4	0.65	3877.55	1.03
	<i>Cinnamomum bejolghota</i> (Buch.-Ham.) Sweet	1	0.16	319.87	0.08
	<i>Cinnamomum iners</i> Reinw. ex Blume	1	0.16	499.16	0.13
	<i>Cryptocarya impressa</i> Miq.	1	0.16	35.09	0.01
	<i>Cryptocarya concinna</i> Hance	5	0.82	669.51	0.18
	<i>Cryptocarya maclurei</i> Merr.	3	0.49	785.75	0.21
	<i>Litsea glutinosa</i> (Lour.) C.B. Rob.	1	0.16	83.02	0.02
	<i>Litsea balansae</i> Lecomte	7	1.14	1219.08	0.32
	<i>Litsea baviensis</i> Lecomte	1	0.16	41.73	0.01
	<i>Litsea rotundiflora</i> Hemsl.	3	0.49	916.32	0.24
	<i>Litsea umbellata</i> (Lour.) Merr.	2	0.33	75.38	0.02
	<i>Litsea verticillata</i> Hance	3	0.49	11721.27	3.11
	<i>Machilus grandifolia</i> S.K.Lee & F.N.Wei	4	0.65	7086.26	1.88
	<i>Neolitsea aurata</i> (Hayata) Koidz.	5	0.82	5368.45	1.42
	<i>Neolitsea ellipsoidea</i> C.K. Allen	1	0.16	852.45	0.23
	<i>Neolitsea umbelliflora</i> Bl	1	0.16	198.94	0.05
	<i>Caryodaphnopsis baviensis</i> (Lecomte) Airy Shaw	2	0.33	343.11	0.09
	<i>Nothaphoebe umbelliflora</i> (Blume) Blume	2	0.33	143.72	0.04
	<i>Phoebe cuneata</i> B.	8	1.31	2621.52	0.69
	<i>Persea pallida</i> (Nees) Oliv.	4	0.65	992.77	0.26
	<i>Phoebe macrocarpa</i> C.Y. Wu	2	0.33	507.82	0.13

Appendix 1: Tree species and their proportions in the botanical plots at Tat Ke Sector (continued).

Family	Latin name	No. of stems	% of stems	Basal area (cm ²)	% of total basal area of plots
Linnaceae	<i>Ixonanthes chinensis</i> (Hook. & Arn.) Champ.	1	0.16	29.95	0.01
Magnoliaceae	<i>Magnolia coco</i> (Lour.) DC.	3	0.49	877.85	0.23
	<i>Magnolia balansae</i> A.DC.	1	0.16	241.60	0.06
Meliaceae	<i>Aglaia gigantea</i> (Pierre) Pellegr.	2	0.33	9342.16	2.48
	<i>Aglaia globosus</i> Piere	1	0.16	875.67	0.23
	<i>Aphanamixis polystachya</i> (Wall.) R.Parker	1	0.16	68.32	0.02
Mimosaceae	<i>Archidendron balansae</i> (Oliv.) I.C.Nielsen	3	0.49	532.31	0.14
Moraceae	<i>Antiaris toxicaria</i> Lesch.	3	0.49	444.05	0.12
	<i>Artocarpus gomezianus</i> Wall. ex Trécul	2	0.33	266.55	0.07
	<i>Artocarpus styracifolius</i> Pierre	1	0.16	3215.00	0.85
	<i>Artocarpus tonkinensis</i> A.Chev	1	0.16	175.79	0.05
	<i>Ficus glaberrima</i> Blume	1	0.16	164.02	0.04
	<i>Ficus langkokensis</i> Drake	24	3.92	11490.51	3.05
	<i>Ficus lacor</i> Buch.-Ham.	4	0.65	2817.35	0.75
	<i>Streblus macrophyllus</i> Blume	121	19.77	20734.49	5.49
	<i>Streblus ilicifolius</i> (Vidal) Corner	1	0.16	105.44	0.03
Myristicaceae	<i>Knema conferta</i> (King) Warb.	5	0.82	1446.44	0.38

Appendix 1: Tree species and their proportions in the botanical plots at Tat Ke Sector (continued).

Family	Latin name	No. of stems	% of stems	Basal area (cm ²)	% of total basal area of plots
Myrsinaceae	<i>Ardisia tsangii</i> E.Walker	10	1.63	2108.84	0.56
Myrtaceae	<i>Syzygium chanlos</i> (Gagnep.) Merr. & L.M.Perry	2	0.33	568.14	0.15
	<i>Syzygium jambos</i> var. <i>jambos</i>	6	0.98	754.44	0.20
	<i>Syzygium zeylanicum</i> (L.) DC.	10	1.63	3514.23	0.93
Oleaceae	<i>Osmanthus matsumuranus</i> Hayata	4	0.65	896.40	0.24
Podocarpaceae	<i>Dacrycarpus imbricatus</i> (Bl.) De Laub	1	0.16	3091.45	0.82
Proteaceae	<i>Helicia grandifolia</i> Lecomte	1	0.16	94.72	0.03
Rosaceae	<i>Photinia benthamiana</i> Hance	1	0.16	30.26	0.01
	<i>Pygeum arboreum</i> Endl	3	0.49	2946.42	0.78
Rubiaceae	<i>Aidia oxyodonta</i> (Drake) T. Yamaz.	1	0.16	2621.45	0.69
	<i>Psydrax pergracilis</i> (Bourd.) Ridsdale	2	0.33	131.56	0.03
	<i>Canthium parvifolium</i> Roxb.	5	0.82	1256.95	0.33
	<i>Mussaenda pubescens</i> Ait.f	1	0.16	63.28	0.02
	<i>Pavetta graciliflora</i> Wall. ex Ridl.	5	0.82	800.37	0.21
	<i>Pavetta tonkinensis</i> Bremek.	3	0.49	791.49	0.21

Appendix 1: Tree species and their proportions in the botanical plots at Tat Ke Sector (continued).

Family	Latin name	No. of stems	% of stems	Basal area (cm ²)	% of total basal area of plots
	<i>Psychotria asiatica</i> L.	3	0.49	3365.29	0.89
	<i>Aidia pycnantha</i> (Drake) Tirveng.	1	0.16	12328.19	3.27
	<i>Aidia pycnantha</i> (Drake) Tirveng.	2	0.33	250.43	0.07
	<i>Catunaregam spinosa</i> (Thunb.) Tirveng.	1	0.16	34.43	0.01
Rutaceae	<i>Evodia bodinieri</i> Dode	2	0.33	1037.09	0.27
Sapindaceae	<i>Euphoria frugifera</i> Gagnep	1	0.16	3399.93	0.90
	<i>Michocarpus sundaicus</i> Blume	2	0.33	148.96	0.04
	<i>Nephelium chryseum</i> Blume	1	0.16	141.71	0.04
	<i>Xerospermum tonkinense</i> Radlk.	1	0.16	48.94	0.01
Sarcospermaceae	<i>Sideroxylon wightianum</i> Hook. & Arn.	4	0.65	9911.63	2.63
Simarubaceae	<i>Ailanthus altissima</i> (Mill.) Swingle	4	0.65	23085.84	6.12
Stalhyllaceae	<i>Turpinia cochinchinensis</i> (Lour.) Merr.	5	0.82	662.39	0.18
Staphyleaceae	<i>Turpinia indochinensis</i> Merr.	1	0.16	100.85	0.03
Sterculiaceae	<i>Reevesia thyrsoides</i> Lindl.	2	0.33	867.15	0.23
	<i>Sterculia lanceolata</i> Cav.	14	2.29	1123.18	0.30

Appendix 1: Tree species and their proportions in the botanical plots at Tat Ke Sector (continued).

Family	Latin name	No. of stems	% of stems	Basal area (cm ²)	% of total basal area of plots
Styracaceae	<i>Alniphyllum fortunei</i> (Hemsl.) Makino	3	0.49	2271.68	0.60
Theaceae	<i>Adinandra glischroloma</i> Hand.-Mazz.	1	0.16	137.71	0.04
	<i>Adinandrra integerrima</i> T. And. Ex Dye	2	0.33	174.80	0.05
	<i>Eurya ciliata</i> Merr.	4	0.65	1896.96	0.50
	<i>Gordonia axillaris</i> (Roxb. ex Ker) Endl.	1	0.16	200.54	0.05
Tiliaceae	<i>Burretiodendron hsienmu</i> W.Y.Chun & F.C.How	6	0.98	96882.89	25.68
Ulmaceae	<i>Celtis philippensis</i> Blanco	3	0.49	406.32	0.11
	<i>Celtis sinensis</i> Pers.	4	0.65	287.78	0.08
	<i>Ulmus sp</i>	5	0.82	1335.61	0.35
	<i>Ulmus lanceifolia</i> Roxb. ex Wall.	1	0.16	291.27	0.08
Urticaceae	<i>Pouzolzia sanguinea</i> (Blume) Merr.	8	1.31	904.15	0.24
Verbenaceae	<i>Vitex quinata</i> (Lour.) F.N.Williams	1	0.16	945.46	0.25
Xanthophyllaceae	<i>Xanthophyllum eberhardtii</i> Gagnep.	3	0.49	289.21	0.08

Appendix 2: Tree species and their proportions in the botanical plots at Khau Ca Forest.

Family	Latin name	No. of stems	% of stems	Basal area (cm ²)	% of total basal area of plots
Aceraceae	<i>Acer oblongum</i> Wall. ex DC.	2	0.39	184.81	0.09
	<i>Acer oliverianum</i> Pax	5	0.98	1376.43	0.68
Actinidiaceae	<i>Saurauia tristyla</i> DC.	7	1.37	2007.16	1.00
Altingiaceae	<i>Altingia chinensis</i> (Champ.) Oliv. ex Hance	1	0.20	221.85	0.11
Annonaceae	<i>Alphonsea tonquinensis</i> A.DC.	3	0.59	473.04	0.23
	<i>Milium chunii</i> W.T. Wang	2	0.39	2012.35	1.00
	<i>Polyalthia lauii</i> Merr.	11	2.15	914.11	0.45
Apocynaceae	<i>Kitabalia macrophylla</i> (Pierre) Woodson	2	0.39	677.49	0.34
	<i>Alstonia scholaris</i> (L.) R. Br.	1	0.20	122.28	0.06
Araliaceae	<i>Schefflera delavayi</i> (Franch.) Harms	3	0.59	106.78	0.05
	<i>Schefflera obovatifoliolata</i> C.B. Shang	1	0.20	28.73	0.01
	<i>Trevesia palmata</i> (Roxb. ex Lindl.) Vis.	3	0.59	1063.48	0.53
Bigoniaceae	<i>Markhamia stipulata</i> (Wall.) Seem.	2	0.39	1176.24	0.58
Burseraceae	<i>Canarium parvum</i> Leenh.	1	0.20	43.95	0.02
Clusiaceae	<i>Calophyllum membranaceum</i> Gardner & Champ.	1	0.20	50.94	0.03

Appendix 2: Tree species and their proportions in the botanical plots at Khau Ca Forest (continued).

Family	Latin name	No. of stems	% of stems	Basal area (cm ²)	% of total basal area of plots
	<i>Garcinia fagraeoides</i> A.Chev.	8	1.56	1586.47	0.79
	<i>Garcinia lanceifolia</i> Roxb.	1	0.20	84.57	0.04
Dilleniaceae	<i>Dillenia turbinata</i> Finet & Gagnep.	2	0.39	200.40	0.10
Dipterocarpaceae	<i>Hopea chinensis</i> (Merr.) Hand.-Mazz.	1	0.20	1217.67	0.60
Ebenaceae	<i>Diospyros choboensis</i> Lecomte	2	0.39	463.53	0.23
	<i>Diospyros pilosiuscula</i> G.Don	7	1.37	4823.55	2.39
Elaeocarpaceae	<i>Elaeocarpus petiolatus</i> (Jacq.) Wall.	3	0.59	485.83	0.24
Euphorbiaceae	<i>Antidesma japonicum</i> var. <i>japonicum</i>	4	0.78	504.83	0.25
	<i>Antidesma fordii</i> Hemsl.	2	0.39	186.81	0.09
	<i>Antidesma montanum</i> Blume	1	0.20	100.85	0.05
	<i>Aporosa microcalyx</i> Hassk	1	0.20	34.76	0.02
	<i>Aprosa</i> sp	1	0.20	15546.54	7.71
	<i>Bischofia javanica</i> Blume	2	0.39	116.66	0.06
	<i>Chaetocarpus castanocarpus</i> (Roxb.) Thwaites	1	0.20	557.49	0.28
	<i>Cleistanthus oblongifolius</i> (Roxb.) Müll.Arg.	1	0.20	75.98	0.04
	<i>Mallotus japonicus</i> (L.f.) Müll.Arg.	1	0.20	47.38	0.02
	<i>Triadica cochinchinensis</i> Lour.	2	0.39	186.51	0.09
Fabaceae	<i>Castanopsis faberi</i> Hance	2	0.39	67.46	0.03
	<i>Lithocarpus</i> sp	1	0.20	137.71	0.07

Appendix 2: Tree species and their proportions in the botanical plots at Khau Ca Forest (continued).

Family	Latin name	No. of stems	% of stems	Basal area (cm ²)	% of total basal area of plots
	<i>Lithocarpus vestitus</i> (Hickel & A. Camus) A. Camus	3	0.59	2139.43	1.06
	<i>Ormosia pinnata</i> (Lour.) Merr.	5	0.98	288.64	0.14
	<i>Quercus acutissima</i> Carruth.	2	0.39	1418.43	0.70
	<i>Quercus chrysocalyx</i> Hickel & A. Camus	18	3.52	10000.91	4.96
Hamamelidaceae	<i>Quercus variabilis</i> Blume	7	1.37	5114.77	2.54
Icacinaceae	<i>Mytilaria laosensis</i> Lecomte	43	8.40	5732.25	2.84
	<i>Gomphandra mollis</i> Merr.	3	0.59	300.92	0.15
Illiciaceae	<i>Stemonurus</i> sp	2	0.39	629.24	0.31
Juglandaceae	<i>Illicium petelotii</i> A.C Sm	1	0.20	34.43	0.02
	<i>Engelhardtia roxburghiana</i> Lindl.	3	0.59	507.18	0.25
Kygelariaceae	<i>Platycarya strobilacea</i> Siebold & Zucc.	3	0.59	1205.43	0.60
Lauraceae	<i>Hydnocarpus hainanensis</i> (Merr.) Sleumer	2	0.39	1625.95	0.81
	<i>Actinodaphne sinensis</i> Benth.	1	0.20	1108.03	0.55
	<i>Beilschmiedia percoriacea</i> Allen	1	0.20	33.12	0.02
	<i>Beilschmiedia balansae</i> Lecomte	3	0.59	2542.24	1.26
	<i>Beilschmiedia laevis</i> C.K. Allen	1	0.20	64.64	0.03
	<i>Cinnamomum parthenoxylon</i> (Jack) Meisn.	1	0.20	97.48	0.05
	<i>Cryptocarya chinensis</i> (Hance) Hemsl.	10	1.95	8234.25	4.08
	<i>Cryptocarya</i> sp	1	0.20	282.67	0.14
	<i>Cryptocarya impreses</i> Mig.	1	0.20	150.58	0.07

Appendix 2: Tree species and their proportions in the botanical plots at Khau Ca Forest (continued).

Family	Latin name	No. of stems	% of stems	Basal area (cm ²)	% of total basal area of plots
	<i>Lindera communis</i> Hemsl.	4	0.78	1384.96	0.69
	<i>Lindera polyantha</i> Boerl.	3	0.59	478.10	0.24
	<i>Litsea glutinosa</i> (Lour.) C.B. Rob.	1	0.20	74.03	0.04
	<i>Litsea balansae</i> Lecomte	3	0.59	1454.24	0.72
	<i>Litsea rotundifolia</i> Hemsl.	2	0.39	926.61	0.46
	<i>Machilus bonii</i> Lecomte	33	6.45	24736.36	12.27
	<i>Machilus grandifolia</i> S.K.Lee et F.N.Wei	1	0.20	145.09	0.07
	<i>Machilus sp</i>	5	0.98	1610.29	0.80
	<i>Machilus velutina</i> Champ. ex Benth.	2	0.39	121.52	0.06
	<i>Neolitsea ellipsoidea</i> C.K. Allen	6	1.17	14888.71	7.38
	<i>Caryodaphnopsis baviensis</i> (Lecomte) Airy Shaw	4	0.78	721.02	0.36
	<i>Nothaphoebe umbelliflora</i> (Blume) Blume	2	0.39	227.61	0.11
	<i>Persea pallida</i> (Nees) Oliv.	1	0.20	229.48	0.11
	<i>Phoebe sp</i>	1	0.20	61.50	0.03
Magnoliaceae					
	<i>Magnolia dandyi</i> Gagnep.	2	0.39	1122.75	0.56
	<i>Magnolia insignis</i> Wall.	1	0.20	166.92	0.08
	<i>Magnolia foveolata</i> (Merr. ex Dandy) Figlar	1	0.20	86.66	0.04
Melastomaceae					
	<i>Allomorphia arborescens</i> Guillaumin	17	3.32	1793.48	0.89
	<i>Memecylon ligustrifolium</i> Champ. ex Benth.	5	0.98	235.10	0.12
Meliaceae					
	<i>Aglaia globosus</i> Pierre	5	0.98	1753.08	0.87
	<i>Aglaia spectabilis</i> (Miq.) S.S.Jain & S.Bennet	4	0.78	6840.26	3.39
	<i>Chisocheton sp</i>	1	0.20	839.32	0.42
	<i>Chisocheton cumingianus</i> subsp. <i>balansae</i> (C.DC.) Mabb.	2	0.39	346.02	0.17

Appendix 2: Tree species and their proportions in the botanical plots at Khau Ca Forest (continued).

Family	Latin name	No. of stems	% of stems	Basal area (cm ²)	% of total basal area of plots
Mimosaceae					
Moraceae	<i>Archidendron balansae</i> (Oliv.) I.C.Nielsen	2	0.39	824.21	0.41
	<i>Ficus altissima</i> Blume	2	0.39	127.87	0.06
	<i>Ficus langkokensis</i> Drake	2	0.39	619.35	0.31
	<i>Ficus hirta</i> Vahl	2	0.39	99.07	0.05
	<i>Ficus hispida</i> L.f	4	0.78	411.23	0.20
	<i>Ficus variegata</i> Blume	1	0.20	82.00	0.04
	<i>Morus</i> sp	1	0.20	58.87	0.03
Myricaceae					
Myristicaceae	<i>Myrica esculenta</i> var. <i>chevalieri</i> (Dode) Phamhoang, Ho	5	0.98	1503.95	0.75
Myrsinaceae	<i>Horsfieldia amygdalina</i> (Wall.) Warb.	1	0.20	45.84	0.02
	<i>Ardisia humilis</i> Vahl	2	0.39	78.95	0.04
	<i>Ardisia tsangii</i> E. Walker	1	0.20	133.12	0.07
	<i>Myrsine seguinii</i> H. Lév.	4	0.78	522.85	0.26
Myrtaceae					
	<i>Syzygium brachybotryum</i> Miq.	2	0.39	759.08	0.38
	<i>Syzygium cumini</i> (L.) Skeels	8	1.56	1627.63	0.81
	<i>Syzygium jambos</i> var. <i>jambos</i>	2	0.39	173.75	0.09
	<i>Syzygium</i> sp	1	0.20	31.20	0.02
	<i>Syzygium lanceolatum</i> (Lam.) Wight & Arn.	1	0.20	30.88	0.02
	<i>Syzygium zeylanicum</i> (L.) DC.	7	1.37	3778.70	1.87
Oleaceae					
	<i>Fraxinus chinensis</i> Roxb.	3	0.59	2022.32	1.00
	<i>Osmanthus matsumuranus</i> Hayata	17	3.32	3626.66	1.80

Appendix 2: Tree species and their proportions in the botanical plots at Khau Ca Forest (continued).

Family	Latin name	No. of stems	% of stems	Basal area (cm ²)	% of total basal area of plots
Podocarpaceae	<i>Nageia fleuryi</i> (Hickel) de Laub.	4	0.78	1034.90	0.51
Rhizophoraceae	<i>Carallia brachiata</i> (Lour.) Merr.	1	0.20	48.55	0.02
Rosaceae	<i>Photinia beauverdiana</i> C.K. Schneid.	1	0.20	214.35	0.11
	<i>Rhaphiolepis indica</i> (L.) Lindl. ex Ker	3	0.59	454.80	0.23
Rubiaceae	<i>Adina pilulifera</i> (Lam.) Franch. ex Drake	1	0.20	772.08	0.38
	<i>Psydrax pergracilis</i> (Bourd.) Ridsdale	6	1.17	608.36	0.30
	<i>Gardenia sootepensis</i> Hutch.	14	2.73	3003.08	1.49
	<i>Mussaenda pubescens</i> W.T. Aiton	1	0.20	1151.65	0.57
	<i>Pavetta tonkinensis</i> Bremek.	3	0.59	181.29	0.09
	<i>Psychotria asiatica</i> L.	1	0.20	52.97	0.03
	<i>Aidia pycnantha</i> (Drake) Tirveng.	3	0.59	1016.46	0.50
	<i>Wendlandia paniculata</i> (Roxb.) DC.	6	1.17	921.11	0.46
Rutaceae	<i>Atalantia roxburghiana</i> Hook.f.	3	0.59	362.09	0.18
	<i>Evodia bodinieri</i> Dode	1	0.20	67.39	0.03
	<i>Acronychia pedunculata</i> (L.) Miq.	1	0.20	138.38	0.07
	<i>Micromelum falcatum</i> (Lour.) Tanaka	1	0.20	32.15	0.02
Samydaceae	<i>Casaeria balansae</i> Gagnep.	1	0.20	32.79	0.02
Sapindaceae	<i>Amesiodendron chinense</i> (Merr.) Hu	5	0.98	2048.43	1.02
	<i>Dinocarpus fumatus</i> spp <i>indochinensis</i> Leenh.	1	0.20	175.79	0.09

Appendix 2: Tree species and their proportions in the botanical plots at Khau Ca Forest (continued).

Family	Latin name	No. of stems	% of stems	Basal area (cm ²)	% of total basal area of plots
Sapotaceae					
	<i>Eberhardtia tonkinensis</i> Lecomte	1	0.20	581.73	0.29
Sarcospermaceae					
	<i>Sideroxylon wightianum</i> Hook. & Arn.	6	1.17	3530.64	1.75
Stalhyllaceae					
	<i>Turpinia cochinchinensis</i> (Lour.) Merr.	2	0.39	402.86	0.20
	<i>Turpinia indochinensis</i> Merr.	1	0.20	156.17	0.08
Sterculiaceae					
	<i>Sterculia lanceolata</i> Cav.	1	0.20	122.28	0.06
	<i>Sterculia monosperma</i> var. <i>monosperma</i>	1	0.20	3344.24	1.66
	<i>Reevesia thyrsoidea</i> Lindl.	1	0.20	132.47	0.07
Styracaceae					
	<i>Alniphyllum fortunei</i> (Hemsl.) Makino	11	2.15	881.49	0.44
Taxaceae					
	<i>Amentotaxus yunnanensis</i> H.L.Li	1	0.20	58.87	0.03
Theaceae					
	<i>Camellia sasamqua</i> Nakai	4	0.78	1945.11	0.96
	<i>Gordonia axillaris</i> (Roxb. ex Ker) Endl.	3	0.59	1312.56	0.65
	<i>Gordonia tonkinensis</i> Pit.	1	0.20	108.94	0.05
	<i>Terstroemia gymnanthera</i> (Wight et Arn.) Sprague	4	0.78	928.34	0.46
Tiliaceae					
	<i>Grewia hirsuta</i> Vahl	1	0.20	1074.49	0.53
Ulmaceae					
	<i>Celtis sinensis</i> Pers.	10	1.95	8877.35	4.40
	<i>Ulmus</i> sp	1	0.20	623.27	0.31

Appendix 2: Tree species and their proportions in the botanical plots at Khau Ca Forest (continued).

Family	Latin name	No. of stems	% of stems	Basal area (cm ²)	% of total basal area of plots
Urticaceae	<i>Pouzolzia sanguinea</i> (Blume) Merr.	22	4.30	2035.02	1.01
Verbenaceae	<i>Callicarpa arborea</i> Roxb.	1	0.20	83.02	0.04
	<i>Gmelina arborea</i> Roxb.	3	0.59	2929.23	1.45
	<i>Premna chevalieri</i> Dop	7	1.37	5034.45	2.50

Appendix 3. Food species and items reported for *R. avunculus*.

L: Leaves; ML: Mature leaves; YL: Young leaves; LB: Leave buds; Pe: Petiole; Fl: Flowers; Fr: Fruit; RF: Ripe fruit; UF: Unripe fruits; SUF: Seeds of unripe fruits; St: Stem; Ba: Bark; Sh: Shoot

Family/species	This study	Le, 2006	Pham, 2002	Pham, 1994	Pham, 1993a	Pham, 1993b
Aceraceae						
<i>Acer tonkinensis</i>	Fl	Pe				
<i>Acer chapaense</i>	YL, Fl					
Anacardiaceae						
<i>Allopondias lakonensis</i>			L, Fr	L, Fr	L, Fr	L, Fr
<i>Choerospondias axillaris</i>	YL		L, Fr	Fr	L, Fr	L, Fr
<i>Dubanga sonneratioides</i>			Fr		Fr	Fr
<i>Dracontomellum duperreanum</i>			L, Fr	L, Fr	L, Fr	L, Fr
<i>Canarium tonkinensis</i>					L, Fr	
<i>Canarium album</i>					L, Fr	
<i>Canarium nigrum</i>					L, Fr	
<i>Spondias pinnata</i>			L, Fr			
Annonaceae						
<i>Alphonsea tonkinensis</i>	YL					
<i>Limacia sp</i>	ML					
<i>Polyalthia memosalic</i>			L, Fr	L, Fr	L, Fr	L, Fr
<i>Polyalthia sp.</i>	YL, Fl					
Apocynaceae						
<i>Melodinus tourneri</i>		UF				
<i>Apocynaceae sp.</i>		Pe				

Appendix 3. Food species and items reported for *R. avunculus* (continued).

Family/species	This study	Le, 2006	Pham, 2002	Pham, 1994	Pham, 1993a	Pham, 1993b
Aquifoliaceae						
<i>Ilex purpurea</i>	YL					
<i>Ilex sp</i>	YL, ML					
<i>Ilex macrocarpa</i>	ML					
Araliaceae						
<i>Brassaiopsis stellata</i>		RF				
<i>Brassaiopsis sp.</i>		RF				
<i>Schefflera aff. velunosa</i>		St				
<i>Schefflera delavayi</i>	YL, Fl, UF, SUF, St					
<i>Schefflera palmiformis</i>		Pe				
<i>Trevesia palmata</i>	YL, UF, SUF					
Arecaceae						
<i>Caryota lancium</i>						Fr
<i>Dendrocalamus flagellifer</i>			Fr			
<i>Livistona saribus</i>					Fr	
<i>Caryota mitis</i>			Fr		Fr	
Asclepiadaceae						
<i>Goniostemma punctatum</i>		Pe				
Bignoniaceae						
<i>Rhadermachera sp.</i>		Fl				
Burceraceae						
<i>Canarium tonkinense</i>				Fr		L, Fr
<i>Canarium album</i>			L, Fr	Fr		L, Fr
<i>Canarium nigrum</i>			L, Fr	Fr		L, Fr

Appendix 3. Food species and items reported for *R. avunculus* (continued).

Family/species	This study	Le, 2006	Pham, 2002	Pham, 1994	Pham, 1993a	Pham, 1993b
Caesalpiniaceae						
<i>Peltophorum tonkinense</i>						Fr, FL
<i>Tamarindus indica</i>			L, Fr		L, Fr	
<i>Saraca dives</i>			L, Fr		L, Fr	
Clusiaceae						
<i>Garcinia ablongifolia</i>			L, Fr	L, Fr	L, Fr	L, LB, Sh
<i>Garcinia bracteata</i>		Pe, RF				
<i>Garcinia cowa</i>		Pe, RF	L, Fr	L	L, Fr	L, LB
<i>Garcinia fagraeoides</i>	YL, FI, UF		L	L	L	
<i>Garcinia mangostana</i>						L
<i>Garcinia multiflora</i>			L, Fr	L, Fr	L, Fr	L, LB
<i>Garcinia tinctoria</i>	YL, FI, UF					
<i>Garcinia sp.</i>		Pe, RF				
Dilleniaceae						
<i>Dillenia heterosepada</i>				Fr		Fr
Ebenaceae						
<i>Diospyros choboensis</i>	YL, FI					
<i>Diospyros tonkinensis</i>			Fr		Fr	
<i>Diospyros pilosula</i>	YL, FI					
<i>Diospyros syvatica</i>			Fr			
<i>Diospyros sp.</i>		YL, FI			Fr	

Appendix 3. Food species and items reported for *R. avunculus* (continued).

Family/species	This study	Le, 2006	Pham, 2002	Pham, 1994	Pham, 1993a	Pham, 1993b
Euphorbiaceae						
<i>Bacaurea sapida</i>			L, Fr	Fr	L, Fr	L, Fr
<i>Antidesma</i> sp.		YL				
<i>Bischofia trifoliata</i>			L, Fr	L, Fr	L, Fr	L, Fr
<i>Bridelia monoica</i>	RF					
<i>Bridelia retusa</i>		RF				
<i>Endospermum chinense</i>			Fr	Fr	Fr	Fr
<i>Phyllanthus emblica</i>			L, Fr	L, Fr	L, Fr	L, Fr
<i>Sapium rotundifolium</i>		Se				
Fabaceae						
<i>Bowringia callicarpa</i>	FL					
<i>Dalbergia tonkinensis</i>		RF				
<i>Ormosia</i> sp.	SUF					
Fagaceae						
<i>Castanea mollissima</i>			Fr	Fr	Fr	Fr
<i>Castanopsis tonkinensis</i>	Fl					
<i>Castanopsis chinensis</i>	YL					
<i>Castanopsis boissi</i>			Fr	Fr	Fr	Fr
<i>Pasania ducampi</i>			Fr	Fr	Fr	Fr
<i>Quercus acutissima</i>	YL					
<i>Quercus platycalyx</i>			Fr	Fr	Fr	Fr
Gesneriaceae						
<i>Anna submontana</i>	YL					

Appendix 3. Food species and items reported for *R. avunculus* (continued).

Family/species	This study	Le, 2006	Pham, 2002	Pham, 1994	Pham, 1993a	Pham, 1993b
Gnetaceae						
<i>Gnetum montanum</i>			Fr		Fr	Fr
Icacinaceae						
<i>Iodes seguini</i>		Pe, RF				
Lauraceae						
<i>Lauraceae sp.</i>		RF				
<i>Litsea baviensis</i>		RF				
<i>Litsea sp.</i>		RF				
<i>Machilus bonii</i>	YL					
<i>Cryptocarya sp.</i>	Ba, St					
Marantaceae						
<i>Phrynium parvifolium</i>			L	LB	L	
Meliaceae						
<i>Amoora gigantea</i>				FL, Fr		
<i>Ananamixis grandifolia</i>						L, Fr
<i>Averrhoa carambola</i>				L, FL, Fr		
<i>Chisochenton paniculatus</i>						L
<i>Sapondias pinnata</i>				Fr	Fr	
<i>Sandoricum kontape</i>	Fl					
<i>Toona sinensis</i>	Yl					
Menispermaceae						
<i>Diplospora viridiflora</i>	UF					

Appendix 3. Food species and items reported for *R. avunculus* (continued).

Family/species	This study	Le, 2006	Pham, 2002	Pham, 1994	Pham, 1993a	Pham, 1993b
Mimosaceae						
<i>Archidendron sp.</i>		Se				
<i>Adenanthera microsperma</i>						L, FL
Moraceae						
<i>Broussonetia papyrifera</i>				L, Fr		Fr
<i>Ficus auriculata</i>			L, Fr			
<i>Ficus vasculosa</i>			L, Fr	L, Fr	L, Fr	L, Fr
<i>Ficus chrysocarpa</i>				L, Fr		L, Fr
<i>Ficus championii</i>			Fr		Fr	
<i>Ficus hispida</i>			L, Fr	Fr	Fr	LB, Fr
<i>Ficus retusa</i>			L, Fr	L, Fr	L, Fr	L, Fr
<i>Ficus variegata</i>			L, Fr	L, Fr	L, Fr	L, Fr
<i>Ficus glomerata</i>			L, Fr	L, Fr	L, Fr	L, Fr
<i>Ficus religiosa</i>			Fr	Fr	Fr	Fr
<i>Bleekrodea tonkinensis</i>			L, Fr	L, Fr	L, Fr	L, Fr
<i>Ercussonetia papyrifera</i>			Fr		Fr	
<i>Ficus sp.</i>		YL				
<i>Strebus asper</i>				Fr		
Musaceae						
<i>Musa coccinea</i>			L, Fr	LB, Fr	L, Fr	L, Fr
Myrsinaceae						
<i>Ardisia ramondiaeformis</i>	Fl					
<i>Ardisia quinquegona</i>	YL					

Appendix 3. Food species and items reported for *R. avunculus* (continued)

Family/species	This study	Le, 2006	Pham, 2002	Pham, 1994	Pham, 1993a	Pham, 1993b
<i>Ardisia crispa</i>	YL					
Myrtaceae						
<i>Cleistocalyx operculatus</i>			Fr		Fr	
<i>Eugenia brachiata</i>					Fr	Fr
<i>Syzygium sp</i>	YL					
<i>Syzygium cinereum</i>			Fr			
<i>Syzygium zeylanicum</i>	YL, ML					
<i>Syzygium wightianum</i>	YL, ML					
Oleaceae						
<i>Olea sp.</i>		UF				
Orchidaceae						
<i>Bulbophyllum pectinatum</i>	YL, St					
<i>Bulbophyllum affine</i>		L				
<i>Tropidia curculigoides</i>	YL, St					
Oxalidaceae						
<i>Overrhoa carambola</i>			L, Fr		L, Fr	L, FL, Fr
Poaceae						
<i>Bambusa spinosa</i>			Sh	Sh	Sh	Sh
<i>Dendrocalamus flagellifer</i>			Sh	Sh	Sh	
<i>Dendrocalamus patellaris</i>			Sh	Sh	Sh	Sh
<i>Dendrocalamus dulloca</i>			Sh	Sh	Sh	Sh
<i>Silocalamus giganteus</i>			Sh	Sh	Sh	
<i>Silocalamus latiflorus</i>			Sh	Sh	Sh	
<i>Phyllostachys bambusoides</i>			Sh	Sh	Sh	

Appendix 3. Food species and items reported for *R. avunculus* (continued).

Family/species	This study	Le, 2006	Pham, 2002	Pham, 1994	Pham, 1993a	Pham, 1993b
Rhamnaceae						
<i>Berchemia floribunda</i>	RF					
Rosaceae						
<i>Rubus moluccana</i>	YL					
Rubiaceae						
<i>Pavetta tonkinensis</i>	YL					
<i>Gardenia sootepesis</i>	YL, Fl					
Rutaceae						
<i>Acronychia pedunculata</i>				Fr		
<i>Clausenia lancicum</i>			L, Fr	L, Fr	L, Fr	L, Fr
<i>Clausenia excavata</i>			L, Fr			
<i>Clausenia laevis</i>			L, Fr			
Sabiaceae						
<i>Meliosma fordii</i>		Pe				
Sapindaceae						
<i>Euphoria longana</i>						Fr
<i>Neppheliium bassacense</i>				Fr		Fr
<i>Neppheliium chryseum</i>						Fr
<i>Litchi chinensis</i>			Fr		Fr	
<i>Pometia pinnata</i>		RF, UF				
<i>Sapindus mukorisisii</i>			Fr	Fr	Fr	
Sapotaceae						
<i>Eberhardtia tonkinensis</i>			Fr	Fr	Fr	Fr
<i>Madhuca pasquieri</i>			Fr	Fr	Fr	Fr

Appendix 3. Food species and items reported for *R. avunculus* (continued).

Family/species	This study	Le (2006)	Pham (2002)	Pham (1994)	Pham (1993a)	Pham (1993b)
<i>Manilkhara sapota</i>			Fr		Fr	
<i>Sarcosperma laurium</i>	YL, ML					
<i>Sarcosperma laurina</i>				Fr	Fr	Fr
<i>Sinosideroxylon wightianum</i>	YL	Pe				
Theaceae						
<i>Camellia sasamqua</i>	YL					
Tiliaceae						
<i>Excentrodendron tonkinense</i>		Fl, UF				
<i>Grewia paniculata</i>			L, Fr	Fr	Fr	Fr
<i>Burretiodendron hsienum</i>			Fr	Fr	Fr	
Verbenaceae						
<i>Congea sp</i>	ML					
<i>Premna balansae</i>	YL					
<i>Premna flavescens</i>	ML					
Vitaceae						
<i>Tetrastigma gaudichaudianum</i>	RF, UF					
<i>Tetrastigma oliviforme</i>		UF				
<i>Tetrastigma sp.</i>		UF				
Ulmaceae						
<i>Celtis sinensis</i>	SUF					
Urtiaceae						
<i>Debregeasia squamata aff. Etuberculata</i>		YL				

Appendix 4.1 Ranking of Threats in Tat Ke Sector, Na Hang NR.

No	Threats	Criteria rankings			Total	Rank
		Area	Intensity	Urgency		
	Hunting					
1	Hunters encountered	12	13	13	38	2
2	Gunshots heard	13	14	14	41	1
3	Fire camps and hunting huts	8	5	11	24	6
4	Used trails for hunting	14	12	12	38	2
5	Dogs	5	3	10	18	9
	Habitat destruction					
6	Felling trees for timber	10	10	9	29	4
7	Stacked timber boards	9	9	6	24	6
8	Campsites for logging	4	2	3	9	13
9	Used trails for transporting logs	6	7	5	18	9
10	Livestock grazing and cutting trees for grazing fodder	3	6	2	11	12
11	Mining	1	1	1	3	14
12	Dam construction	2	4	7	13	11
	NTFPs collection					
13	Bamboo shoot	7	11	4	22	8
14	Orchid	11	8	8	27	5
Total						

Appendix 4.2. Ranking of Threats in Cham Chu NR.

No	Threats	Criteria rankings			Total	Rank
		Area	Intensity	Urgency		
	Hunting					
1	Hunters encountered	6	8	7	21	4
2	Gunshots heard	9	9	10	28	2
3	Fire camps and hunting huts	8	6	8	22	3
4	Used trails for hunting	10	10	9	29	1
	Habitat destruction					
5	Felling trees for timber	7	7	6	20	5
6	Stacked timber boards	4	4	4	12	7
7	Campsites for logging	3	3	3	9	8
8	Used trails for transporting logs	5	5	5	15	6
9	Livestock grazing and cutting trees for grazing fodder	1	1	1	3	10
	NTFPs collection					
10	Bamboo shoot collection	2	2	2	6	9
Total						

Appendix 4.3. Ranking of Threats in Than Sa-Phuong Hoang NR.

No	Threats	Criteria rankings			Total	Rank
		Area	Intensity	Urgency		
	Hunting					
1	Hunters encountered	3	3	2	8	7
2	Fire camps and hunting huts	2	3	3	8	7
3	Used trails for hunting	5	4	5	14	5
	Habitat destruction					
4	Felling trees for timber	9	9	9	27	1
5	Stacked timber boards	8	8	8	24	2
6	Campsites for logging	6	6	6	18	4
7	Used trails for transporting logs	7	7	7	21	3
	NTFPs collection					
8	Bamboo shoot collection	1	1	1	3	9
9	Rattan	4	5	4	13	6
Total						

Appendix 4.4. Ranking of Threats in Ba Be NP.

No	Threats	Criteria rankings			Total	Rank
		Area	Intensity	Urgency		
	Hunting					
1	Hunters encountered	5	5	9	19	8
2	Gunshots heard	6	9	8	23	5
3	Fire camps and hunting huts	9	4	7	20	6
4	Used trails for hunting	11	10	11	32	3
5	Dogs	1	3	3	7	11
	Habitat destruction					
6	Felling tree for timber	13	13	13	39	1
7	Stacked timber boards	12	12	12	36	2
8	Campsites for logging	7	7	6	20	6
9	Used trails for transporting logs	10	11	10	31	4
10	Livestock grazing and cutting trees for grazing fodder	4	8	5	17	10
11	Firewood collection	2	1	1	4	13
	NTFPs collection					
12	Bamboo shoot harvesting	3	2	2	7	11
13	Plant medicinal collection	8	6	4	18	9
Total						

Appendix 4.5. Ranking of Threats in Nam Xuan Lac HSCA.

No	Threats	Criteria rankings			Total	Rank
		Area	Intensity	Urgency		
	Hunting					
1	Hunters encountered	9	11	11	31	1
2	Gunshots heard	7	10	10	27	3
3	Fire camps and hunting huts	4	7	8	19	6
4	Used trails for hunting	10	9	9	28	2
	Habitat destruction					
5	Felling trees for timber	8	6	7	21	5
6	Stacked timber boards	6	5	6	17	7
7	Campsites for logging	2	3	2	7	9
8	Used trails for transporting logs	5	4	5	14	8
9	Livestock grazing and cutting trees for grazing fodder	1	1	3	5	11
10	Mining	3	2	1	6	10
	NTFPs collection					
11	Plant medicinal collection	11	8	4	23	4
Total						

Appendix 4.6. Ranking of Threats in Khau Ca HSCA.

No	Threats	Criteria rankings			Total	Rank
		Area	Intensity	Urgency		
	Habitat destruction					
1	Livestock grazing and cutting trees for grazing fodder	1	1	2	4	3
2	Mining	2	3	3	8	1
	NTFPs collection					
3	Plant medicinal collection	3	2	1	6	2

