Conservation strategies for Delacour’s langur
*(Trachypithecus delacouri)* in Vietnam:
Behavioural comparisons and reviewing a release

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

*Submitted February 2014*
Statement of originality

The work presented in this thesis is, to the best of my knowledge and belief, original and my own work except where otherwise acknowledged. This material has not been submitted either in whole or in part, for a degree at this or any other university.

Fiona L. Agmen
My mum, Aline Agmen, at the entrance to Cúc Phuong National Park, Vietnam.
Dedicated to my amazing Mum,

I know you would have been so proud to have seen this work completed
– this is for you.

28.02.1951 – 15.08.2013
Acknowledgments

My PhD has been a truly eye-opening experience in ways I could never have predicted, and it would not have been possible without the help of many people along the way – to them I am forever grateful.

Firstly, to my advisory team – many thanks for all the time you have invested in this project and for your comments on previous drafts of this thesis. To my supervisor, Professor Colin Groves – thank you for taking me on as a fresh-faced student and supporting me throughout the many unpredicted twists and turns of research; for your amazingly quick e-mail responses to my questions; and for your endless pearls of wisdom on seemingly any topic! To Dr Alison Behie – many thanks for coming on-board and providing limitless invaluable advice and guidance on the analysis and write-up of this thesis, I couldn’t have done it without you. To Dr Ben Rawson – thanks for your insights and sage words of advice offered over many catch-ups in Hanoi, and since. These chats not only helped shape this thesis, but more importantly kept me sane!

Thank you to Tilo Nadler for introducing me to Delacour’s langur, and along with Nguyễn Thị Thu Hiền and the entire EPRC family, for your guidance and many organisational efforts during my year in Vietnam. To Nguyễn Hồng Chung and Nguyễn Văn Linh, for your assistance, forest knowledge, and translation services in Van Long, and for continuing the langur tracking in my absence – you were a great asset to this project. To Bùi Văn Liên, thanks for your skills in the boat and your amazing ability to mime the location of a langur when I couldn’t spot it – I greatly enjoyed our attempts to converse despite speaking different languages! Also, thank you to the many people I encountered in both Cuc Phuong and Van Long, for your attempts to teach me some more Vietnamese or by helping me out with a task here and there. Thank you to anyone who conversed in English with me during my fieldwork, and especially to my Cuc Phuong housemate, Anne-Karin Schuster, for your friendship and company during the ups and downs. Thank you to the management boards of the Van Long Nature Reserve and Cuc Phuong National Park for permission to conduct this research.
My sincere thanks to those who assisted with a piece of the puzzle at various stages – Scott Bradley, Dr Jack Fenner, and Gavin Perri for ArcGIS help; Professor Rob Magrath for help with Raven; Pauline Ding from the Statistics Consulting Unit; Piers Agmen and Charlotte Rae for proofreading; and many others who gave advice or answered questions. A mention must also go to the wonderful people of the Archaeology and Anthropology department at ANU, with a special thanks to Liz Walters for her support and advice in all things PhD related!

This research was generously supported by grants from the Australian National University, National Geographic Young Explorers Grant, Conservation International’s Primate Action Fund, and La Vallee des Singes Conservatoire pour la Protection des Primates programme.

On a more personal note, thanks to my family and friends who’ve cheered me on from start to finish. To Mum and Dad – for raising me to think anything is possible if I try, and supporting my dreams as an ambitious 14-year-old when I announced I wished to do a PhD! Thank you for always sticking up for your kids and doing all you could to help us make it in the real world. Mum – I know I caused you many sleepless nights whilst off on my adventures and for that I am sorry! But thank you for the endless Skype calls when I was lonely in Vietnam, and for all the advice towards my thesis – even on a topic you didn’t always understand. I would have never achieved this goal without you both; – and Mum, I still can’t believe that you are no longer with us to see the final product to which you contributed so much.

To my friends – both at home in NZ, the Burgmann Postgrad crew in Canberra, and those of you now scattered further afield – thanks for all your support throughout, every little e-mail helped brighten my lonely days. Notable mention to Alli Drake, – for being someone who truly understands the trials and tribulations of a PhD; you became a great friend with whom I could share this process!

Lastly, to my fiancé Mike – you have suffered the most at the hands of this PhD, and for that I am indebted to you. But thank you for letting me chase my dreams, and continuing to stand by my side throughout, even though we spent a lot of it separated by oceans. Your support to get me over the line following the tragedy in these tough last months has been indispensable. We made it, and I can’t wait to get on with the rest of our lives together – bring on the wedding!
Cúc Phượng village, on the edge of the National Park
Abstract

Delacour’s langur (*Trachypithecus delacouri*) is a critically endangered Southeast Asian colobine, found in the karst outcrops of northern Vietnam. Half of the remaining population (estimated at fewer than 200 individuals) resides within Van Long Nature Reserve, Ninh Binh Province. This thesis aims to further the conservation of *T. delacouri* by reviewing the first release of captive-bred individuals as a potential conservation tool for the species, along with acquiring a greater understanding of the species’ behaviour. Behavioural focal observations were conducted throughout 2011, both on wild groups at Van Long and captive individuals at the Endangered Primate Rescue Center (EPRC) at Cuc Phuong National Park. A group of three individuals was released by the EPRC into Van Long in August 2011 in an aim to connect populations and promote interbreeding, and was tracked using GPS radio collars for a period of up to 13.5 months, with the release then evaluated in line with IUCN reintroduction guidelines.

Activity budgets of the wild versus captive *T. delacouri* populations showed significant differences, although both were in line with typical colobine budgets. Inactivity dominated (wild 75.0%, captive 61.9%), with feeding behaviours also playing a major part (wild 21.3%, captive 29.0%). Sex differences were minimal, but age differences showed that young were more social, and adults spent more time inactive and less time feeding. Both affiliative and antagonistic social interactions were common, with females and young most likely to be involved in affiliative behaviours. Infants showed significant changes in their behaviour as they aged, becoming increasingly social and independent, with allomothering witnessed. Vocalisations were predominantly performed by adult males, with grunts the most common call (61.2%) of the seven identified. An individual’s sex/age class was significantly linked to the type of vocalisation performed. *T. delacouri* vocalisation behaviour was relatively similar to that of other limestone langurs, although some differences in call structure were found.

The released individuals all survived for a minimum of five months before tracking was disrupted for one, showing some wild-like behaviours, although their behaviours were largely atypical. The group quickly separated to travel as individuals, and ranged
extensively with the adult male covering 1020ha in 9.5 months. Average day journey lengths were comparable to other limestone langurs (453m–735m), but the individuals did not develop distinct home ranges. A strong diurnal trend in movement showed two peaks at early morning and late afternoon, but minimal seasonal differences were detected. More extensive monitoring is needed to determine whether or not the release was a success, but the project fulfilled an important role as a pilot study to learn how best to conduct a release and how the animals will behave. In reviewing the release it was found to have broadly followed the IUCN guidelines, although gaps were identified suggesting more formalised planning, risk assessments, and consultation was needed. Moving forward, the possibility of translocating existing *T. delacouri* subpopulations, rather than conducting further captive releases, should be explored as a conservation strategy, along with continuing the effective protection measures in place at Van Long.
Table of Contents

ACKNOWLEDGMENTS ........................................................................................................... VI

ABSTRACT ........................................................................................................................ IX

TABLE OF CONTENTS ........................................................................................................ XI

LIST OF FIGURES ................................................................................................................ XVIII

LIST OF TABLES .................................................................................................................. XX

CHAPTER 1: INTRODUCTION ............................................................................................. 1

  1.1 PROJECT BACKGROUND ......................................................................................... 1

  1.2 RESEARCH AIMS ..................................................................................................... 2

  1.3 RESEARCH SIGNIFICANCE ...................................................................................... 4

  1.4 RESEARCH LIMITATIONS ....................................................................................... 5

  1.5 PERMISSION OBTAINED .......................................................................................... 5

  1.6 THESIS OVERVIEW ................................................................................................ 6

CHAPTER 2: BACKGROUND ............................................................................................... 9

  2.1 CONSERVATION IN VIETNAM ............................................................................... 9

    2.1.1 History of Vietnamese conservation ................................................................. 9

    2.1.2 The current situation in Vietnam ...................................................................... 11

    2.1.3 Major environmental issues in Vietnam ............................................................ 13

  2.2 ANIMAL CONSERVATION RELEASES .................................................................. 17

    2.3.1 Primate releases ............................................................................................... 17

    2.3.2 Vietnamese releases ......................................................................................... 19

  2.3 OVERVIEW OF DELACOUR’S LANGUR ................................................................. 21

    2.3.1 Taxonomy of the limestone langurs ................................................................. 21

    2.3.2 Distribution and status of limestone langurs ...................................................... 23

    2.3.3 Distribution and status of Delacour’s langur ..................................................... 27
CHAPTER 3: METHODS AND STUDY SITES

3.1 STUDY POPULATIONS

3.1.1 Endangered Primate Rescue Center study population

3.1.2 Vân Long Nature Reserve study population

3.1.3 Released study population

3.2 STUDY SITES: CỨC PHƯƠNG NATIONAL PARK AND THE ENDANGERED PRIMATE RESCUE CENTER

3.2.1 Cúc Phượng National Park

3.2.2 Endangered Primate Rescue Center

3.2.3 Site selection rationale

3.3 STUDY SITES: VÀN LONG NATURE RESERVE

3.3.1 Overview of Vân Long

3.3.2 Vân Long ecosystem

3.3.3 The community, tourism and infrastructure

3.3.4 Site selection rationale

3.4 CLIMATE AND WEATHER

3.4.1 Weather in Vân Long

3.4.2 Weather in Cúc Phượng

3.5 BEHAVIOURAL FOCAL OBSERVATIONS

3.5.1 Behavioural ethogram

3.5.2 Captive focal sampling protocol

3.5.3 Infant focal sampling protocol

3.5.4 Wild focal sampling protocol

3.6 SOCIAL INTERACTIONS

3.6.1 Social interactions ethogram

3.6.2 Social interactions sampling protocol
3.7 Vocalisation behaviour

3.7.1 Vocal types

3.7.2 Vocalisation sampling protocol

3.8 Tracking of released individuals

3.8.1 Description of the radio-GPS collars

3.8.2 Methods for tracking

CHAPTER 4: Activity budgets and behaviour

4.1 Introduction

4.2 Methods

4.2.1 Activity budgets

4.2.2 Social interactions

4.2.3 Infant development

4.3 Results

4.3.1 Activity budgets

4.3.2 Social interactions

4.3.3 Infant development

4.4 Discussion

4.4.1 Activity budgets

4.4.2 Social interactions

4.4.3 Infant development

4.5 Summary

CHAPTER 5: Vocalisation behaviour

5.1 Introduction

5.2 Methods

5.2.1 Vocalisation type, use and functions

5.2.2 Vocalisation spectrograms

5.3 Results
5.3.1 Vocal types and functions ................................................................. 112
5.3.2 Effect of sex/age class on vocalisations ........................................... 115
5.3.3 Effect of time of day on vocalisations .............................................. 120
5.3.4 T. delacouri spectrogram analysis ..................................................... 121
5.3.5 Limestone langur spectrogram analysis ........................................... 130
5.3.6 Spectrogram comparisons between species ....................................... 134
5.4 DISCUSSION ................................................................................................. 141
  5.4.1 Possible function of vocalisations ..................................................... 141
  5.4.2 Factors impacting on vocalisations .................................................. 143
  5.4.3 Spectrogram analysis ......................................................................... 145
  5.4.4 Interspecific differences .................................................................... 146
5.5 SUMMARY .................................................................................................... 148

CHAPTER 6: RELEASE OF DELACOUR’S LANGURS ........................................... 151

6.1 INTRODUCTION ............................................................................................ 151
6.2 DESCRIPTION OF THE RELEASE ............................................................. 152
  6.2.1 Preparations .......................................................................................... 152
  6.2.2 Transportation ..................................................................................... 155
  6.2.3 Release .................................................................................................. 157
6.3 METHODS ...................................................................................................... 157
  6.3.1 Data mapping and day journey length ............................................... 157
  6.3.2 Ranging patterns ................................................................................ 158
  6.3.3 Proximity of individuals ................................................................. 159
  6.3.4 Accuracy of equipment ...................................................................... 159
6.4 RESULTS ....................................................................................................... 160
  6.4.1 Initial post release dispersal and behaviour ...................................... 160
  6.4.2 Total tracking period ........................................................................ 163
  6.4.3 Day journey and path length .......................................................... 170
6.4.4 Ranging patterns ................................................................. 173
6.4.5 Proximity of individuals ..................................................... 180
6.4.6 Significant events and wild interactions ............................... 182
6.4.7 Accuracy of equipment ....................................................... 184

6.5 DISCUSSION ........................................................................... 186
6.5.1 Movements and day journey length ................................. 186
6.5.2 Ranging patterns and dispersal ........................................ 188
6.5.3 Comparisons to wild and captive Delacour’s langurs ............... 192

6.6 SUMMARY .............................................................................. 193

CHAPTER 7: EVALUATION OF THE RELEASE ................................. 197

7.1 INTRODUCTION ..................................................................... 197

7.2 REVIEW OF STEPS TAKEN COMPARED TO IUCN GUIDELINES ............................................. 198
7.2.1 Principle 1 – Identifying reintroduction need and overall assessment ...... 199
7.2.2 Principle 2 – Define aims, objectives, and time frame ...................... 200
7.2.3 Principle 3 – Establish a multi-disciplinary team .......................... 200
7.2.4 Principle 4 – Assess proposed release site ................................ 201
7.2.5 Principle 5 – Review socioecological and behavioural data .............. 203
7.2.6 Principle 6 – Determine if the socioeconomic, financial, and legal
requirements can be met .............................................................. 204
7.2.7 Principle 7 – Assess suitability of release stock ......................... 205
7.2.8 Principle 8 – Evaluate the genetic status of release stock ............... 206
7.2.9 Principle 9 – Ensure release stock has been cleared by a veterinary team 207
7.2.10 Principle 10 – Develop strategy for transport and final release ......... 208
7.2.11 Principle 11 – Establish post-release monitoring and follow-up ......... 210
7.2.12 Principle 12 – Document project outcomes ............................. 212

7.3 WAS THE RELEASE ‘SUCCESSFUL’? ........................................ 213
7.3.1 Definition of ‘success’ .......................................................... 213
7.3.2 Case studies of ‘success’ analysis ................................................................. 214
7.3.3 Was the EPRC’s Delacour’s langur release successful? ............................ 216
7.4 FUTURE RECOMMENDATIONS ......................................................................... 217
7.4.1 Greater discussion on initial plans and release site........................................... 217
7.4.2 Further risk assessment and increase knowledge of existing situation ..... 218
7.4.3 Changes to tracking equipment settings and processes .................................... 219
7.4.4 Increased post-release monitoring ................................................................. 220
7.5 SUMMARY .............................................................................................................. 221

CHAPTER 8: CONCLUSIONS ...................................................................................... 225
8.1 ACTIVITY BUDGETS AND BEHAVIOUR .............................................................. 225
8.2 VOCALISATION BEHAVIOUR .............................................................................. 226
8.3 THE DELACOUR’S LANGUR RELEASE ................................................................. 228
8.4 CONSERVATION STRATEGIES FOR DELACOUR’S LANGUR ......................... 230
  8.4.1 Current conservation risk factors ................................................................. 230
  8.4.2 T. delacouri population size estimate ........................................................... 231
  8.4.3 Recommended conservation strategies ....................................................... 232

REFERENCES ............................................................................................................. 237

APPENDIX I: COMPLETE EThOGRAM ..................................................................... 260

APPENDIX II: DVD INDEX ........................................................................................... 266
## List of Figures

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 2.1</td>
<td>Map of the distribution of the limestone langurs</td>
<td>26</td>
</tr>
<tr>
<td>Figure 2.2</td>
<td>Map of <em>T. delacouri</em>'s range</td>
<td>28</td>
</tr>
<tr>
<td>Figure 2.3</td>
<td>Wild group of <em>T. delacouri</em> at Van Long Nature Reserve</td>
<td>30</td>
</tr>
<tr>
<td>Figure 3.1</td>
<td>Location of wild study groups on Dong Quyen</td>
<td>39</td>
</tr>
<tr>
<td>Figure 3.2</td>
<td>Number of tourists entering Cuc Phuong, 1994-2011</td>
<td>41</td>
</tr>
<tr>
<td>Figure 3.3</td>
<td>Number of tourists per month at Cuc Phuong in 2011</td>
<td>41</td>
</tr>
<tr>
<td>Figure 3.4</td>
<td>Map of Cuc Phuong and Van Long boundaries</td>
<td>44</td>
</tr>
<tr>
<td>Figure 3.5</td>
<td>Descriptive map of Van Long Nature Reserve</td>
<td>46</td>
</tr>
<tr>
<td>Figure 3.6</td>
<td>Tourists heading out on the waters of Van Long</td>
<td>49</td>
</tr>
<tr>
<td>Figure 3.7</td>
<td>A cement factory looming over Van Long Nature Reserve</td>
<td>50</td>
</tr>
<tr>
<td>Figure 3.8</td>
<td>Weather data from Van Long, February 2011 – October 2012</td>
<td>53</td>
</tr>
<tr>
<td>Figure 3.9</td>
<td>Weather data from Cuc Phuong, 2011</td>
<td>55</td>
</tr>
<tr>
<td>Figure 3.10</td>
<td>Radio-GPS collars</td>
<td>64</td>
</tr>
<tr>
<td>Figure 3.11</td>
<td>Use of basestation to download GPS data</td>
<td>66</td>
</tr>
<tr>
<td>Figure 4.1</td>
<td>Activity budget for wild compared with captive <em>T. delacouri</em></td>
<td>75</td>
</tr>
<tr>
<td>Figure 4.2</td>
<td>Activity budget summary for captive population</td>
<td>79</td>
</tr>
<tr>
<td>Figure 4.3</td>
<td>Activity budget male/female comparisons</td>
<td>80</td>
</tr>
<tr>
<td>Figure 4.4</td>
<td>Activity budget age class comparisons</td>
<td>82</td>
</tr>
<tr>
<td>Figure 4.5</td>
<td>Frequency of social interaction types</td>
<td>83</td>
</tr>
<tr>
<td>Figure 4.6</td>
<td>Affiliative versus antagonistic interactions by cage</td>
<td>84</td>
</tr>
<tr>
<td>Figure 4.7</td>
<td>Socioiogram of cage interactions</td>
<td>85</td>
</tr>
<tr>
<td>Figure 4.8</td>
<td>Effect of sex on social interactions</td>
<td>86</td>
</tr>
<tr>
<td>Figure 4.9</td>
<td>Effect of age on social interactions</td>
<td>87</td>
</tr>
<tr>
<td>Figure 4.10</td>
<td><em>T. delacouri</em> infant at two weeks of age</td>
<td>89</td>
</tr>
<tr>
<td>Figure 4.11</td>
<td><em>T. delacouri</em> infant at one month of age</td>
<td>89</td>
</tr>
<tr>
<td>Figure 4.12</td>
<td><em>T. delacouri</em> infant at two to five months of age</td>
<td>90</td>
</tr>
<tr>
<td>Figure 4.13</td>
<td>Infant activity budget by age</td>
<td>91</td>
</tr>
<tr>
<td>Figure 4.14</td>
<td>Changes in infant play behaviour over time</td>
<td>93</td>
</tr>
<tr>
<td>Figure 4.15</td>
<td>Frequency of allomothering</td>
<td>94</td>
</tr>
<tr>
<td>Figure 5.1</td>
<td>Percentage of vocalisation types used by limestone langurs</td>
<td>112</td>
</tr>
</tbody>
</table>
Figure 5.2  Summary of vocalisations used, by species ......................... 113
Figure 5.3  Effect of sex/age class on vocalisation behaviour ................. 116
Figure 5.4  Effect of sex/age class on call type for limestone langurs ...... 119
Figure 5.5  Effect of sex/age class on call type for T. delacouri ................ 119
Figure 5.6  Adjusted summary of vocalisation type used ....................... 120
Figure 5.7  Spectrograms for all T. delacouri vocalisation types .............. 122
Figure 5.8  Box and whisker plots of call attributes ............................ 127
Figure 5.9  Spectrograms of T. francoisis and T. hatinhensis vocalisations ... 131
Figure 5.10 Spectrograms of grunt calls ....................................... 134
Figure 5.11 Spectrograms of hoot calls ........................................... 138
Figure 6.1  Map of release cage site at Van Long ................................ 154
Figure 6.2  Transfer of the langurs .................................................. 156
Figure 6.3  Individuals post-release, with collars visible ....................... 160
Figure 6.4  Map of langur movements in first nine days post-release ...... 163
Figure 6.5  Individual 1-09’s recovered collar .................................... 165
Figure 6.6  Map of the groups movements for the entire tracking period .... 166
Figure 6.7  Map of individual 1-10’s movements ................................ 167
Figure 6.8  Map of individual 1-20’s movements ................................ 168
Figure 6.9  Map of individual 1-09’s movements ................................ 169
Figure 6.10 Box and whisker plot of day journey length ....................... 170
Figure 6.11 Average journey leg distance across the day ...................... 171
Figure 6.12 Average seasonal day journey length ............................... 172
Figure 6.13 Average day journey length across months ........................ 173
Figure 6.14 Minimum convex polygons of ranging areas ..................... 175
Figure 6.15 Habitat range use by quadrant system ............................. 176
Figure 6.16 Habitat range use by quadrant system, Aug 2011 – Jan 2012 ... 178
Figure 6.17 Commonly frequented habitat areas ............................... 180
Figure 6.18 Proximity of individual 1-10 to 1-09 ............................... 181
Figure 6.19 Proximity of individual 1-10 to 1-20 ............................... 181
Figure 6.20 Proximity of individual 1-09 to 1-20 ............................... 182
Figure 6.21 Locations of existing T. delacouri groups at Van Long ........... 184
List of Tables

Table 2.1  Seven limestone langur species and their distribution…. 23
Table 3.1  Age/sex class descriptions for T. delacouri………………. 36
Table 3.2  Cage composition of captive study population at the EPRC…… 37
Table 3.3  Group composition of wild study population…………………. 38
Table 3.4  Outline of behavioural categories used for T. delacouri…… 57
Table 3.5  Social interaction behaviours for T. delacouri…………………. 61
Table 4.1  Activity budget behaviour categories………………………… 72
Table 4.3  Activity budget summary…………………………………….. 77
Table 5.1  T. delacouri vocalisation types………………………………… 109
Table 5.2  Average calls per bout and bout length……………………… 114
Table 5.3  Vocalisation rate by sex/age class…………………………….. 117
Table 5.4  Summary of attribute values for vocalisation types…………… 124
Table 5.5  Comparisons between T. delacouri call types………………… 127
Table 5.6  Attribute values for T. francoisi and T. hatinhensis vocals…….. 132
Table 5.7  Comparisons between T. francoisi call types………………….. 133
Table 5.8  Summary of grunt call attributes across species……………….. 135
Table 5.9  Comparisons of grunt calls between species…………………. 137
Table 5.10 Summary of hoot call attributes across species………………… 138
Table 5.11 Comparisons of hoot calls between species………………….. 139
Table 5.12 Summary of squeal call attributes across species……………… 140
Table 5.13 Comparisons of squeal calls between species…………………. 141
Table 6.1  The release group……………………………………………… 154
Table 6.2  Minimum convex polygon versus quadrant range sizes………… 175
Table 6.3  Habitat range use by month…………………………………… 179
Hò Mạc, in Cúc Phuong National Park
CHAPTER 1

Introduction

1.1 Project background

Delacour’s langur, *Trachypithecus delacouri*, is a critically endangered Vietnamese primate belonging to the genus *Trachypithecus* within the Old World Monkey subfamily Colobinae (Groves, 2001; Nadler *et al.*, 2008). Within this genus it is part of a subgroup of seven taxa informally known as the ‘limestone langurs’, typically found in limestone karst environments in Vietnam, Laos and southern China (Davies & Oates, 1994; Groves, 2001; Groves, 2004; Groves, 2005; Workman, 2010b; Blair *et al.*, 2011; Harding, 2011). *T. delacouri* was first described in 1932 following the collection of a type specimen from Indochina during the Kelley-Roosevelt expedition (Osgood, 1932). It then slipped into scientific obscurity, before being brought to attention by a report on the 1987 sighting of three individuals in Cuc Phuong National Park, Ninh Binh Province, Vietnam (Ratajszczak, 1988). This sighting interested the Frankfurt Zoological Society (FZS), and triggered a series of population surveys, ultimately resulting in the creation of the Endangered Primate Rescue Center (EPRC) at Cuc Phuong to assist in the species’ protection (Nadler, 1996b; Nadler, 1996a; Frankfurt Zoological Society, 2012). These surveys showed that there were very few *T. delacouri* remaining, and the isolated populations were confined to a small area of northern Vietnam, with estimates of no more than 250 individuals (Nadler, 1996b). Further surveys showed the population was continuing to decline, with the most recent published figures estimating fewer than 200 individuals across 10 isolated sites, the largest subpopulation occurring within Van Long Nature Reserve – estimated at 98–105 individuals (Workman, 2010b; Ebenau *et al.*, 2011; Harding, 2011).

Vietnam has a diverse political history and large human population, which have contributed to the country’s natural environments and biodiversity suffering extensive damage over the years (ICEM, 2003; Sterling *et al.*, 2006; Hoang Van Chieu, 2012; World Bank, 2012). *T. delacouri* has suffered from years of habitat destruction caused by forest degradation, agricultural encroachment, and the mining
of limestone rock, meaning there are few suitable environments remaining for the species (Nadler et al., 2003; Conservation International, 2005; Nguyen Vinh Thanh, 2009; Workman, 2010b; Ebenau et al., 2011; Mittermeier et al., 2012). In addition, many of these habitats have been isolated from one another, cutting off the potential for migration between the remaining populations. This lack of migration leads to potential problems of inbreeding and genetic degradation within subpopulations, but the major factor thought to be responsible for T. delacouri’s demise to its present critically endangered status is the intensive hunting that has occurred over the years, predominantly for the use of its bones, organs, and tissues in Asian traditional medicines (Nadler, 2001; Nadler et al., 2003; Conservation International, 2004; Nguyen Ba Thu, 2004; Mittermeier et al., 2006; Alves et al., 2010).

In 2009, when the concept of this doctoral project was formulated, the only major behavioural ecology study on the species to date was that of Workman (2010b), “The foraging ecology of the Delacour’s langur (Trachypithecus delacouri) in Van Long”, which was still being completed. Extensive population surveys had uncovered considerable information about the species’ habitat and its appearance (Ratajszczak, 1988; Nadler, 1996b; Nadler, 2001; Nadler et al., 2003; Conservation International, 2004; Fauna & Flora International - Vietnam Programme, 2004; Nadler, 2004a; Nadler et al., 2004), but there was still fairly limited information about the species’ behaviour. This project therefore aimed in part to fill this gap in the knowledge of its behaviour, as well as including the unique element of monitoring and reviewing the EPRC’s first-ever release of captive T. delacouri back into the wild environment of Van Long Nature Reserve. This allowed for the comparison of the behaviours of wild and captive animals, giving a greater understanding of the adjustments released individuals would have to undergo to live in a wild environment. By synthesising all this information, recommendations for the best continued conservation strategies to support the T. delacouri population can be gained.

1.2 Research aims

This thesis aims to further the conservation of Delacour’s langur (Trachypithecus delacouri) by reviewing the first release of captive individuals into the wild as a potential conservation tool for the species, along with acquiring a greater
understanding of the species’ behaviour. Within this general aim, several questions were addressed to formulate this study:

1. What is the history of conservation in Vietnam?
   i. What are the common problems encountered and lessons learned in animals’ releases?
   ii. What factors, both environmental and anthropogenic, are threatening primate populations in Vietnam?
   iii. How does environmental policy and management in Vietnam function to protect primate populations?

2. What are the social and daily behaviours of *T. delacouri*?
   i. Do activity budgets vary between captive and wild individuals? Between sex and age classes?
   ii. What social interaction behaviours do *T. delacouri* show?
   iii. How does infants’ behaviour change as they age and develop?
   iv. What vocalisations do *T. delacouri* display? What is the function of the different vocalisations?
   v. How do the vocalisations compare with those of other “limestone langurs”?

3. What behaviours do released *T. delacouri* show in the wild?
   i. What are their daily journey lengths, ranging and dispersal patterns?
   ii. What social groups do they form?
   iii. What similarities do the released individuals show to both wild and captive groups?
4. How can releases be used as a conservation tool for *T. delacouri*?

   i. What problems have been encountered in the 2011 release of *T. delacouri*?

   ii. Can the 2011 release be deemed a ‘success’?

   iii. What recommendations can be made for potential future releases?

1.3 Research significance

Delacour’s langur remains one of the world’s most critically endangered species, the population being fragmented into just 10 remaining subpopulations in northern Vietnam, with a total reported wild population of less than 200 individuals (Ebenau *et al.*, 2011). With such an endangered species, where there has been relatively little opportunity for research, any additional information we can learn about its behaviour and environment will aid in its ongoing protection, as well as potentially contributing to our knowledge of the taxonomic group as a whole. This dissertation gives additional detail on *T. delacouri*’s daily activity budget, along with providing new information on social interactions and the development of infant behaviour. In addition it presents a comprehensive catalogue of the species’ vocalisations along with potential usages and functions.

The release of captive-bred *T. delacouri* into the wild is a first for this species, or indeed any of the limestone langurs, meaning it has great potential implications for the species’ future. A continued release programme could potentially be an effective conservation tool for the management of this species, with prospects of not only supplementing existing populations, but of creating new ones in suitable habitats. Therefore, a detailed review of this initial release is crucial in analysing its success. This thesis provides an impartial evaluation of the release process, and gives recommendations for how things could be changed. Additionally, a detailed analysis of the collected post-release monitoring data gives an invaluable insight into the ranging and dispersal behaviour of the released individuals. This allows for comparisons between captive, released, and wild *T. delacouri*, giving insight into how the three groups may differ and the possible consequences of this for future conservation strategies.
1.4 Research limitations

Whilst efforts were made to collect all data possible and avoid bias, there are some limitations which have constrained the scope of this thesis. The wild groups of *T. delacouri* were not habituated, as it is arguably not advisable to habituate a species prone to poaching by humans (Workman, 2010b), but this does limit opportunities to collect data from them, and made individual identification of animals impossible. The *T. delacouri* on Dong Quyen could be observed only from a boat, and were sometimes being observed at large distances meaning that detailed observations could not always be completed. In addition, the terrain throughout Van Long Nature Reserve meant the langurs were often obscured from view and were hard to follow. In addition, it was initially intended that behavioural focal observations of the released group would also be conducted, in the same manner as was done for the wild and captive populations, to allow comparisons between the three groups, but it quickly became apparent that this was not feasible as the released animals were very rarely seen due to the complex terrain of western Van Long.

Weather conditions, including rough waters and high winds during tropical storms and frequent flooding of roads, limited data collection at times. Technological difficulties with the GPS and weather station equipment also hampered data collection, and unpredictable delays in the EPRC’s schedule of the release introduced significant time constraints. The combination of these factors resulted in data sets being not as comprehensive as I would have liked, and there is reduced statistical power in some areas.

1.5 Permission obtained

Ethics permission for this study was granted by the Australian National University Animal Experimentation Ethics Committee on 15 June 2010, for proposal R.BSB.01.10. A research permit was obtained through the Ninh Binh Forest Protection Department, along with support from the management boards of Van Long Nature Reserve and Cuc Phuong National Park.
1.6 Thesis overview

This thesis is organised into eight chapters, with the initial three chapters explaining the background and methods behind the project, the next four (Chapters 4–7) presenting the data and findings of the study, and the final chapter synthesising all these ideas to address the research aims. Following the current chapter, which provides an overview of the thesis and its aims, Chapter 2 lays out the background to the topic, addressing the first research aim, by discussing the historical and current state of conservation in Vietnam, the use of captive animal releases as a conservation tool focusing on primates and Vietnamese examples, and an overview of all current knowledge of *Trachypithecus delacouri* and its place within the limestone langur group. Chapter 3 goes on to inform the reader of the study populations and study sites used, giving a background on the two areas’ history, environment, and climate. Additionally, this chapter describes the methods used to conduct all behavioural observations, vocalisation sampling, and the process behind the tracking of the released individuals.

Chapter 4, the first data chapter, presents the results of the activity budget studies of both wild and captive populations, including an analysis of sex/age class differences. Additionally, behavioural studies focusing on the social interactions between individuals, and the development milestones of an infant from birth to three months of age, are discussed. In Chapter 5, the results from the vocalisation studies are presented, with an in-depth look into the possible functions of different vocalisations, along with detailed spectrogram results looking at the form of each vocalisation for *T. delacouri* and other limestone langur species. Chapter 6 provides a factual description of the build-up and execution of the EPRC’s first ever *T. delacouri* release into the wild, and presents and analyses the tracking data collected post release. Chapter 7 goes on to evaluate the release in the light of the IUCN guidelines, and makes recommendations for possible changes.

Finally, Chapter 8 concludes by presenting the main findings and ideas from this thesis, identifying areas for further research, and discussing how this study impacts on the potential conservation strategies for Delacour’s langur.
The Mường village of Khanh, on the northwest edge of Cúc Phượng National Park
CHAPTER 2

Background

This chapter gives the necessary background on conservation and environmental issues in Vietnam, the use of animal releases in both a Vietnamese and primatological context, and an overview of what is already known about *T. delacouri*. This background information is crucial in enabling the reader to understand the current conservation management challenges that face *T. delacouri*.

2.1 Conservation in Vietnam

In the heart of Southeast Asia, on the Indochinese Peninsula, Vietnam is a varied country ranging from the expansive Mekong and Red River deltas to mountainous highlands, with forests, grasslands and an extensive coastline in-between (Nguyen Tuong Van, 1997; ICEM, 2003; Nguyen Hai Hoa, 2006; Sterling *et al.*, 2006; IUCN, 2007). Vietnam’s approximate 33 million hectares of land stretches from 8°N to 23°N in latitude, and ranges from sea level plains to the highest peaks at over 3000m. The country is bordered by China in the North, with Laos and Cambodia on the western side.

2.1.1 History of Vietnamese conservation

Vietnam’s conservation and forestry policies have in part been shaped by its political history. From 1887 Vietnam became formally part of French Indochina, split into the administrative colonies of Tonkin, Annam and Cochinchina, and was under colonial rule with Catholicism and Western systems being implemented (Lawrence, 2008; Smith, 2009). Exports of tobacco, tea and coffee along with other plantation crops were established, and several policies on forestry management and development were introduced along with the establishment of the Indochina Forestry Bureau in 1900 (Biggs, 2005; Hoang Van Chieu, 2012). In 1945, in the midst of World War II and the Japanese occupation, Ho Chi Minh proclaimed independence from the French and set up a provisional government in Hanoi (Ang, 2005; Westheider, 2007). The French did not accept this declaration, and sent in troops to
try and quell the liberation movement leading to the ‘First Indochina War’ that continued till 1954 with the defeat of the French. At this stage the Geneva Accords were enacted, which split Vietnam into the communist controlled Viet Minh zone in the north and the Western backed State of Vietnam in the south with elections scheduled in both states, in an effort to restore peace. However, infighting and instability continued, with what is now known as the Vietnam War (or ‘American War’ in Vietnam) soon erupting, which involved large numbers of American troops along with troops from 11 other countries (Ang, 2005; Westheider, 2007; Lawrence, 2008; Hoang Van Chieu, 2012). This period of fighting took place over 19 years, with extensive bombing and chemical defoliation, including the use of ‘Agent Orange’, impacting on the Vietnamese landscape (Eames & Robson, 1993; Lang, 2001; Workman, 2004). American involvement alongside South Vietnam peaked in 1968 following the ‘Tet Offensive’, with American and allied troop numbers then gradually decreasing till they were withdrawn in 1973, and the fall of Saigon in April 1975 marking the end of the war.

During this period, land management and development followed very different approaches in the South compared to the North (Lang, 2001; Ang, 2005; Hoang Van Chieu, 2012). In the North the land was held collectively by the people in communes with the government overseeing the ownership, in line with socialist policies, whilst in the South land remained privately owned by individuals, along with some state owned areas.

In 1976 the country was officially reunified and became the Socialist Republic of Vietnam under the leadership of Ho Chi Minh’s successors (Gilmour & Nguyen Van San, 1999; Ang, 2005; Westheider, 2007; Lawrence, 2008). Northern policies of collectivisation and planned economy were implemented, with land managed exclusively by the state, but this led to mass inflation and severe poverty throughout the war torn country, in part due to lack of productivity. By the mid-1980s the extreme rate of deforestation became apparent under the collective farming and ‘top down planning’ strategies, which focused on intensive plantation cropping (Gilmour & Nguyen Van San, 1999). This led to changes in forest policy along with the implementation of ‘Doi moi’ or ‘renovation’ in 1986 to replace the old economic systems, shifting the country to a market-orientated economy with some private ownership encouraged (Hirsch et al., 1992; ICEM, 2003; Hoang Van Chieu, 2012;
World Bank, 2012). In terms of forest policy, there was a shift in focus to rehabilitating the environment, considering both socioeconomic needs along with environmental protection objectives. *Doi moi* is largely credited with leading to great improvements in the country’s growth and development (Hirsch *et al.*, 1992; ICEM, 2003; Hoang Van Chieu, 2012; World Bank, 2012). As the modern Vietnam continued to form, the National Environmental Action Plan and Vietnam Biodiversity Action Plan were instigated in 1995, with focuses on the conservation of the vulnerable upland forests and protecting their biodiversity (Gilmour & Nguyen Van San, 1999).

### 2.1.2 The current situation in Vietnam

As of 2012 Vietnam is estimated to have a population of 88.78 million, making it the world’s 13th most populated country (World Bank, 2012). Poverty levels have fallen dramatically, from 58% of the population being classed as ‘in poverty’ in the early 1990s to 14.2% in 2010, as the per capita Gross Domestic Product (GDP) has increased. However, poverty is unequally dispersed with rates still high in ethnic minority groups and rural areas, especially in the highlands. These are the same areas where biodiversity tends to be concentrated (Vietnam Environment Administration, 2008; Hoang Van Chieu, 2012). Although the 2009 census showed that a migration has begun of people moving to urban areas, 70.4% of the population still lives in rural zones with approximately 19% in the highlands (Sterling *et al.*, 2006; Hoang Van Chieu, 2012; World Bank, 2012). Whilst the majority Kinh ethnic group makes up approximately 85% of the population, there are 53 ethnic minority groups who predominantly live in the highlands.

The Vietnamese governmental system is structured into four administration levels, stepping from the Central Governmental to the Provincial People’s Committees, down to the District and Commune level (Nguyen Tuong Van, 1997; ICEM, 2003; Hoang Van Chieu, 2012; Nguyen Kim Dung *et al.*, 2013). Within Central Government the Ministry of Agriculture and Rural Development (MARD) is involved in conservation policy, and includes the Forest Protection Department (FPD) which is pivotal in regulation management and enforcement at a local level. After ratifying the Convention on Biological Diversity and the Convention of International Trade in Endangered Species (CITES) in 1994, along with adopting the Ramsar Convention, Vietnam has placed increasing importance on its protected areas
(Global Environment Facility Project, 1994; ICEM, 2003; Nguyen Hai Hoa, 2006; Vietnam Environment Administration, 2008; Bruun, 2012; Nguyen Kim Dung et al., 2013). Forests in Vietnam are classified into three categories – Production Forests which are allocated to various stakeholders and utilised as a commercial resource, which make up 51.7% of Vietnam’s forest land; Protection Forests (35%) which are exclusively managed by the State and function to protect watersheds, other environmental values, and mitigate natural disasters; and Special Use Forests (13.3%) which are what could be broadly described as Protected Areas under international guidelines (Hoang Van Chieu, 2012). Protected ‘Special Use Forests’ have four subcategories – National parks, Natural conservation areas consisting of nature reserves or species and habitat conservation areas, Landscape protection areas including historical and cultural sites, and Research and experimental forest areas. Cuc Phuong National Park was the first protected area in Vietnam established in 1962 by Ho Chi Minh himself; and as of 2010 and there are now 161 Special Use Forests, covering 2,198,744 ha (Nguyen Kim Dung et al., 2013). Whilst the latest 2011 World Bank figures indicated 45% forest cover in Vietnam, this is predominantly made up from forestry plantations, with approximately 6.5% of the country’s land decreed as a protected area (ICEM, 2003; Vietnam Environment Administration, 2008; Hoang Van Chieu, 2012; Nguyen Kim Dung et al., 2013).

Vietnam is one of the world’s most biologically diverse areas, in part due to its transitional nature across multiple habitat types at different latitudes and elevations (Sterling et al., 2006). The ‘Biodiversity Action Plan’ was implemented to provide regulations and guidance around conservation activities and sustainable development (Global Environment Facility Project, 1994; Gilmour & Nguyen Van San, 1999). Vietnam is estimated to contain 10% of the world’s mammal, bird and fish species, and over 40% of Vietnam’s plant species are believed to be endemic (Global Environment Facility Project, 1994; IUCN, 2007). The country is estimated to contain over 13,200 species of flora and 10,000 of fauna in its terrestrial ecosystems, along with 3,000 fresh-water aquatic species and 11,000 salt-water aquatics (Vietnam Environment Administration, 2008). Following the end of many years of war, scientists started to explore the more remote regions of the country which led to the discoveries of new species, such as a large hoofed mammal, the Saola (*Pseudoryx nghetinhensis*), which when identified in 1992 was the largest new land-dwelling
animal discovered since 1937 (Van Dung et al., 1994; Sterling et al., 2006). There was also the ‘rediscovery’ of a lot of species that were feared extinct such as the Lesser One-horned or Javan Rhinoceros (*Rhinoceros sondaicus annamiticus*) in 1988 (Schaller et al., 1990), and the Tonkin snub-nosed monkey (*Rhinopithecus avunculus*) which when found in 1992 had not been documented since 1926 (Sterling et al., 2006; Covert & Wright, 2008). The grey-shanked douc langur, *Pygathrix cinerea*, from Central Vietnam, was not described until 1997 (Nadler, 1997). Altogether there are 25 primate taxa found in Vietnam, including gibbons, lorises, macaques, langurs, and douc langurs, five of which are included in the IUCN/SSC Primate Specialist Group’s list of ‘The World’s 25 Most Endangered Primates’, four of these being endemic (Nadler, 2010b; Mittermeier et al., 2012). Many other species in Vietnam are also endangered, with a wide variety of issues contributing to their decline. Vietnam operates its own Red Book of endangered species catalogue, based on the IUCN system, as a tool to assist in conservation efforts, which following a 2007 revision listed 882 species as endangered (Vietnam Environment Administration, 2008). In 2010 what was thought to be the last remaining Javan rhino in the country was shot by a poacher in Cat Tien National Park, and the subspecies *Rhinoceros sondaicus annamiticus* is now regarded as extinct, despite efforts to protect it (Brook et al., 2011).

### 2.1.3 Major environmental issues in Vietnam

Biodiversity in Vietnam is largely continuing to decrease, with several endangered species remaining at risk due to a variety of interrelated factors (Eames & Robson, 1993; Global Environment Facility Project, 1994; Sterling et al., 2006; Geissmann, 2007; World Bank, 2012; Cano & Tellería, 2013). The destruction of species’ habitat is a major environmental issue in the country, with logging, agricultural encroachment, pollution, mining and the over-exploitation of resources impacting on a wide variety of ecosystems. The country’s habitats have suffered from years of war which resulted in large tracts of forest being cleared through defoliation and bombing, especially in the central and southern areas (Workman, 2004; Sterling et al., 2006). Logging, both commercial and illegal timber smuggling, is a major cause for deforestation; it is thought that logging rates peaked in 1992 when 1.2 million cubic meters of timber was taken from Vietnam’s forests (Global Environment Facility Project, 1994; Lang, 2001; Sodhi et al., 2004; Zhao et al.,
Associated with logging is the construction of road networks which allow access and transportation of timber, but bring with them their own sets of problems by creating dispersal barriers for animals and opening up the forest to further human exploration (Hoang Hoe, 2001; Nadler et al., 2003). The roads are also used to access plantations, and large tracts of primary forest have been cleared to make way for commercial crops such as acacia, rubber, coffee, and cashews (Hoang Hoe, 2001; Lang, 2001; Bruun, 2012). As the population of Vietnam has expanded, more and more land has been cleared for agriculture, both for personal subsistence and for commercial gains. Vietnam is now the world’s second largest rice exporter and this is a major earner for their economy, but this intensive form of agriculture also takes up large tracts of land (Workman, 2004; World Bank, 2012). Forest fires, both naturally occurring and inadvertently lit, often occur during the dry season when there are high winds, and can burn 20,000 – 30,000ha annually, destroying animals in their path (Global Environment Facility Project, 1994). Mining for gold and limestone is another cause of deforestation, along with the flooding of valleys to create reservoirs for hydroelectric dams (Global Environment Facility Project, 1994; Nadler et al., 2003). During the Hoa Binh dam project, 58,000 people had to be resettled meaning that not only was 11,000ha of their agricultural land flooded along with forested land, but new agricultural land had to be cleared by the resettled residents to replace this (Hirsch et al., 1992). All these actions result in fragmented and degraded forests, which isolates animal populations putting them at risk of inbreeding and genetic degradation (Workman, 2004; Conservation International, 2005; Geissmann, 2007). Medium-to-large mammals, such as primates, are particularly sensitive to the impacts of deforestation as they tend to require larger habitats to survive (Cano & Tellería, 2013).

The interaction of the local people with the environment is an on-going conservation issue in Vietnam. The country is extremely densely populated, and there are a lot of people competing for space and resources (Global Environment Facility Project, 1994; Workman, 2004; World Bank, 2012; Cano & Tellería, 2013). The creation of a National Park or other Protected Area can quickly become a source of conflict, as it is essentially denying the local people access to resources, and without the creation of alternative employment opportunities and sources of income, it can leave them without options (Lang, 2001; Rugendyke & Nguyen Thi Son, 2005;
Hoang Van Chieu, 2012). Protected Areas and their buffer zones are often not well marked, and with confusion over the limits of the area and what regulations apply, local communities can become frustrated (Gilmour & Nguyen Van San, 1999; Hoang Hoe, 2001). Communities traditionally use the forests to collect firewood and construction timber, practice shifting cultivation, hunt, and gather fruits and medicinal plants (Eames & Robson, 1993; Global Environment Facility Project, 1994; Nadler et al., 2003). However, the encroachment of people and continuing heavy use of a Protected Area can seriously jeopardise the endangered species it was created to protect (Gilmour & Nguyen Van San, 1999; Nguyen Hai Hoa, 2006).

Other ecosystems are also suffering from habitat destruction; marine pollution in shipping ports, such as Haiphong which is on the edge of the UNESCO World Heritage Site of Ha Long Bay, is causing irreparable damage to the environment’s biodiversity (Global Environment Facility Project, 1994; Lask & Herold, 2004). The leakage and dumping of oil from commercial ships along with the dumping of waste from the ever increasing tourist ‘junk’ boats cruising the waters is destroying the area’s unique karst-marine ecosystem. Fishing grounds in many areas are being over-exploited, with non-sustainable practices being used such as the destructive dynamite fishing (Global Environment Facility Project, 1994). Fish of all stages in the life-cycle are being caught, allowing little protection for breeding grounds. Additionally, rising sea levels over the next 50 years due to climate change could potentially impact on 10% of Vietnam’s lowland rice growing areas, decreasing available agricultural lands (IUCN, 2007; Bruun, 2012).

Hunting and the illegal trade of wildlife is a significant risk factor for the long-term conservation of Vietnam’s biodiversity, and for some species is arguably the main obstruction to their survival (Zimmerman, 2003; Workman, 2004; Alves et al., 2010; Nijman, 2010). Despite there now being several governmental policies and international treaties in place protecting wildlife (for example The Biodiversity Action Plan, CITES), unauthorised hunting is still occurring at high rates throughout the country (Hoang Van Chieu, 2012). Some of this hunting is conducted by local people to gather meat for personal consumption, but a lot of it is for economic gain or as part of a commercial operation (Nadler et al., 2003; Workman, 2004; Nijman, 2010). As the population in Vietnam continues to increase there is increased hunting pressure on the country’s remaining wildlife (Cano & Tellería, 2013). Hunters
frequently use non-selective trapping methods, such as metal snare traps, as well as firearms which are common and widely available (Nadler et al., 2003). Vietnam is key in the Southeast Asian wildlife trade network, with animals from both Laos and Cambodia often being funnelled through the country en route to China in what is frequently a well-organised operation, although there is also business for domestic trade (Nadler et al., 2003; Zhang et al., 2008; Nijman, 2010). In 2002, at least 138 species of animal were recorded to have been illegally traded over the 600km long border between Vietnam and China (Workman, 2004). Wildlife is frequently hunted for its use in traditional medicines, used both in China and domestically (Nadler et al., 2003; Conservation International, 2004; Workman, 2004; Alves et al., 2010).

Monkeys’ brains are thought to bring intelligence, and ‘monkey balm’ is used to cure madness and fatigue. Wildlife may be bottled in alcohol to produce ‘snake wine’, or wine of another species, frequently seen in the cities of Vietnam and advertised to carry health benefits. Some wildlife are kept alive for trade as pets; a live douc langur reportedly fetches US$1500, and baby gibbons are especially popular (Eames & Robson, 1993; Nadler et al., 2003; Conservation International, 2005; Geissmann, 2007). The harvesting of bile from ‘farmed’ Asiatic Black bears (Ursus thibetanus) and Malayan sun bears (Helarctos malayanus), which both occur in Vietnam, is a prime example of illegal wildlife trade (Quyen Thi Vu, 2010). Wild bears are caught and farmed, with the bile extracted from the gall bladder for sale. In a 2010 survey 22% of people stated that they used bear bile, most commonly as a traditional medicine to treat a variety of ailments (Quyen Thi Vu, 2010). Primates remain a particularly vulnerable group, in part due to their ‘rarity’, resulting in them being seen as a valuable addition to traditional medicines (Workman, 2004; Conservation International, 2005; Geissmann, 2007; Tran Thu Hang, 2008; Alves et al., 2010; Dong Thanh Hai, 2012). Although fewer primates are now seen for sale in city markets, this is likely to be largely due to their dwindling numbers, with 22 of the 25 Vietnamese primate taxa listed as ‘near threatened’ to ‘critically endangered’ by the IUCN (Nadler et al., 2007; Nadler, 2010b). Although mammals are the most frequently targeted group, turtles are also a victim of the wildlife trade business, with reports of over 2000 hawksbill turtle (Eretmochelys imbricata) shells being traded in the 1990s (Global Environment Facility Project, 1994; Cano & Tellería, 2013).
Lack of enforcement of environmental and wildlife regulations remains a continuing issue for conservation in Vietnam (Lang, 2001; Nadler et al., 2003; Workman, 2004; Sodhi et al., 2010; Bruun, 2012; Hoang Van Chieu, 2012). Despite the government having taken many steps to implement policies protecting vulnerable areas and their species, bribery and corruption is common meaning that those breaking the laws are often not charged or penalised, and may even be allowed to continue their operations. Illegal logging is common, and rangers are often put in the awkward position of trying to police family members and friends, and a lack of protection for whistle-blowers means that crimes are often not reported (Lang, 2001; Workman, 2004; Bruun, 2012; Hoang Van Chieu, 2012). Officially a licence is required to possess a firearm, but after the war their existence was widespread and this rule is not patrolled, with weapons rarely confiscated (Nadler et al., 2003). Without adequate policing of these regulations, achieving conservation goals in Vietnam will continue to be an uphill battle, but the interrelated issues of community rights and economic hardship must be considered.

2.2 Animal conservation releases

2.3.1 Primate releases

As conservation efforts to save endangered species around the world increase, the option of releasing primates back into the wild has gained popularity. Primate rescue and rehabilitation centres, especially for apes, were often overflowing with animals, so releasing them back into the wild was frequently the only feasible option, short of euthanasia (Aveling & Mitchell, 1982; Bennett, 1992; Ware, 2001; Cheyne & Brulé, 2004; Goossens et al., 2005). Additionally the use of releases to help boost wild population numbers and give captured animals a second chance has great potential conservation benefits (Konstant & Mittermeier, 1982; Griffith et al., 1989; Nadler & Streicher, 2003; Britt et al., 2004; Vogt & Forster, 2008b; King et al., 2012). The Golden Lion Tamarin Conservation project, started in 1983, was one of the first large-scale primate release programmes (Kleiman et al., 1991; Kierulff et al., 2002; Stoinski et al., 2003; Kierulff et al., 2012). As the numbers of wild golden lion tamarins (Leontopithecus rosalia) continued to decline, a reintroduction programme, in collaboration with zoos, began to try and stabilise the species. The programme is
largely considered a success, so that a species once thought to have just 100 – 200 individuals remaining in the wild in the 1970s and classified as ‘Critically Endangered’ by the IUCN, is now reclassified as ‘Endangered’, with the population estimated at 1600 wild individuals (Kierulff *et al.*, 2012).

Many other primate release programmes have followed (for example orangutans, including the Wanariset Orangutan Reintroduction Project (*Yeager*, 1997; *Sodaro & Weber*, 2000; *Russon*, 2009); chimpanzees (*Tutin et al.*, 2001; *Goossens et al.*, 2003; *Farmer et al.*, 2006); black howler monkeys (*Horwich et al.*, 1993; *Horwich*, 1998; *Ostro et al.*, 1999)), and the reintroduction processes and monitoring systems used have continued to improve as practitioners have learned from others’ successes and failures. Detailed considerations must be given to selecting an appropriate release site, choosing suitable candidates for release, and how to monitor their progress (*Konstant & Mittermeier*, 1982; *Griffith et al.*, 1989; *Box*, 1991; *Chivers*, 1991; *Kleiman et al.*, 1991; *Schrudde*, 2009; *Guy et al.*, 2012; *King et al.*, 2012). Baker (2002) and the IUCN/SSC Reintroduction Specialist Group have developed guidelines to assist in this process for non-human primates. Initially, radio telemetry was the only method available for tracking released primates, but the advancements in Global Positioning System (GPS) techniques have allowed for complimentary systems to be utilised (American Society of Mammalogists, 1998; *Phillips et al.*, 1998; *Dominy & Duncan*, 2002; *Sprague et al.*, 2004; *Trayford & Farmer*, 2012). GPS tracking, although expensive, allows for detailed data of the animals’ movements to be recorded and has the potential for remote real-time tracking. This can be especially helpful in challenging terrain where on the ground tracking may be difficult, but dense forest canopies can affect the accuracy of GPS.

Animal releases do need careful consideration as there are a number of potential risks – disease transmission being a considerable risk with primates (*Woodford & Kock*, 1991; *McCallum & Dobson*, 1995; *Cunningham*, 1996; *Wolfe et al.*, 1998; *Homsy*, 1999; *Wallis & Lee*, 1999; *Miller*, 2007). Due to their close relation to humans, primates are very susceptible to picking up diseases off their human carers, along with the risk of acquiring diseases off other animals. In a captive environment animals are held in close quarters and the transmission of diseases is higher. The impact of transferring a novel disease to what is in most cases an already vulnerable wild population could be devastating for the species involved. The choice of release
site is another crucial step to consider, as there needs to be sufficient suitable unoccupied habitat for the released individuals to thrive (MacKinnon & MacKinnon, 1991; Sarrazin & Barbault, 1996; Ware, 2001). Often, with endangered species, the destruction of their habitat combined with hunting pressures has been a big contributing factor in their decline, so it is key that these factors have been mitigated. The released individuals must also have the skills to survive in the wild, and some practitioners recommend pre-release training and social learning to help ensure this (Box, 1991; Custance et al., 2002; Britt & Iambana, 2003; Britt et al., 2003; Stoinski et al., 2003; Cheyne & Brulé, 2004). The financial burden of release projects must be taken into account, as due to their nature they are expensive endeavours and consideration must be given to whether funds could be better spent elsewhere (Kleiman, 1989; MacKinnon & MacKinnon, 1991; Laidlaw, 2001). Additionally, active participation of the local human community in any conservation project is essential as their support and understanding, as stakeholders of the land, is crucial to these projects’ long term success (May, 1991; Baker, 2002 #135; Marshall et al., 2007).

2.3.2 Vietnamese releases

Whilst animal conservation releases have been informally conducted in Vietnam for some time, reports of them in the scientific literature are relatively rare. Local conservation groups, such as Education for Nature – Vietnam (ENV) and Wildlife at Risk (WAR), Provincial Forest Protection Department (FPD), and several rescue centres, frequently release animals directly back into the wild after confiscation, provided they are in good health (Nadler & Streicher, 2003; ENV, 2012; WAR, 2012b; T. McCormack, pers. comm. 2012). This means that the majority of releases go unreported, and are often conducted for welfare purposes, rather than as part of an organised programme aiming to contribute to the survival of the species as a whole.

In November 2000, the Turtle Conservation and Ecology Project (TCEP) conducted a large-scale release of 366 elongated tortoises (Indotestudo elongata), confiscated from traders, back into Cat Tien National Park in southern Vietnam (TCEP, 2000). Another large-scale turtle and tortoise release at Cat Tien was also conducted in 2003, involving more elongated tortoises along with 19 orange-headed temple turtles (Heosemys grandis), the animals being confiscated individuals and some hatchlings from the Turtle Conservation Center at Cuc Phuong National Park.
In December 2001, 19 critically endangered Siamese crocodiles (*Crocodylus siamensis*), sourced from a variety of captive situations including crocodile farms, were released at Cat Tien in an effort to boost numbers, after their genetic status as non-hybrids was confirmed (Fitzsimmons *et al.*, 2002). During 2002 nine pygmy lorises (*Nycticebus pygmaeus*), which had been confiscated animals housed at the Endangered Primate Rescue Center, were released into Cuc Phuong National Park and monitored both with radio telemetry and direct observation (Streicher & Nadler, 2003). WAR has conducted many welfare releases, including the primate species of pygmy slow loris (*Nycticebus pygmaeus*) and buffed-cheeked gibbons (*Nomascus gabriellae*) (WAR, 2012b; WAR, 2012a; Nguyen Khoi, pers. comm. 2012). The Carnivore and Pangolin Conservation Programme (CPCP) has recently conducted a release of Sunda pangolins (*Manis javanica*) into Cat Tien National Park, and is now considering a release of leopard cats (*Prionailurus bengalensis*) (Tran Quang Phuong, 2011a; Tran Quang Phuong, 2011b; Carnivore & Pangolin Conservation Program, 2013).

There have also been a few release programmes in Vietnam specifically focusing on langurs, starting with the release of Hatinh langur (*Trachypithecus hatinhensis*) into a semi-wild enclosure at Phong Nha-Ke Bang National Park in central Vietnam, with the long term aim of releasing these animals into the wild (Vogt & Forster, 2008b; Vogt & Forster, 2008a; Vogt *et al.*, 2008). In 2012 the Cat Ba Langur Conservation Project successfully translocated two wild *T. poliocephalus* individuals, as part of their long term goals to increase interbreeding between the fragmented groups of the critically endangered species (Cat Ba Langur Conservation Project, 2009; Schrudde, 2009; Passaro, 2012b; Passaro, 2012a). There has now been a release programme for the closely related Delacour’s langur (*T. delacouri*) at Van Long Nature Reserve, which this thesis evaluates.

There are many challenges to conducting animal releases in Vietnam, especially the lack of facilities available in the country meaning a lot of veterinary testing needs to be outsourced (Schrudde, 2009; T. McCormack, pers. comm. 2012). Additionally, foreign-run and even local environmental groups often struggle with the paperwork that needs to be done by consulting various governmental departments and boards, before release programmes can take place (Schrudde, 2009; WAR, 2012b; Nguyen Khoi, pers. comm. 2012). Funding remains a constant problem for most high-cost
conservation projects, especially when working with ‘non-priority’ species, and can compromise the level of medical checks and preparations that can be done (Nadler & Streicher, 2003; Schrudde, 2009; ENV, 2010; WAR, 2012b). The lack of set processes when one-off welfare releases are conducted can mean that animals are being released into inappropriate localities or habitats (T. McCormack, pers. comm. 2012). Cat Tien National Park has become a popular release site for almost any animal found in the southern region of Vietnam, but in some cases the animals are not suited to this environment. Trade and corruption can also impact, with reports that some animals said to have been released by the local FPD after being confiscated, are simply sold back into trade (ENV, 2010; WAR, 2012b; T. Nadler, pers. comm. 2011).

2.3 Overview of Delacour’s langur

2.3.1 Taxonomy of the limestone langurs

The ‘limestone langurs’ is a group of folivorous Southeast Asian primates, including the critically endangered Delacour’s langur (Trachypithecus delacouri). Langurs are members of the family Cercopithecidae, belonging to the subfamily Colobinae. Colobine monkeys occur across both Africa and Asia, divided into 10 genera and approximately 59 species (Groves, 2005; Blair et al., 2011; Harding, 2011). Seven of these genera are found in Asia, making up two phyletic groups - the ‘langur/leaf monkeys’ (genera Trachypithecus, Presbytis, and Semnopithecus) and the ‘odd-nosed’ monkeys (Pygathrix, Rhinopithecus, Nasalis, and Simias). Trachypithecus is the largest colobine genus, containing approximately 17 species (Groves, 2005; Harding, 2011). A sub-group within Trachypithecus, occurring east of the Mekong River and north of 17° latitude in northern Vietnam, Laos and southern China, has been informally named the ‘limestone langurs’ due to their association with karst limestone environments (Groves, 2004; Workman, 2010b). However the taxonomy of this group, also referred to as the T. francoisi group, is much debated and there is disagreement over which of the taxa within it should be considered distinct species, rather than simply subspecies or even morphs (Groves, 2004; Roos, 2004; Groves, 2007; Roos et al., 2007; Duckworth et al., 2010; Nadler, 2010b).
There is debate over whether the white-headed (*T. leucocephalus*) and the Cat Ba or golden-headed (*T. poliocephalus*) langurs should be considered two distinct species or two subspecies of a single species. Roos *et al.* (2007) argued that the genetic divergence between the taxa is not sufficient for two distinct species, and hence identified *T. poliocephalus poliocephalus* and *T. p. leucocephalus*, whilst Groves follows the phylogenetic species concept and places them as separate species (Groves, 2004; Groves, 2005; Groves, 2007). The status of the black langur (*T. ebenus*) and its relationship to the Hatinh (*T. hatinhensis*) and Laos langurs (*T. laotum*) is another area of much dispute; there has been suggestion that the Hatinh langur is a subspecies of the Laos langur, based on genetic data (Brandon-Jones *et al.*, 2004; Roos, 2004; Roos *et al.*, 2007; Blair *et al.*, 2011), while Roos (2004) and Nadler *et al.* (2003) argue that *T. ebenus* is merely an all-black melanistic morph of the Hatinh langur and not a species at all. This is based on mtDNA evidence seeming to place *T. ebenus* specimens within the range of variation of the Hatinh langur, and their anatomical and behavioural features showing strong similarities. Groves (2004; 2005; 2007), alternately, argues that since *T. ebenus* has been shown to form its own troops separate from the *T. hatinhensis*, as well as occurring in a separate region not overlapping with the range of the latter, it is a species in its own right. Groves goes on to suggest that *T. hatinhensis* may in fact be a recent hybrid of *T. laotum* x *T. ebenus* – offering an explanation for the mtDNA findings (Groves, 2004; Groves, 2007).

The least debated of the group is the Delacour’s langur (*T. delacouri*), which is generally acknowledged by all parties to be a species in its own right (Fooden, 1996; Groves, 2001; Brandon-Jones *et al.*, 2004; Blair *et al.*, 2011; Harding, 2011). The Delacour’s was first described in 1932 (Osgood), from specimens collected by the ornithologist Jean Delacour. In this thesis the taxonomy of Groves (2004; 2007), identifying seven distinct species in the limestone langur group (*T. delacouri, ebenus, francoisi, hatinhensis, laotum, leucocephalus and poliocephalus*; see Table 2.1) will be followed.
Table 2.1 A list of the seven limestone langur species and their distribution.

<table>
<thead>
<tr>
<th>Species name</th>
<th>Common name</th>
<th>Distribution</th>
<th>Population size</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Trachypithecus</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>francoisi(^{1})</td>
<td>François’s langur</td>
<td>Southern China, Northern Vietnam</td>
<td>1700-1950</td>
<td>Endangered</td>
</tr>
<tr>
<td><em>T. leucocephalus</em></td>
<td>White-headed</td>
<td>Southern China</td>
<td>&lt; 700</td>
<td>Critically</td>
</tr>
<tr>
<td></td>
<td>langur</td>
<td></td>
<td></td>
<td>Endangered</td>
</tr>
<tr>
<td><em>T. poliocephalus</em></td>
<td>Cat Ba langur</td>
<td>Cat Ba Island, Vietnam</td>
<td>60-70</td>
<td>Critically</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Endangered</td>
</tr>
<tr>
<td><em>T. delacouri</em></td>
<td>Delacour’s langur</td>
<td>Northern Vietnam</td>
<td>&lt; 200</td>
<td>Critically</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Endangered</td>
</tr>
<tr>
<td><em>T. laotum</em></td>
<td>Laos langur</td>
<td>Central Laos</td>
<td>unknown</td>
<td>Vulnerable</td>
</tr>
<tr>
<td><em>T. hatinhensis</em></td>
<td>Hatinh langur</td>
<td>Central Laos, North-Central Vietnam</td>
<td>unknown</td>
<td>Endangered</td>
</tr>
<tr>
<td><em>T. ebenus</em></td>
<td>Black langur</td>
<td>Central Laos, North-Central Vietnam</td>
<td>unknown</td>
<td>Not classified</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 (Nadler et al., 2003; Groves, 2007; Li et al., 2007; Bleisch et al., 2008a)
2 (Nadler et al., 2003; Groves, 2007; Bleisch et al., 2008c; Bleisch et al., 2008b; Chengming Huang et al., 2008)
3 (Nadler et al., 2003; Groves, 2007; Bleisch et al., 2008b; Bleisch et al., 2008d; Schneider et al., 2010)
4 (Nadler et al., 2003; Groves, 2007; Nadler et al., 2008; Workman, 2010b; Ebenau et al., 2011)
5 (Nadler et al., 2003; Groves, 2007; Timmins & Boonratana, 2008)
6 (Nadler et al., 2003; Groves, 2007; Xuan Canh et al., 2008)
7 (Nadler et al., 2003; Groves, 2007)

2.3.2 Distribution and status of limestone langurs

*T. francoisi* is the group’s northern-most distributed species, occurring throughout southern China, predominantly in Guangxi, Guizhou, and Chongqing, along with various patches northeast of the Red River in Vietnam (Nadler et al., 2003; Chengming Huang et al., 2004; Hu, 2007; Yang et al., 2007; Bleisch et al., 2008a; Zhou et al., 2012). It is the most wide-spread of the limestone langurs, but the population is highly fragmented, especially in Vietnam where land is under intense pressure for agricultural developments. Like the rest of the species in the group, their predominant habitat is karst limestone semi-tropical/rainforests (Zhou et al., 2007a; Bleisch et al., 2008a; Hu, 2011). In areas where their range overlaps with *T.
leucocephalus there is evidence of some interbreeding (Groves, 2001). Most recent available figures estimate the total population size at 1700 - 1950, mostly living in China, with just 300 individuals in Vietnam, split into at least 10 subpopulations (Nadler et al., 2003; Bleisch et al., 2008a; Li, 2009). The population continues to decrease, in part due to habitat degradation and poaching for meat and traditional medicines (Li et al., 2007). T. francoisi has a glossy black coat with a narrow tract of white hair running from the corner of its mouth to its ears forming a moustache appearance, along with a ‘mohawk’ style crest on its head, as is typical for the limestone langurs (Groves, 2001; Nadler et al., 2003).

T. leucocephalus remains in the Guangxi region of southern China, adjoining the range of T. francoisi, although its population is much depleted and highly fragmented (Groves, 2001; Li & Rogers, 2005b). The species now exclusively occurs in its refuge of fragmented limestone hills, the population having rapidly declined in recent years due to agricultural encroachment and firewood collection causing habitat degradation, as well as poaching (Li & Rogers, 2004a; Li & Rogers, 2004b; Li & Rogers, 2005b; Li & Rogers, 2005a; Li & Elizabeth Rogers, 2006; Zhou et al., 2011). The population is estimated to have declined to no more than 700 individuals, making it critically endangered (Chengming Huang et al., 2008). T. leucocephalus is distinguished by its white head, with the white colouration extending down to its shoulders and blending into a black pelage (Groves, 2001). A ‘mohawk’ style crest can have black tips, and in most specimens the tip of the tail is a white/brownish colour.

The Cat Ba langur (T. poliocephalus) is restricted to Cat Ba Island in Vietnam’s scenic limestone formations of Ha Long Bay, and is not known to have ever occurred on the mainland (Nadler et al., 2003; Schneider et al., 2010). Whilst locals report that the langur used to occur in large numbers, estimated at 2,400 – 2,700 in the 1960’s, poaching throughout 1960 - 2000 nearly eradicated the species, the numbers dropping to just 53 individuals at their lowest in 2000 (Nadler et al., 2003; Bleisch et al., 2008b; Schneider et al., 2010; Passaro, 2012a; Passaro, 2012b). Between 1970 and 1986 alone, some 500 – 800 individuals are known to have been hunted. The current population is thought to consist of 60-70 individuals in six isolated subpopulations, and is protected by the Cat Ba National Park and its rangers (Bleisch et al., 2008b; Schneider et al., 2010; Passaro, 2012b). The head of T. poliocephalus
is a golden-yellow to greyish colour, with this colouration extending down to the shoulders (Groves, 2001; Nadler et al., 2003). Additionally there is a thick grey band of hairs around the sacral region, extending to the thighs, with the rest of the pelage being predominantly black.

*T. laotum* is perhaps one of the least understood limestone langurs, but it is known to occur in both Khammouane and Bolikhamsai province in central Laos (Timmins & Boonratana, 2008; Nadler, 2009c; Duckworth et al., 2010; Steinmetz et al., 2011). Whilst there is little information on the population size, the species is described as being ‘common’ throughout the limestone habitat in these areas, although parts of the population are fragmented and hunting has caused the species to decline (Duckworth et al., 2010; Steinmetz et al., 2011). Additionally there is confusion over whether some *T. ebenus* groups are being incorrectly identified as *T. laotum*, which may affect estimated population numbers. *T. laotum* has a broad white band around the head, crossing over the forehead with white around the face (Groves, 2001). This gives the head a predominantly white appearance with the exception of a black ‘mohawk’ crest. The remainder of the body is a glossy black pelage.

*T. hatinhensis* occurs in limited parts of Khammouane and Savannakhet Provinces in central Laos along with Quang Binh and Quang Tri Province in central Vietnam, with the largest population within Phong Nha – Ke Bang National Park (Nadler et al., 2003; Nguyen Manh Ha, 2006; Xuan Canh et al., 2008; Duckworth et al., 2010). Continued hunting is a major threat to *T. hatinhensis*, for both traditional medicines and for meat, with the species occurring at low density levels despite there being a large amount of suitable habitat at Phong Nha – Ke Bang (Nadler et al., 2003; Vogt & Forster, 2008a; Haus et al., 2009). Outside of the park habitat degradation is a problem, with few remaining forested areas. Although population size for the species as a whole remains unknown, Haus et al. (2009) estimated a population of 2100 individuals in Phong Nha – Ke Bang. *T. hatinhensis* is of similar appearance to *T. francoisi* with a predominantly black pelage and a thin white strip forming a moustache appearance, but in *T. hatinhensis* the strip extends behind the ears towards the back of the head, and the form of the crest on the crown is characteristically different (Groves, 2001; Nadler et al., 2003).
*T. ebenus,* the debated limestone langur species, is thought to occur in central Laos, predominantly to the south of the *T. laotum* range in Khammouane Province (Xuan Canh *et al.*, 2008; Nadler, 2009c; Duckworth *et al.*, 2010; Steinmetz *et al.*, 2011). Additionally the population extends into Quang Binh Province in central Vietnam. Total population numbers are unknown as its uncertain taxonomic status means it is sometimes counted in with *T. hatinhensis* or *T. laotum.* *T. ebenus* is distinguished by having a completely black pelage, with no white markings (Groves, 2001).

![Figure 2.1 Approximate distribution of six of the limestone langur species, throughout China, Vietnam and Laos, as illustrated in the IUCN Red List (Bleisch *et al.*, 2008a; Bleisch *et al.*, 2008c; Bleisch *et al.*, 2008b; Bleisch *et al.*, 2008d; Nadler *et al.*, 2008; Timmins & Boonratana, 2008; Xuan Canh *et al.*, 2008). *T. ebenus* is not included as its debated species status means there is not comprehensive information available on its distribution. Image from Google Earth (Google Inc., 2012).](image)
2.3.3 Distribution and status of Delacour’s langur

Delacour’s langur was first identified as a species after its discovery by Jean Delacour and Willoughby Lowe in 1930, and was subsequently described by Osgood in 1932. The type specimen was collected from Hoi Xuan in Thanh Hoa Province, and the species was initially classified as *Pithecus delacouri*, with similarities to the Francois’ and Laos langur noted – these were also at the time considered members of the genus *Pithecus* (Osgood, 1932). Following this, the species sank back into anonymity in the science community, with the exception of four specimens from Hoa Binh Province being sent to Hanoi University during 1960 - 1965 (Nadler, 2001). In 1987 Ratajszczak made the first reported live sighting of three *T. delacouri* individuals in Cuc Phuong National Park, and suggested that their distribution may extend both north and south of the park based on local information (Ratajszczak, 1988; Nadler, 2001). This was followed by the first videotaping of four animals at Cuc Phuong made by park staff in 1989. Although debate over the classification of the species continued, it was generally acknowledged that population numbers were very low (Ratajszczak, 1988; Nisbett & Ciochon, 1993; Baird & Ha Dinh Duc, 1996; Fooden, 1996). These discoveries prompted increased awareness of the species, which led to the Frankfurt Zoological Society (FZS) conducting population surveys.

In a 1996 report for FZS, Nadler identified 10 subpopulations of the species, across the northern provinces of Hoa Binh, Ha Nam, Ninh Binh, Thanh Hoa and Nghe An using the knowledge of local hunters to identify possible localities. At the sites surveyed, the population was estimated at 121 – 186 animals, and Nadler stated that the total population likely numbered no more than 250 individuals, the only protected site being Cuc Phuong National Park (Nadler, 1996b). The populations were noted to be small and isolated, indicating that the chance of long-term survival of the species was slim. Further surveys refined what was known about the species’ distribution, and Nadler in 2001 increased the count of *T. delacouri* locations to 19 subpopulations, occurring in 49 - 53 groups, totalling 270 – 302 individuals. The distribution was spread over a limited area of about 500km² between 20° – 21° N and 105° – 106° E covering Ninh Binh, Ha Nam, Hoa Binh and Thanh Hoa provinces (Nadler, 2001; see Figure 2.2). Pu Luong and Van Long Nature Reserves were identified as containing the largest populations, but populations were also present in three other protected areas (Hoa Lu Cultural and Historical Site, Huong Son Cultural...
and Historical Site, and Ngoc Son Nature Reserve) as well as the previously identified Cuc Phuong National Park. In 2004 the estimated population size was slightly increased to 281 – 317 individuals split into 50 -57 groups across the 19 subpopulations after the discovery of further groups in Van Long Nature Reserve (Nadler, 2004a), but it was noted that the actual area occupied by all *T. delacouri* groups when combined totalled only 400 – 450km$^2$, with 60% of individuals in subpopulations of less than 20 animals. Continuing surveys showed the steady decline and eradication of subpopulations, the population in Van Long Nature Reserve being the only one identified as increasing (Nadler, 2010b). Most recent figures estimate less than 200 *T. delacouri* individuals remaining in approximately 10 isolated subpopulations (Ebenau et al., 2011), with five protected sites remaining after the eradication of populations in Ngoc Son Nature Reserve (Nadler, 2010b; Workman, 2010a; Ebenau et al., 2011; Harding, 2011). The Van Long population remains the largest, and is thought to have doubled in size in the 10 years from 2001, now containing approximately 50% of the entire population with figures prior to this study estimating 98 – 105 individuals within the reserve (Workman, 2010b; Ebenau et al., 2011; Harding, 2011).

![Figure 2.2](image_url)
Given the continued hunting pressure on *T. delacouri* and its small and fragmented population size, the species has been included in the IUCN/SSC Primate Specialist Group’s list of ‘The World’s 25 Most Endangered Primates’ since its inception in 2000, and is listed as ‘Critically Endangered’ on the IUCN Red List (Nadler *et al.*, 2008; Mittermeier *et al.*, 2012). The species is thought to have once been relatively common, based on historical records of known subpopulation extinctions and the knowledge of local communities (Nadler *et al.*, 2003), but it has been heavily hunted over the years, despite its protected status, predominantly for use of the bones, organs and tissues in Chinese traditional medicines, although the meat is also occasionally consumed (Conservation International, 2004; Nguyen Ba Thu, 2004; Mittermeier *et al.*, 2006; Alves *et al.*, 2010). Between 1990 – 1999 alone there were 316 confirmed cases of *T. delacouri* being poached (Nadler, 2001), and this constant hunting over the past century is thought to be the prime factor in bringing the species to the brink of extinction (Nadler *et al.*, 2003). The animals’ use of caves as sleeping sites also makes them particularly vulnerable as hunters can easily follow them to their sleeping sites and trap them there.

Because the population is highly fragmented, there are no longer opportunities for interbreeding between groups, and the loss of a group’s key adult male can lead to eventual eradication (Nadler *et al.*, 2003; Conservation International, 2005; Nguyen Vinh Thanh, 2009; Workman, 2010b; Mittermeier *et al.*, 2012). Additionally, genetic degradation of populations due to lack of immigration and inbreeding can be a problem (Ebenau *et al.*, 2011). The average group size of 5 –6 individuals in small populations is well below the normal level for other closely related species (20 – 30 individuals), indicating that groups are struggling to stay established (Harding, 2011). There is also limited habitat available for *T. delacouri* because of agricultural encroachment and forest degradation, and the species is now totally confined to limestone ranges (Nadler, 2004a; Nadler *et al.*, 2007; Harding, 2011).

### 2.3.4 Ecology and behaviour of Delacour’s langur

*T. delacouri* is easily distinguished from other species in its adult form by its black pelage with white ‘shorts’, extending over its rump and legs above the knees (Groves, 2001; Nadler *et al.*, 2003; Harding, 2011; see Figure 2.3). There is a whiteish-grey fluffy patch on the cheeks, which stretches into a white line curving round behind the ears. Like the other limestone langurs, *T. delacouri* has a black
‘mohawk’ style crest on its head. The tail is long and thick, with an average length of 84-86 cm and a diameter of approximately 10cm at the root, with a ‘carrot like’ tapering shape. Whilst the skin pigmentation is predominantly black, females have an un-pigmented white pubic patch. Males are typically larger, with a head and body length of 57 – 62 cm and a weight of 7.5 – 10.5kg, whilst females are 57 – 59cm in length and weigh 6.2 – 9.2kg (Nadler et al., 2003). Additionally, females can sometimes be distinguished by the slightly yellowish appearance to their white shorts, which is caused by sweat and common in breeding females. Young are born with a bright orange coat with lightly pigmented skin, as is typical for limestone langurs (Nadler et al., 2003; Workman, 2010b). The coat slowly darkens and their skin becomes black, the coat being completely black at approximately four months of age. By nine months, dark grey ‘shorts’ have formed and the head is light brown, and the shorts progress to fully white by about three years of age.

![Image](image.jpg)

**Figure 2.3** A wild group of *T. delacouri* at Van Long Nature Reserve, including a young orange-coloured infant

*T. delacouri* has a diploid chromosome number of 44, and has been shown to be a genetically distinct species, with evidence of low genetic diversity in some populations (Roos et al., 2007; Ebenau et al., 2011; Harding, 2011). Like the rest of the *Trachypithecus* genus, *T. delacouri* has three stomach chambers, and may use its enlarged colic chamber as a secondary fermentation chamber (Caton, 1999). Being a
T. delacouri depends on a high mastication rate to process their food, which is typically very tough (Wright et al., 2008; Workman & Le Van Dung, 2009). Reproductively, males reach sexual maturity at about five years of age and females four years (Nadler et al., 2003). Based on other limestone langurs, the gestation period is estimated at 170 – 200 days, with an oestrous cycle of 24 ± 4 days and an interbirth interval of 17 – 25 months (Nadler et al., 2003). Typically just one precocial young is born at a time, with their eyes open and the ability to cling and nurse from their mother. Although the species’ lifespan is uncertain, based on captive animals it is estimated to be at least 20 years for males, and 19 years for female (Harding, 2011).

T. delacouri live in limestone karst forests, although it may well be that they reside in such areas due to lack of other available habitat through deforestation and degradation, rather than a specific preference for karst environments (Workman, 2010b). Groups have been recorded reaching a maximum elevation of 174m asl (Workman, 2010b). If available, groups will use caves for shelter and to sleep in, typically utilising three to five caves in their home range (Nadler, 1996b; Nadler et al., 2007). Caves may serve a purpose in helping the animals regulate their temperature as well as offer some protection from natural predators. Previous research has found an estimated home range size of 36 – 46ha at Van Long Nature Reserve, with an average daily path length of 66 – 792m (Nguyen Vinh Thanh & Le Vu Khoi, 2006; Nguyen Vinh Thanh, 2008a; Nguyen Vinh Thanh & Le Vu Khoi, 2008a). Workman (2010b) estimated a daily path length of 476m in the same area. Research on feeding ecology indicates that the species is highly folivorous with 78% of its annual diet being leaves (Workman, 2008; Workman & Le Van Dung, 2008; Wright et al., 2008; Workman & Le Van Dung, 2009; Workman, 2010a; Workman, 2010b). Young leaves were the preferred food when available, with deciduous trees also playing an important role. T. delacouri was found to consume 42 out of the 145 species occurring within their habitat, but just 16 species made up 93% of their diet. Water is consumed from natural catchment pools in the limestone or from streams and wetlands. In captivity, T. delacouri obtains 60% of its water needs through leaves and 40% by actively drinking (Kullik, 2010).
*T. delacouri* typically occurs in single male-multi female groups with a dominant adult male leader, although there can also be multi male-multi female groups, all-male bands and solitary males travelling alone (Nadler *et al.*, 2007; Nguyen Vinh Thanh & Le Vu Khoi, 2008b; Workman, 2010b). Historic reports indicate that group sizes of 20 – 30 individuals used to occur, but more recently groups have been reported to number 5 - 7 individuals, or up to 16 individuals in Van Long.

When looking at locomotion in captivity, greater than 90% of *T. delacouri*’s behaviours were quadrupedal walking, running, and bounding on tops of arboreal supports, with little suspensory locomotion recorded (Byron & Covert, 2004). The young are more active than their adult counterparts, and are much more likely to use suspensory locomotion (Workman & Covert, 2005). In the wild *T. delacouri* was predominantly quadrupedal (up 66% of locomotion episodes), with leaping accounting for just 6% (Workman & Schmitt, 2012). Whilst the groups move across both trees and rocks, nearly 80% of postural and locomotor behaviours occurred on a rocky substrate, but with leaping more common in trees. Sitting is by far the most dominant postural position, making up 95% of all records. In relation to tail posture, *T. delacouri* often arches its tail in a high concave downwards position, and may use sweeping tail motions as it moves to assist with balance (Stevens *et al.*, 2008). Intragroup aggression is often observed, along with cooperative activities such as grooming (Nguyen Vinh Thanh & Le Vu Khoi, 2008b; Workman, 2010b). Dominant males are often seen to act as sentries and will defend territories in intergroup encounters, frequently using ‘bounding displays’ accompanied by a ‘hoot’ sound during conflicts (Workman, 2010b). Stunkel (2003) also identified a ‘loud call’, similar to that of related species, for *T. delacouri*. When considering the activity budget of wild individuals, resting dominates their behaviours making up 61% of the time, with feeding accounting for 29%, socialising 6% and travelling 4%. Nearly all work on the species’ behaviour has been conducted at Van Long Nature Reserve or in captivity at the Endangered Primate Rescue Center.
Vân Long Nature Reserve, looking down between Dong Quyen (right) and Meo Cao (left) outcrops towards Ba Chon mountain, with Hang Tranh outcrop in front
CHAPTER 3

Methods and Study Sites

This chapter provides a summary of the methods and study sites used for data collection throughout this study. Individual chapters detail the analysis undertaken, as well as giving a short review of the relevant methodology.

3.1 Study populations

3.1.1 Endangered Primate Rescue Center study population

The captive study population was housed at the Endangered Primate Rescue Center (EPRC) in Cúc Phượng National Park, Vietnam. ‘Captive’ individuals in this study were defined as animals kept in a caged environment where food was provided. All *T. delacouri* individuals in the study were born into captivity at the EPRC.

To assist data collection, a classification system was needed to accurately assign each individual an age and sex category (see Table 3.1). The classifications were based on an existing framework developed by previous researchers (Nadler et al., 2003; Workman, 2010b), along with amendments based on my own observations of animals at the EPRC and in the wild.

Delacour’s infants are easily identified at a distance, as they are born with a natal coat of bright orange colouration, like most other *Trachypithecus* species (Rowe, 1996; Baker et al., 2000; Nadler et al., 2003). As the infant ages the coat blackens, the white ‘shorts’ begin to form and the tail fur thickens. Relative size determines the difference between subadults and adults. Identifying an individual’s sex at distance can be challenging, but close inspection using, binoculars when required, reveals the presence of a white pubic patch and prominent nipples in females or a pink penis surrounded by tufts of white fur in males.
Table 3.1 Age/Sex classification descriptions for *T. delacouri*, with approximate age in months. For captive juveniles the sex could be determined by close-up inspection of the genitalia, so classifications were recorded as ‘JF’ or ‘JM’. If sex was uncertain for any age class it was marked with a ‘?’.  

<table>
<thead>
<tr>
<th>Classification</th>
<th>Age (Months)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>IO</em> Orange Infant</td>
<td>0 - 4</td>
<td>Coat completely bright orange to dark orange</td>
</tr>
<tr>
<td><em>IB</em> Black Infant</td>
<td>4 - 9</td>
<td>Coat blackened all over; tail thickening, ‘mohawk’ forming</td>
</tr>
<tr>
<td><em>J</em> Juvenile</td>
<td>9 – 36</td>
<td>Coat black; ‘shorts’ forming in dark grey, becoming white; head light brown - black; tassel on tail</td>
</tr>
<tr>
<td><em>SA</em> Subadult Female</td>
<td>36 - 48</td>
<td>White pubic patch visible; ‘shorts’ white; tail has ‘carrot-like’ shape with larger diameter at root</td>
</tr>
<tr>
<td><em>AM</em> Adult Male</td>
<td>60 +</td>
<td>Full growth reached (8.5kg) i.e. larger than SAM</td>
</tr>
</tbody>
</table>

For captive *T. delacouri*, three caged family groups were used as the study population (see Table 3.2). Cage 2B consisted of an adult male and female pair and their subadult son, Cage 3B of an adult male and his adult and subadult sons, and Cage 6B of an adult male and female pair, their juvenile female daughter and a newborn male infant. There were three other caged adult males at the EPRC, but they were excluded from the study population as they were housed individually and so would not have been representative of natural behaviour in a group setting. In addition, there was a family group of five individuals (adult male and female pair and their offspring – adult female, subadult male and juvenile female) housed in the 2ha semi-wild area within the EPRC. Initial sampling was conducted on this group, but visibility in the enclosure was challenging because of the dense foliage and the fact that the enclosure could not be entered due to the territorial aggressiveness of the males. This meant that the animals were only spotted when perched in tree-tops, meaning that any sampling opportunities were severely limited. Therefore data collected from the semi-wild enclosure was discarded before analysis, as there was not enough data to form a distinct sample group.
In the vocalisation investigation, the captive study population was expanded to include the five other limestone langur species kept at the EPRC (T. hatinhensis, T. francoisi, T. poliocephalus, T. laotum, and T. ebenus) to give the opportunity to compare and contrast vocalisation differences between species (see Table 3.2).

**Table 3.2** Composition of the captive *T. delacouri* study population housed at the EPRC, along with the other captive EPRC limestone langur species surveyed for the vocalisation study. The individual’s EPRC identification code and sex/age class is given. AM = adult male, AF = adult female, SAM = subadult male, SAF = subadult female, JM = juvenile male, JF = juvenile female, IB = infant black, IO = infant orange.

<table>
<thead>
<tr>
<th>Species</th>
<th>Cage</th>
<th>Individuals</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>T. delacouri</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cage 2B</td>
<td>1-10 AM</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1-09 AF</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1-20 SAM</td>
</tr>
<tr>
<td></td>
<td>Cage 3B</td>
<td>1-04 AM</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1-16 AM</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1-18 SAM</td>
</tr>
<tr>
<td></td>
<td>Cage 6B</td>
<td>1-07 AM</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1-13 AF</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1-21 JF</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1-25 IOM</td>
</tr>
<tr>
<td><em>T. ebenus</em></td>
<td>Cage 5B</td>
<td>14-01 AM</td>
</tr>
<tr>
<td><em>T. francoisi</em></td>
<td>Cage 18B</td>
<td>17-02 AM</td>
</tr>
<tr>
<td></td>
<td></td>
<td>17-01 AF</td>
</tr>
<tr>
<td></td>
<td></td>
<td>17-05 IOM</td>
</tr>
<tr>
<td><em>T. hatinhensis</em></td>
<td>Cage 1A</td>
<td>2-01 AM</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2-09 AF</td>
</tr>
<tr>
<td></td>
<td>Cage 5B</td>
<td>2-14 AF</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2-57 SAM</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2-64 JM</td>
</tr>
<tr>
<td></td>
<td>Cage 6A</td>
<td>2-11 AF</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2-17 AF</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2-20 AF</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2-53 AF</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2-54 SAM</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2-58 SAF</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2-63 JF</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2-68 IBM</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2-73 IOM</td>
</tr>
<tr>
<td></td>
<td>Cage 19</td>
<td>2-13 AM</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2-36 AF</td>
</tr>
<tr>
<td><em>T. laotum</em></td>
<td>Cage 23</td>
<td>3-01 AM</td>
</tr>
<tr>
<td><em>T. poliocephalus</em></td>
<td>Cage 1B</td>
<td>15-04 AM</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15-01 AF</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15-06 JM</td>
</tr>
</tbody>
</table>
3.1.2 Vân Long Nature Reserve study population

All studies on wild individuals – defined as animals that are wild-born and free ranging in a natural environment - were carried out at Dong Quyen outcrop within Van Long Nature Reserve, Vietnam. Five different groups were identified and numbered from west to east along the cliff face (Groups 1 – 4), with an additional ‘Group 0’ added during the study when they were seen on the extreme western end of the study area (see Table 3.3 and Figure 3.1). The sex/age class composition of each group was recorded throughout the study whenever possible giving an estimated total group size, with some groups increasing in number due to births during the study. Furthermore, some individuals were re-classified to a new sex/age class as they aged. In total approximately 60 individuals were monitored along the south-western edge of Dong Quyen, and it is likely further groups of T. delacouri exist in other areas of this outcrop.

Table 3.3 Group composition of the study population on Dong Quyen outcrop at Van Long Nature Reserve. Composition of the sex/age class of each group member is given when known, with AM = adult male, AF = adult female, SAM = subadult male, SAF = subadult female, SA? = a subadult of unknown sex, J = juvenile, IB = infant black, IO = infant orange. When two sex/age classes are given this indicates that the individuals’ status changed during the study i.e. IO/IB means an ‘infant orange’ moving to an ‘infant black’ status.

<table>
<thead>
<tr>
<th>Sex/Age Class</th>
<th>G0</th>
<th>G1</th>
<th>G2</th>
<th>G3</th>
<th>G4</th>
</tr>
</thead>
<tbody>
<tr>
<td>AM</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>AF</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>SAM</td>
<td>-</td>
<td>1</td>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>SAF</td>
<td>-</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>SA?</td>
<td>-</td>
<td>-</td>
<td>2</td>
<td>-</td>
<td>3</td>
</tr>
<tr>
<td>J</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>IB/J</td>
<td>-</td>
<td>-</td>
<td>3</td>
<td>2</td>
<td>-</td>
</tr>
<tr>
<td>IB</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>IO/IB</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>IO</td>
<td>-</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>3</td>
</tr>
<tr>
<td>Unknown</td>
<td>8</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>13+</td>
<td>10-12+</td>
<td>14+</td>
<td>7+</td>
<td>14+</td>
</tr>
</tbody>
</table>
Figure 3.1 The five wild groups (G0 – G4) identified for this study on Dong Quyen outcrop, in Van Long Nature Reserve. Points represent recorded locations of the groups noted during observations, calculated from my own GPS position and the bearing and approximate distance to the group. Note there is some overlap along the edges of the home ranges of neighbouring groups. Due to the topography of the area, groups were only visible along the edge of the cliff face.

3.1.3 Released study population

A study population of released individuals was also used - defined as captive bred animals housed at the EPRC and released into a free-ranging wild environment at Van Long Nature Reserve. The released population consisted of a family group of three individuals previously housed as a captive group in Cage 2B at the EPRC (refer back to Table 3.2). The general term of ‘released’ (as opposed to ‘reintroduced’), has been used in this study to avoid confusion as at the time it was undertaken it was unclear whether or not the EPRCs project could be termed a strict ‘reintroduction’ according to the definition provided in the IUCN/SSC Re-introduction Specialist Group’s Guidelines for Non-human Primate Reintroductions (Baker, 2002). This matter will be discussed further in Chapter 7.
3.2 Study sites: Cúc Phượng National Park and the Endangered Primate Rescue Center

The EPRC, situated at Cúc Phượng National Park was one of two study sites used in this research.

3.2.1 Cúc Phượng National Park

Cúc Phượng National Park was the first national park in Vietnam, established by President Ho Chi Minh in the midst of the Vietnam-American war in 1962 (Hoang Hoe, 2001; ICEM, 2003; Do Van Lap, 2004; Rugendyke & Nguyen Thi Son, 2005; Sterling et al., 2006; Ray et al., 2009; Cuc Phuong Tourism, 2011). Located predominantly within Ninh Binh Province, the park is 120km southwest of Hanoi and covers 22,200ha of primary tropical rainforest in a limestone karst landscape. The park is rich in flora and fauna, including several endemic species, and is well known for bird watching and has been home to several rare mammal species, including *Trachypithecus delacouri*, but many species are now less common as a result of continued poaching and habitat destruction. Within the park there are three animal rescue centres – the Turtle Conservation Center, the Carnivore and Pangolin Conservation Program and the Endangered Primate Rescue Center.

Tourism numbers in the National Park have increased steadily since records began in 1994, with its proximity to Hanoi making it popular with Vietnamese as a weekend destination or for school trips, and approximately 70,000 Vietnamese now visit every year (see Figure 3.2, data provided by the Tourist Office at Cuc Phuong National Park Headquarters). Vietnamese tourists far outnumber international visitors, with only 15% of tourists in 2011 being from outside the country. Although international tourist numbers are increasing, likely due to the park now being mentioned in several guide books and Hanoi tourism agencies promoting trips to Cuc Phuong. Tourism numbers peak in February to May when weather is typically mild and dry (see Figure 3.3).
Figure 3.2  Number of tourists entering Cuc Phuong National Park (1994 – 2011). Data courtesy of Cuc Phuong National Park Headquarters.

Figure 3.3  The number of tourists per month that visited Cuc Phuong National Park in 2011. Data courtesy of Cuc Phuong National Park Headquarters.

### 3.2.2 Endangered Primate Rescue Center

The Endangered Primate Rescue Center (EPRC) was established in 1993 as part of a memorandum, supported by the Vietnamese Ministry of Forestry, the IUCN Primate Specialist Group and various NGO’s, for the purpose of rescuing rare
primates and establishing a captive breeding programme (Nadler, 1996a; Nguyen Ba Thu, 1996). The not-for-profit organisation, financed by the Frankfurt Zoological Society, began with the confiscation of two Delacour’s langurs in January 1993 in poor condition, requiring a facility to house them as they were not fit for re-release (Nadler, 1996a; Dang Huy Huynh, 2004). The National Park organised the construction of a cage to house the animals, and two months later a confiscated Hatinh langur was added to the newly formed EPRC. Staff, both Vietnamese and experienced foreign zoo keepers, joined the EPRC as the complex and the number of animals it housed began to grow. By 1996 two cage complexes, along with associated management and treatment buildings, had been constructed in a permanent site designated by the National Park director, with the EPRC housing over 30 individuals from 10 species.

The Center continued to grow and the site expanded further to cover 3.5ha plot within Cuc Phuong National Park (Nadler, 1999; Nadler, 2000). As of 2012, the Center comprised of over 50 cages and two semi-wild areas of 2ha and 5ha (Nadler, 2007). Cages are typically 10 x 5 x 3.5m with a concrete floor and wire mesh fencing on all sides, and bamboo vertical and horizontal poles forming a climbing frame along with a few natural branches. A shelter is provided using plastic panels in one corner of the cage with a small sleeping box provided over winter, or a separate indoor winter house for some species from warmer climates. The cages are all adjoined to another cage, with smaller holding cages in-between, where the animals are moved when a keeper is cleaning the main cage. The animals were fed three times a day, at approximately 06:30h, 11:00h and 15:00h, along with an additional sweet potato feed at 09:00h. Feedings consisted of several bundles of leaves tied to the cage walls, freshly cut from a variety of species around the Cuc Phuong area. The EPRC also contains a quarantine station including a surgery clinic and a station house with administration and preparations areas.

As of the last published report (Nadler, 2012b; information dated December 2011) the Center housed 149 primates including 121 langurs, 18 gibbons, and 10 lorises cared for by approximately 20 staff under a foreign head zoo keeper. Since the facility began, 236 primates have been confiscated or handed over to the EPRC, and 150 individuals have been born, contributing to the ever increasing numbers being housed (Nadler, 2007; Nadler, 2008; Nadler, 2009b; Nadler, 2010a; Nadler, 2011).
The Center holds 16 primate species, including seven species kept nowhere else in the world (T. delacouri, T. hatinhensis, T. ebenus, T. laotum, T. policephalus, Pygathrix cinerea, Nomascus annamensis). At the end of 2011, there were 16 T. delacouri, the Center’s ‘flagship species’, housed at the EPRC (Nadler, 2012b).

Although the EPRC was initially set up to care for rescued primates and develop captive breeding programmes for these rare species, the scope of the Center has grown over time (Nadler, 2007; Nadler, 2011; Frankfurt Zoological Society, 2012). As part of Frankfurt Zoological Society’s ‘Vietnam Primate Conservation Program’, of which EPRC director Tilo Nadler is a leader, the Center has expanded in to research and community training. Various research projects have been conducted at the EPRC as it presents a unique opportunity to observe rare species close-up as well as providing opportunities for genetic and taxonomic studies. The arrival of an unusually coloured douc langur at the EPRC in August 1995 led to the description of a new species, the grey-shanked douc langur (Pygathrix cinerea) (Nadler, 1997). The EPRC has also been involved in conservation projects throughout Vietnam such as primate range and population surveys, establishment of new protected areas and release programmes such as with the Hatinh langur in Phong Nha-Ke Bang National Park. The protection of the primates’ natural habitats is an integral part of the Center’s work, which involves lobbying provincial Forest Protection Departments to protect key areas of remaining forest (Nadler, 2012a). Additionally, the EPRC has organised various symposia and educational training programmes, assisted with forest ranger training, and promoted community wildlife awareness (Nadler, 2012a).

The Center is predominantly funded through the Frankfurt Zoological Society but also receives funding from zoological gardens and societies, private donations and on-site souvenir sales (Nadler, 2004b; Nadler, 2007; Nadler, 2011). Funding is also obtained through various external conservation grants which are awarded to support specific projects.

3.2.3 Site selection rationale

The EPRC was used as the site for all captive experiments in this study, as it is the only place where T. delacouri can be found outside of the wild. Being able to observe the species in this captive environment allowed for investigation of elements of their behaviour which would not have been visible in a wild setting. Additionally,
the animals that were used in the release to Van Long Nature Reserve were housed at the EPRC prior its commencement (see Figure 3.4).

![Figure 3.4](image_url)

**Figure 3.4** Map of Vietnam (left) showing in red the location of Ninh Binh Province, with province boundaries marked in white in the zoomed in right hand map. The boundaries for Van Long Nature Reserve and Cuc Phuong National Park are shown in red and the location of the EPRC marked in yellow. Image from ArcMap10 (ESRI, 2010).

### 3.3 Study sites: Vân Long Nature Reserve

Van Long Nature Reserve was the second site used in this study, also located in Ninh Binh Province, approximately 90km from Hanoi (refer back to Figure 3.4).

#### 3.3.1 Overview of Vân Long

The Van Long wetland, located in Gia Vien district, has long been considered an important ecosystem dating back to its use by the Le Dynasty in the 10th century which operated from nearby Hoa Lu, the ancient capital (Nguyen Dao, 2008). The name Van Long means “Dragon flying in clouds” and alludes to the area’s many karst outcrops often shrouded in mist.

The Van Long Nature Reserve (20.39°N, 105.87°E), of approximately 3000ha, was gazetted, with a surrounding buffer zone, by the Ninh Binh Provincial People’s Committee in December 2001 (Nguyen Ngoc Quynh, 2001; Nguyen Ngoc Quang et al., 2004; Pu Luong – Cuc Phuong Limestone Landscape Conservation Project, 2004; Do Van Cac, 2010; Workman, 2010b). Prior to this the area had been managed through the Provincial Authority programmes in the 1990’s where the local communities were contracted to protect specific areas of forest for an annual
payment. The discovery of a breeding population of *T. delacouri* in the area in 1993 greatly increased research interest by external groups. Frankfurt Zoological Society, along with the EPRC, became involved, and aided by the community leaders worked to formalise management arrangements of the area to protect the langurs and their habitat. Pressure was put on the Provincial Authorities to form a recognised protected area, and surveys were conducted in 2000-2001 to show the diversity and importance of the region. This eventually resulted in the formation of an official Nature Reserve.

The reserve is governed through the Ninh Binh Forest Protection Department, which instigated the Van Long Management Board to oversee the day to day supervision (Nguyen Dao, 2008; Do Van Cac, 2010). The Management Board headquarters, located in Gia Van commune on the edge of the reserve, works with the seven communes surrounding Van Long to draw up yearly management plans. The board contracts local individuals to work as rangers patrolling the reserve and assisting management projects. Additionally, Frankfurt Zoological Society supports the employment of approximately 27 forest guards across ten different stations within the reserve (Nguyen Dao, 2008; Nadler, 2010b). They also assist with staff training, equipment, conservation advice and continued research on the ecosystem. Financial support from the provincial government only covers the most basic of costs, therefore support from external funders is crucial in ensuring Van Long’s success.

### 3.3.2 Vân Long ecosystem

Van Long can be separated into two main sections divided by a road running south to north through the middle of the reserve (see Figure 3.5). The eastern section is a fresh-water wetland area at approximately sea level with karst limestone outcrops rising from the water (Nguyen Ngoc Quang *et al.*, 2004; Workman, 2010a; Ebenau *et al.*, 2011). The largest outcrop is Dong Quyen, which comprises 265ha with a highest peak of 328m, and is surrounded by water or cleared marsh pasture on all sides (Workman, 2010b). Hang Tranh outcrop is connected to Dong Quyen by a thin (80m wide) grass dam when water levels are low, and is bordered by the road on its western side (Ebenau *et al.*, 2011). Meo Cao is surrounded by water except at its northern tip where it is connected by marsh pasture to the central dividing road, depending on water levels. The western section of the reserve is part of a large
limestone and arenaceous mountain range that extends in to Hoa Binh Province on the north-west boundary. The terrain is extremely rugged with sharp jagged rocks spread over several valleys, cliffs and peaks including Ba Chon, the highest in the reserve at 428m (Nguyen Ngoc Quynh, 2001). Geologically the area sits upon the Middle Triassic Dong Giao limestone formation, with karst created reflecting the area’s thick limestone strata and general environmental conditions (Gillieson, 2005).

Figure 3.5 Van Long Nature Reserve (approximate boundary in red), showing the Management Board Headquarters (yellow star) and the three large karst outcrops in the eastern wetland portion of the reserve – DQ = Dong Quyen, HT = Hang Tranh, MC = Meo Cao. The mountainous western portion is separated by a road running through the middle of the reserve, with Ba Chon (BC) mountain marked. Image from Google Earth, 2012 (Google Inc., 2012).

The reserve, due to its situation in northern Vietnam, is on the boundary of tropical and subtropical/temperate ecosystems, and this is reflected in the diversity of flora and fauna (Nisbett & Ciochon, 1993; Sterling et al., 2006; Workman, 2010a).
The vegetation within Van Long consists predominantly of dense limestone forest, mainly evergreen but with some deciduous flora. Dong Quyen is largely covered by woody trees and lianas (Workman, 2010b). Large parts of the forest have also suffered from over-exploitation and now consist of low-growing scrub, with some small open grasslands also occurring in the western area (Pu Luong – Cuc Phuong Limestone Landscape Conservation Project, 2004). Orchids typical of Vietnam’s limestone forests are diverse, and at least three species occur within the reserve (Sterling et al., 2006; Workman, 2010b). Twelve vascular plant species occurring at Van Long are listed in the Red Data Book of Threatened Species in Vietnam (Nguyen Dao, 2008). There is also a wide range of aquatic flora in the reserve’s nearly 1000ha of wetland, including several algal species (Do Van Cac, 2010).

There are 39 recorded mammal species in Van Long, 13 of which are listed in the Vietnam Red Data Book of threatened species (Nguyen Dao, 2008) - although it is likely that most of the larger mammals once thought to occur in the area are now locally extinct (for example Clouded Leopard Neofelis nebulosa, Asiatic Black Bear Ursus thibetanus) (Pu Luong – Cuc Phuong Limestone Landscape Conservation Project, 2004; Do Van Cac, 2010) (T. Nadler, pers. comm 2011.). In regard to primates, the northern slow loris (Nycticebus bengalensis) and Assamese macaque (Macaca assamensis) still occur at Van Long, along with T. delacouri (Pu Luong – Cuc Phuong Limestone Landscape Conservation Project, 2004; Workman, 2010b). Macaques are occasionally spotted on the Meo Cao outcrop, and also occur in the western region. Most recent figures prior to this study estimate Delacour’s langurs to number 98-105 individuals in total within the reserve, with approximately 68-70 on Dong Quyen, 10-15 on Hang Tranh, and some 20-28 in the western region (Workman, 2010b; Ebenau et al., 2011; Nadler, 2012c; Nadler et al., 2012; refer back to Figure 3.5). The reserve is also a significant area for bird watching, from birds of prey species such as Bonelli’s eagle (Aquila fasciatus) to a variety of migratory wading birds such as egrets. Aquatic fauna are abundant including frogs, turtles, freshwater fish and a wide range of invertebrates such as crabs and snails (Do Van Cac, 2010). There are 14 species of snake in the area, including the highly venomous king cobra (Ophiophagus hannah). In total 54 species of fish, 32 species of reptiles and 72 species of birds are currently recorded within the reserve (Nguyen Dao, 2008).
3.3.3 The community, tourism and infrastructure

The community around Van Long comprises approximately 45,000 people of Kinh ethnicity (the majority in Vietnam), split among the seven communes (Nguyen Dao, 2008; Do Van Cac, 2010). The people are traditionally an agricultural community relying on rice cultivation, cattle grazing and farming of ducks and fish. The wetland has been used for collecting small aquatic animals such as crabs and snails, as well as harvesting edible vegetation (Workman, 2010b). Additionally the forest has been used for sourcing wood, collecting medicinal plants, grazing of animals and occasionally for hunting. Local communities have created a system of dykes with dam gates to control water flow in the wetland areas, both within and outside the reserve boundaries. Changing water levels are important in the rice cultivation system, and also helps prevent flooding of villages (Nguyen Dao, 2008; Do Van Cac, 2010).

After the discovery of T. delacouri in the area, tourism began to develop, bringing a new potential source of income to the region in the late 1990’s (Nguyen Dao, 2008; Do Van Cac, 2010; Workman, 2010b). With the establishment of a formal reserve in 2001, eco-tourism operators in Hanoi began to advertise Van Long as a potential destination. As the scale of tourism started to expand, Ninh Binh Tourism Department was appointed to manage activities at Van Long, with the input of the Reserve Management Board. In 1998 there were approximately 500 visitors to the reserve, growing to around 50,000 a year in 2008-2010 (Nguyen Dao, 2008; Mr Quang, Ninh Binh Tourism Department, pers. comm. 2011). Approximately 70% of these tourists are international, the majority being bus tours from China, Korea and Japan. Tourists typically take trips in traditional wooden boats across the wetland from a pier opposite the headquarters, hoping to spot langurs or other wildlife (see Figure 3.6). There is a small craft market and a large hotel complex with a restaurant just meters from the pier. There is another tourism restaurant on the corner of the main road which offers bicycle and water buffalo tours popular with international tourists. In 2011 a new large five star resort complex opened just 1km from the main pier, marketing itself to wealthy Vietnamese and diplomats from Hanoi. Many local people are employed as staff in these restaurants/resorts or as tourism operators, such as boat punters, providing additional income opportunities. Other locals have cashed in on the infrastructure that comes with these developments through the new trade
services and stores which they require. Some locals have benefited from rising land prices by selling their plots to developers and moving to work full-time in the tourism industry.

Another major infrastructure in the Van Long area is the cement factory and associated limestone quarries (Nguyen Dao, 2008; Nguyen Vinh Thanh & Le Vu Khoi, 2008a; Workman, 2010b; see Figure 3.7). As development in Vietnam increases, so does the need for cement, and several cement factories have been built in Ninh Binh Province to take advantage of the area’s abundant karst limestone ranges. There is a large quarry on the north east boundary of the reserve and the frequent dynamite blasting is thought to have caused *T. delacouri* groups to move away from this face of the Dong Quyen range (visible on Figure 3.5 as a white area). Along with noise, the factory also creates a considerable amount of smoke and dust that can affect visibility in the area on some days.
Although the local community is very supportive of the reserve, there are some conflicts brought about by its existence and the associated tourism (Nguyen Dao, 2008). Of the money collected through boat trip ticket sales, approximately 85% goes directly to the Provincial Authorities and not back into the conservation of Van Long or community development. Additionally, the vast majority of tourism occurs just within the Gia Van commune, meaning other communes are missing out on any income associated with the reserve despite contributing to measures to protect it. There are also on-going issues with some families continuing to rely on the forests for timber and firewood, against reserve legislation, and illegal grazing of goats and cattle within the reserve (Workman, 2010b). Increasing tourism at the reserve is also a concern as the increase of people causes associated pollution and risk to wildlife (Nguyen Ngoc Quynh, 2001; Pu Luong – Cuc Phuong Limestone Landscape Conservation Project, 2004).

3.3.4 Site selection rationale

Dong Quyen outcrop in Van Long Nature Reserve was selected as the site for observing wild *T. delacouri* as it contains the largest remaining population of the species in the world, with approximately 30% of the total population. Additionally, Dong Quyen is the only site where the langurs are seen on a somewhat regular basis,
providing the best chance for observation and data collection. The position of Dong Quyen within the wetland allows for easy viewing access along the cliffs of the south-west side of the outcrop by a flat-bottomed boat. Previous researchers (Workman, 2010b) have found that the langurs will flee if observers attempt to climb on to the outcrop, so viewing from a boat on the water-bounded side is the most feasible option. The EPRC chose western Van Long as their site for the *T. delacouri* release project, so all surveillance work as part of reviewing this release took place in the western portion of the reserve.

### 3.4 Climate and weather

The climate of Vietnam is considerably varied, due in part to the country spanning a wide range of environments from approximately 8°N to 23°N in latitude (Chuan, 2005; Sterling *et al.*, 2006; Ray *et al.*, 2009; Workman, 2010b). Northern Vietnam is characterised by a cold, relatively dry winter from about November to April, and a hot wet summer from May to October. The comparatively cold winters are caused by monsoon winds bringing cold air from the Tibetan Plateau. As the climate transitions into warmer weather, low mist and drizzle are typical as humidity levels increase. A switch in winds brings warm and wet south-western monsoon flows from the Gulf of Thailand and the Indian Ocean leading to the hot and wet summer where typhoons are common.

#### 3.4.1 Weather in Vân Long

Due to the limited amount of weather data collected at Van Long to date, a Wireless Pro WS2083 weather station was erected at the Reserve headquarters to collect further information. The station collected data during 2011-12 on temperature, humidity, rainfall and wind at half hourly intervals, transmitting wirelessly to a base station inside the building. The sensor on the station broke one month after the start of records, so that data for the year are incomplete as a new part from New Zealand was awaited. Additionally the station was not set up until fieldwork first began in Van Long in February, meaning that January data are also missing. Field assistant Nguyen Hong Chung continued to collect data until October 2012, and these data were added to help fill in the gaps caused by malfunctions of the weather station, so creating a complete picture of the area’s yearly weather patterns.
Daytime temperatures averaged 28.5°C for the summer months of May-October in 2011, although temperatures occasionally reached over 40°C. For the cool season of November – April (2011-2012 data used for completeness), the average was 19.8°C with a minimum temperature of 7.2°C in late December (see Figure 3.8). A combination of wind chill and high humidity at Van Long often makes the ‘real-feel’ of winter much colder. Over winter, thick high cloud blankets the sky continuously for weeks on end, whilst clear skies are customary in summer. Average humidity levels were relatively stable across the year at around 80% (see Figure 3.8). These high levels of humidity contribute to the frequent morning fog that occurs in the area, which would often thickly cover the reserve from ground level. For 2011, rainfall peaked in July with 378mm recorded, and remained above 240mm a month through till September (see Figure 3.8). Thunder and lightning storms were common, with a typhoon occurring during the summer bringing extreme winds and rain (during which the weather station was brought indoors for protection). Parts of Van Long are very exposed, with the flat topography of the surrounding rice paddies providing little shelter, meaning that high winds were common. The highest wind gust was recorded in December at 151kmh⁻¹, but across the year there did not appear to be a seasonal pattern, the average highest wind speed being 35kmh⁻¹.

Weather data may be lacking in accuracy to some degree due to limitations on where the station could be placed for practical reasons, meaning it was not ideally situated for all data classes (Mayes, 2003), along with occasional interference with the station by curious locals. Additionally, the weather station’s recording function appeared to be occasionally malfunctioning during 2012, after my departure from Vietnam, suggesting the possibility of some small inaccuracies in this year’s data. However, allowing for equipment measurement differences, data are broadly comparable with those of Workman (2010b), who recorded data at the same site for the 2007-2008 season.
Figure 3.8 Weather data collected at Van Long Nature Reserve, spanning from February 2011 till October 2012, with a) showing temperature in °C, b) relative humidity as a percentage and c) rainfall in mm. Data for the months of February, March and May 2011 are incomplete (indicated by ‘*’), and there are no data for April 2011 and no humidity data for March 2012 due to technical problems with the weather station. Partial records should be considered cautiously when interpreting data, especially monthly rainfall totals.
3.4.2 Weather in Cúc Phượng

Cúc Phượng National Park is on a plateau at approximately 150m above sea level, therefore temperatures are slightly cooler here than at Van Long, and low lying fog is less common. A copy of weather data collected by the National Park staff for the 2011 year was obtained, but measurements may not be exactly comparable to those in Van Long due to differences in equipment and techniques.

During the summer (May-October) the average daily temperature was 26.1°C with a maximum of 38.5°C recorded, and in winter 17.2°C, with a record minimum of 6.5°C in late December (see Figure 3.9). Humidity levels were fairly constant across the year, with an average of 86%. June was the wettest month, with 20 rainy days including four days above 50mm, with rain levels remaining high through to September as in Van Long. Temperatures were generally cooler across the board by a few degrees in Cúc Phượng, likely due to its elevation and surrounding topography, and humidity levels more stable than in Van Long.
Figure 3.9 Weather in Cuc Phuong during 2011 a) temperature, b) humidity and c) rainfall. In b) and c) note the months of November and December were missing from the records. Data is courtesy of Cuc Phuong National Park.
3.5 Behavioural focal observations

Focal animal sampling (Altmann, 1974) was used to collect behavioural data on *T. delacouri*, in both a captive and a wild setting. Focal sampling was deemed the best method to look at the animal’s full range of behaviours in detail, as it allows for the recording of both state and event behaviour, whereas scan samples only allow for the recording of state behaviour (Altmann, 1974; Clutton-Brock & Harvey, 1977a; Wolfe, 1987; Lehner, 1996; Bart *et al.*, 1998; Paterson, 2001; Setchell & Curtis, 2003; Martin & Bateson, 2007). Additionally, focal sampling is an effective way to collect large amounts of data on animals that may be rarely seen, such is the case with *T. delacouri* in a wild setting, as it maximises the amount of data that can be collected from any given individual when it is in sight (Clutton-Brock, 1977a; Lehner, 1996).

3.5.1 Behavioural ethogram

A draft ethogram was constructed prior to entering the field based on existing *Trachypithecus delacouri* literature, behavioural studies of related primates (e.g. *T. francoisi*), and analysis of other behavioural ethograms (Dolhinow, 1978; Nickelson & Lockard, 1978; Oswald & Lockard, 1980; Davies & Oates, 1994; Lehner, 1996; Bart *et al.*, 1998; Paterson, 2001; Nadler *et al.*, 2003; Workman & Covert, 2005; Nguyen Vinh Thanh & Le Vu Khoi, 2006; Hu, 2007; Martin & Bateson, 2007; White, 2008; Duckworth *et al.*, 2010; Workman, 2010b). An ethogram of 13 core categories was developed (see Table 3.4), with behaviours listed within each of these categories in an effort to cover the full range of behaviours that could be performed in a mutually exclusive approach (see Appendix I for the complete ethogram). If an animal was seen to be performing more than one behaviour at a time, a preferential ranking system was developed for the categories, in which behaviours of higher rank were recorded over behaviours with lower rank. Typically categories containing behaviours of a predominantly short duration were favoured - the order of categories in the complete ethogram (see Appendix I) is that of the preferential ranking. Any behaviour viewed that did not fit within the ethogram was assigned as ‘other’.

The ethogram was trialled on commencement of fieldwork at the EPRC, both with caged animals and with those individuals in the semi-wild enclosure, and adjustments and additional details were added as necessary to form the final working...
product. To ensure consistency, the final ethogram was used for all behavioural collections done on all group types within this project.

### Table 3.4 Outline of behavioural categories used during focal observations of *T. delacouri*.

Categories are listed in dominance order for behavioural recording purposes, where if two behaviours were occurring simultaneously the one in a category higher up the list was preferentially recorded. The full ethogram with all sub-category behavioural descriptions can be viewed in Appendix I.

<table>
<thead>
<tr>
<th>Behavioural Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Out of View</td>
<td>The individual is not visible, may be obscured by terrain or vegetation</td>
</tr>
<tr>
<td>Vocalisation</td>
<td>Individual emits a noise</td>
</tr>
<tr>
<td>Excretion</td>
<td>Excretion of urine or faeces</td>
</tr>
<tr>
<td>Sexual</td>
<td>Individual engages in sexual behaviour e.g. mounting, inspecting or presenting to another individual</td>
</tr>
<tr>
<td>Threat/Submission</td>
<td>Individual engages in an aggression with another individual or performs a threat display</td>
</tr>
<tr>
<td>Cling Behaviours</td>
<td>The transport or cling behaviour of infants, scored for both infant and carer</td>
</tr>
<tr>
<td>Grooming</td>
<td>Grooming or being groomed by another, or auto-grooming</td>
</tr>
<tr>
<td>Play</td>
<td>Play with another individual or object, or by self-locomotion</td>
</tr>
<tr>
<td>Contact</td>
<td>Contacting another individual in a form other than grooming e.g. reaching, muzzling, holding</td>
</tr>
<tr>
<td>Locomotion</td>
<td>Travel by any mode</td>
</tr>
<tr>
<td>Feed</td>
<td>Feeding or drinking by any method, including receiving food from others</td>
</tr>
<tr>
<td>Inactive</td>
<td>Individual is stationary and not engaged in any other behaviour other than scanning</td>
</tr>
</tbody>
</table>

#### 3.5.2 Captive focal sampling protocol

Focal samples of captive *T. delacouri* individuals were conducted at the EPRC on three caged family groups between January and June 2011 (refer back to Section 3.1.1). Sampling effort initially focused on the group in Cage 2B (see Table 3.2 for group composition) as these were the animals earmarked for release into Van Long.

Focal individuals were chosen randomly each day, with efforts made to sample each individual for an equal amount of total time and to spread sampling across the day. Having a set sampling schedule for choosing individuals was not practical because of the day to day activities of the Center - for example animals were often
moved in to holding areas for cleaning and maintenance of the cage, meaning all individuals in that group were unavailable for focals. On choosing a focal individual, five minutes was allotted to allow the animal time to adjust to the presence of the observer and to record basic information, before sampling began. For each focal, group composition, time of day, and weather were recorded. Each focal sample was 60 minutes long, and the behaviours the animal conducted throughout this were period continuously recorded using the ethogram. *Ad libitum* notes (Altmann, 1974) were also taken throughout the study to complement the formal focal observations. If the individual went ‘out of view’ for a continuous period of five minutes the sample was terminated, although in a caged setting this could only occur if the animal moved to the back corner of the sleeping box. Samples were also occasionally terminated for practicality reasons such as the arrival of a large group of tourists disrupting the view of the animal, or EPRC keepers arriving to conduct maintenance on the cage. A video camera was used to film four focals at the beginning of fieldwork, and these were periodically reviewed over the course of fieldwork to ensure observer consistency over time, as per the method described in Paterson (2001). In total 115 focal observations of captive *T. delacouri* were made, comprising 113h 26m 25s of data, when the animals were in sight

3.5.3 Infant focal sampling protocol

In March 2011 a male Delacour’s langur infant was born at the EPRC, and focal samples (using the methodology as described above in 3.1.3) were taken of the infant over a three month period through to June 2011, focusing on its development. *Ad libitum* notes on key events, such as first independent movement, nursing, and allomothering, were also made. Additionally changes in the infant’s physical appearance were tracked through field notes and photographs. In total 62 focal observations were conducted over this period, consisting of 60h and 32m of in sight data.

3.5.4 Wild focal sampling protocol

As outlined in Section 3.3.4, Dong Quyen was chosen as the site for wild focal observations as it is the only site where *T. delacouri* can be spotted on a fairly regular basis. All samples were collected between March and November 2011 from the south-west side of the outcrop from a flat-bottomed puncted boat, as it has been previously found that attempts to climb on the karst to view the langurs causes them
to flee (Workman, 2010b). This of course does create an unavoidable bias in that the animals are only viewed when on exposed cliff faces and rocks, and any behaviours conducted in the more vegetated valleys and sheltered caves are not seen.

On Dong Quyen five different groups were identified, along with a lone adult male seen on the Meo Cao outcrop opposite Dong Quyen. It is presumed that this individual crossed over from Hang Tranh or Dong Quyen during a period of low water levels (T. Nadler, pers. comm. 2011), but was excluded from analysis as only individuals currently resident on Dong Quyen were studied. To allow for comparison between captive and wild individuals, the same sampling protocol was used when collecting data from wild individuals whenever possible. On locating a group on Dong Quyen, the boat was manoeuvred to a suitable viewing position and five minutes were taken to record the boat’s position using GPS (Garmin eTrex Vista HCx), along with the bearing and approximate distance to the visible group in order to locate the group’s position. Additionally, notes were made on the focal individual’s age/sex class, the number of individuals in the group, and the group to which the focal individual most likely belonged, along with weather conditions and time of day. As with the captive animals, 60 minute focals were used, however due to the wild setting the first individual spotted was chosen to be the focal individual. As langurs were often being viewed high on the cliffs, at an average distance of 130m, binoculars (Cannon 15x50IS) or a spotting scope (Braska Naturescape 15-45x50WP) on a tripod were required to make observations. Samples were terminated if the individual was out of view continuously (or in a position such that their behaviours could not be seen) for five minutes. This sample termination rule was necessary as it was extremely difficult to identify an individual on its return to view if it had been out of view for an extended period of time, given the distance involved. On completion of a sample, a ten minute rest period was taken before choosing a new focal individual, preferably an individual from the age/sex class with the fewest focal minutes recorded.

Sampling of wild groups was conducted periodically between March and December 2011, depending on other fieldwork commitments. Sampling efforts were split in to a morning (~6:00am – 11:30am) and a late afternoon session (~2:30pm – 6:00pm), as previous research has shown that the langurs are rarely seen during the rest period around the middle of the day as they move in to the valleys within Dong
Quyen, and this corresponds with the experience of the local field assistants and guards. Weather conditions often prevented sampling when thick fog, heavy rain, high wind and thunder-storms affected visibility or made conditions in the boat too dangerous. In total, 116 focals were made on wild individuals, making up 84h 34m 45s of in sight data. Attempts were made to collect data over 102 sampling sessions, with 58% of these trips being successful.

3.6 Social interactions

3.6.1 Social interactions ethogram

Captive *T. delacouri* were monitored to look at both affiliative and antagonistic interactions between individuals within their caged groups. Thirteen different interaction behaviours were seen (see Table 3.5), employing the behaviours listed in the complete ethogram (see Appendix I). Interactions were classified as affiliative, if they were seen to promote social cohesion and elicit a positive response, or antagonistic if they were aggressive and resulted in a hostile response. Data were also collected on any threat displays (TD), defined as “Individual exhibits, typically in an aggressive fashion - may be accompanied by vocalisations, bounding, thumping, movement etc; display is more than just a one off event movement, and takes place over a few seconds” (see TD in Appendix I). In *T. delacouri* displays typically take the form of a ‘bounding’ motion over the substrate, often accompanied by vocal hoots (Workman, 2010b). Threat displays were included in the social interaction study as they were noted to often occur in response to another animal displaying, and were thought to be linked to dominance hierarchies within the groups.

3.6.2 Social interactions sampling protocol

Three captive groups (Cage 2B, 3B and 6B, see section 3.1.3) were observed from April to June 2011, using all-occurrence sampling to monitor each group for a period of 60 minutes (Altmann, 1974). This sampling method was employed in order to look at the family group as a whole, and to note the targeted social interaction and threat display behaviours. It was not possible to collect data from the semi-wild group, due to the visibility problems as explained in Section 3.1.1, or wild individuals, due to the distance at which they were observed making detailed
assessments of interactions difficult. A sample was terminated if any individual within the group moved ‘out of view’, as all interactions could not be monitored. Sampling sessions were rotated around available cage groups in an effort to sample each group equally. On the occurrence of an interaction behaviour or threat display, data on the performers, their roles, length of the behaviour, any associated vocalisation, and the time of day were recorded. An individual’s ‘role’ was determined to be dominant or non-dominant in the interaction (if this was apparent) by assessing its response to the interaction, whether or not that individual initiated it, and the outcome. A total of 110h 9m of sampling across 10 individuals was collected, resulting in 280 interactions witnessed, along with 52 solo threat displays.

Table 3.5 A list of the different social interaction behaviours identified to occur between group members, which were the target behaviours for the all occurrence sampling. Refer to the ethogram in Appendix I for a description of the behaviour, with the exception that in this study ‘CH Hold/Cling’ also includes infant cling.

<table>
<thead>
<tr>
<th>Interaction</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>SP</td>
<td>Play Mount</td>
</tr>
<tr>
<td>SF</td>
<td>Feasible Mount</td>
</tr>
<tr>
<td>SH</td>
<td>Rump Holding</td>
</tr>
<tr>
<td>TN</td>
<td>Aggression non-contact</td>
</tr>
<tr>
<td>TC</td>
<td>Aggression contact</td>
</tr>
<tr>
<td>GB</td>
<td>Groom</td>
</tr>
<tr>
<td>GQ</td>
<td>Request grooming</td>
</tr>
<tr>
<td>PA</td>
<td>Play with another</td>
</tr>
<tr>
<td>CM</td>
<td>Muzzle</td>
</tr>
<tr>
<td>CE</td>
<td>Embrace</td>
</tr>
<tr>
<td>CH</td>
<td>Hold/Cling</td>
</tr>
<tr>
<td>CA</td>
<td>Contact another</td>
</tr>
<tr>
<td>FR</td>
<td>Steal food</td>
</tr>
</tbody>
</table>

3.7 Vocalisation behaviour

3.7.1 Vocal types

During initial fieldwork at the EPRC, notes were taken on the different vocal types expressed by T. delacouri individuals. Workman (2010b) had identified a ‘hoot’ call that went along with the species characteristic ‘bounding’ threat display.
Over the initial weeks I constructed a vocal ethogram covering a range of seven vocal types heard during this study – click, grunt, hoot, meow, screech, squawk and squeal (see Appendix I for descriptions).

3.7.2 Vocalisation sampling protocol

All occurrence sampling (Altmann, 1974) was used to look at any vocalisations made by *T. delacouri* in a captive group and the context in which they occurred. Sixty-minute samples were conducted on captive family groups at the EPRC between May to June 2011 (groups as outlined in Section 3.1.1). Any vocalisation witnessed was noted and classified to its vocal type, with the performer, the length of the vocalisation and the number of calls in the bout recorded. A bout was defined as a series of one call type with a gap of five seconds or less between calls. The time of day that the vocalisation occurred at was recorded as being ‘morning’ (06:00h – 10:30h), ‘noon’ (10:31h – 15:00h) or ‘afternoon’ (15:01h – 19:00h). The behaviour of the performer at the time of the vocalisation, along with other individuals in the cage, was noted using the complete behavioural ethogram (see Appendix I) to classify behaviours. The possible function of the caller’s vocalisation was also noted, where possible, based on the animals’ behaviour and movements. Functions were classified as - being a response, showing aggression, showing distress, showing excitement, making a request (such as for grooming), or an unknown function. Sample groups were chosen by rotating around available cage groups, moving to the cage with the least number of focal minutes when possible. Samples were terminated if any individual in the sample group went ‘out of view’, using the rules as outlined in Section 3.6.2.

All occurrence sampling was used as it was the most effective way to look at the possible vocal function and behavioural responses of the whole family group, rather than just focusing on one individual. The infrequency of vocalisations meant it was possible to accurately monitor more than just the one individual at a time for the target behaviour. Vocalisation studies were conducted only in a captive setting as in the wild vocalisations were rarely heard because of the distance between langurs and observers - with the exception of the ‘hoots’ which echoed loudly around the limestone outcrops.
Observations of vocalisations were also expanded to the five other limestone langur species kept at the EPRC (T. hatinhensis, T. francoisi, T. poliocephalus, T. laotum, and T. ebenus) to give the opportunity to compare and contrast vocalisation differences between species. The same methodology of 60 minute all-occurrence sampling was used as outlined above. A total of 2033 calls were witnessed during the 150h and 38m of sampling across the six species (covering 34 individuals), with 73% of this time focused on T. delacouri, producing 1543 calls.

A sub-sample of vocalisations was opportunistically recorded using a video camera (Panasonic HDC-SD60). The video camera was set on a tripod approximately two metres away from the cage enclosure, and left running for blocks of approximately 30 minutes at a time in order to capture any vocalisations. Clips were later viewed and edited to separate out all vocalisations heard, and combined with field notes to assist in identifying the caller and events surrounding the vocalisations. Each vocalisation clip was then transferred to Raven Pro 1.4 sound analysis software (Cornell Lab of Ornithology Bioacoustics Research Program, 2011) to create spectrograms and measure attributes of the different vocal types. For T. delacouri 123 recorded vocalisations were of sufficient quality for analysis, along with a further 122 from the other five limestone langur species. Ideally vocalisations would have been recorded using an external microphone to create higher quality recordings (Geissmann, 2003; Strier, 2007), but as this part of the study was not originally planned and only took place because there were delays in other areas of the project, the equipment was not available in the field.

3.8 Tracking of released individuals

3.8.1 Description of the radio-GPS collars

Three captive-bred T. delacouri were released in western Van Long by the EPRC on August 22nd 2011 (see Chapter 6 for full details of the release). Before release each individual was fitted with a VHF radio-GPS collar (selected by the EPRC), manufactured by E-obs Digital Telemetry, Germany (see Figure 3.10), each collar weighing approximately 125g. This weight was well below the recommendation that a tracking collar should not exceed 5% of the animal’s body weight, as the smallest individual released (a subadult male) weighed 5.3kg (American Society of
The collars were 1.5cm wide with a thickness of 0.5cm, and had a 7cm aerial, with the majority of the weight in the battery compartment positioned at the bottom of the collar. On attaching, the collars were cut to fit each animal’s neck, and joined by a bolt attached to the leather section (leather thickness = 0.3cm) which was designed to eventually rot and allow the collar to fall off.

![Figure 3.10](image) One of the three identical radio-GPS collars that were fitted to the langurs prior to release, showing the aerial and GPS receiver on top of the collar with the battery at the bottom, along with the leather attachment piece. The collar is placed next to a 20cm ruler for scale.

The collars were each set to a different radio frequency (around 868Mhz), and the radio pinger signal was set to run for one hour each day per collar (one was set at 8-9am, one at 9-10am, and one at 10-11am) on the theory that the animals would move as a cohesive group allowing three hours of potential radio tracking to find the animals whilst minimising battery usage. A handheld wide-range radio scanner (AOR AR8200 MKIII) with yagi antenna was used to track the collar’s radio signal. The GPS component of the collars was set to attempt 12 GPS fixes a day, starting at 4.00am and finishing at 8.30pm, with fixes taken 1.5 hours apart. Previous research has indicated that *T. delacouri* do not travel during the night, so the collars were set in an effort to capture a full day’s travel whilst conserving battery power (Nadler, 2004a; Nadler *et al.*, 2004; Nguyen Vinh Thanh, 2008a; Workman, 2010b; Harding, 2011). The settings allowed a maximum of 2.5 minutes for the GPS unit to make a fix, otherwise the fix was listed as unsuccessful and was attempted again at the next 1.5 hour mark. Each collar’s inbuilt memory could hold up to 150 days’ worth of data. The collar’s also had an accelerometer function, which was set to the default
basic settings, but the data was not included in this study. The collar’s battery life was estimated at 406 days with these above settings, based on a lifetime calculator supplied by the collar manufacturer. The collar settings were chosen in collaboration with T. Nadler of the EPRC.

3.8.2 Methods for tracking

Prior to release, all the collars and the tracking equipment were tested in the Van Long environment to ensure proper functionality and allow for familiarisation with the tracking process. The group was initially tracked daily post release for the first nine days, with researchers camping in the forest near the langurs and ad libitum notes taken where possible. It had initially been the intention to collect behavioural focal data using the same method that had been employed with captive and wild T. delacouri, in order to allow a comparison of behaviours between the groups. Regrettably, it quickly became apparent that this would not be possible; following release, the group was rarely seen because of the terrain and the dense foliage in the area.

On locating an individual using its radio signal, attempts were made to download any data off the collar using the e-obs Digital Telemetry B5 basestation, a handheld device to which the yagi antenna was attached (see Figure 3.11). On return to the Van Long headquarters, the data could then be downloaded onto a computer and the animal’s location viewed in Google Earth (Google Inc., 2012), and this assisted in tracking the animals over the following days. The tracking interval was extended over time as an individual’s movements became more predictable. In total the different members of the group were tracked from release in August 2011 till the last of the collars stopped transmitting in October 2012, with the tracking being carried out by Nguyen Hong Chung in 2012 following my departure from Vietnam.
Figure 3.11 Field assistant Nguyen Hong Chung uses the handheld basestation with yagi antenna attached to download data from one of the langur’s GPS collars.
Lines of bamboo boats waiting for tourists at Vân Long Nature Reserve
Activity Budgets and Behaviour

4.1 Introduction

The daily activity profile of a primate’s behaviours can reveal a lot about how a species uses its environment, with behaviours typically split between inactivity, feeding, locomotion and social activities (Davies & Oates, 1994; Boitani & Fuller, 2000; Martin & Bateson, 2007; Strier, 2007). Primate activity budgets can vary widely between species, fluctuating due to the time of day, season, and food availability (Clutton-Brock, 1977b; Clutton-Brock & Harvey, 1977b; Symington, 1988; Ding & Zhao, 2004; Hanya, 2004; Sayers & Norconk, 2008; Palma et al., 2011). The average proportion of time spent resting for a species can vary from under 20% (for example lion-tailed macaques, Macaca silenus (Menon & Poirier, 1996); Barbary macaque, Macaca sylvanus (El Alami et al., 2012)) to over 75% (proboscis monkeys, Nasalis larvatus (Matsuda et al., 2009); western black-and-white colobus, Colobus polykomos (Dasilva, 1992)). Typically, colobines have a large proportion of inactivity in their activity budget because of their highly folivorous diet of fibrous leaves, meaning they need an extended period of time to digest their food (Davies & Oates, 1994; Huang et al., 2003; Hu, 2007; Workman, 2010b; Harding, 2011; Hadi et al., 2012).

Generally speaking primates show a peak of activity in the early morning and late afternoon, with resting periods during the middle of the day (Clutton-Brock, 1977b). In times of food scarcity (typically seasonally affected), some primates will move and feed more often due to difficulty in locating food and the low quality of the food sources, whilst other primates will conserve energy and move less during hard times (Clutton-Brock, 1977b; Davies & Oates, 1994; Hanya, 2004; Guo et al., 2007; Strier, 2007; Li, 2009). Additionally, a positive correlation has been found between the species’ average body weight and the proportion of their activity budget that they spend feeding (Clutton-Brock, 1977b). Feeding levels in primate budgets have been found to vary from approximately one quarter of their budget (for example Sichuan snub-nosed monkeys, Rhinopithecus roxellana (Li, 2009)) to about half (northeastern...
Bornean orangutans, *Pongo pygmaeus morio* (Tomoko et al., 2010)). The level of social behaviour a primate engages in also varies greatly between species, with species such as chimpanzees and baboons known to be highly social (Rowell, 1967; Clutton-Brock, 1977a; Leinfelder et al., 2001; Goossens et al., 2005; Strier, 2007; Yamanashi & Hayashi, 2011).

There has been some research to date on the activity budget of the limestone langurs, on *T. francoisi* (Hu, 2007; Yang et al., 2007; Zhou et al., 2007b), *T. leucocephalus* (Huang et al., 2003; Li & Rogers, 2004a), and *T. poliocephalus* (Schneider et al., 2010). Additionally, there has been one study (Workman, 2010b) that included a *T. delacouri* activity budget, which mainly focused on the behaviours from a feeding ecology point of view. The research in this thesis differs by giving a much more detailed overview of the species’ activity budget, including highlighting captive versus wild and sex/age class differences.

Infants often show a unique activity budget compared to adults, which reflects their developmental changes as they become increasingly independent (Thierry, 1985; Hu, 2007; Strier, 2007). In addition, as an infant develops it often undergoes marked physical changes (Hinde, 1983; Hosey, 2005; Hu, 2007). The limestone langur group in particular is known for its transformation from the bright orange natal coat to the adult form of a predominantly black coat (Nadler et al., 2003; Groves, 2007). By closely monitoring an infant’s development in a captive setting as it reaches key milestones, a greater understanding of infants’ behaviour and needs can be gained. Additionally, an understanding of the different affiliative and antagonistic interactions that occur within a species gives a clearer picture of their daily behaviours, and can highlight relationships and hierarchies within the group (Poirier, 1970; Hinde, 1983; Strier, 2007; Ren et al., 2010).

This chapter gives an in-depth overview of the day to day behaviours of *T. delacouri* in both a captive and wild environment, and the differences between these two populations. It also outlines the species’ daily activity budget, with a detailed breakdown given, and the effect of an individual’s sex/age class on its behaviours was explored. Additionally, a focus on social interactions and the development of infant behaviour provides a greater understanding of the species’ behaviour, with potential conservation implications.
4.2 Methods

4.2.1 Activity budgets

Activity budgets were analysed to look at how behavioural patterns varied between wild and captive individuals, and amongst sex and age classes for both populations. All wild samples came from *T. delacouri* groups on Dong Quyen outcrop at Van Long Nature Reserve, whilst captive animals were from the Endangered Primate Rescue Center (EPRC) in Cuc Phuong National Park. Budgets were compiled from focal animal samples collected from both wild and captive individuals, as outlined in detail in Section 3.5. For each focal sample, an individual was continuously followed for a period of up to 60 minutes, during which all behaviours and times of behavioural changes were recorded using the study ethogram (see Appendix I). Efforts were made to sample equally across all sex/age classes, but this was often not possible due to sampling conditions, notably the lack of visibility of individuals in the wild setting. Independence of focal samples was assured by samples of the same individual being conducted at least three hours apart. In total 84h 34m 45s of useable data from 102 focals were collected from wild individuals and 113h 26m 25s from 115 focals from captive individuals.

Focal sample data were recoded into five key mutually exclusive behavioural categories: inactive, feed, locomotion, social and other (see Table 4.1), to give a clearer picture of the species’ activity budget (Saj *et al.*, 1999; Huang *et al.*, 2003; Teichroeb *et al.*, 2003; Hanya, 2004; Behie & Pavelka, 2005; Guo *et al.*, 2007; Prates & Bicca-Marques, 2008). Additional detail of the food species being consumed was not recorded, as the foraging ecology of *T. delacouri* had already been extensively covered by Workman (2010b). Focal data were collated across the different age/sex classes, with out of view time excluded prior to analysis (Hanya, 2004; Workman, 2010b). Although samples were collected across the year, the effects of seasonality were beyond the scope of this study due to inconsistent sampling opportunities across the year, and, as Workman (2010b) had previously found no significant seasonal trends in activity budgets, all data were combined. In some instances behaviours were investigated further by splitting in to subcategories (see Table 4.1). Raw figures were converted to proportions for statistical analysis to allow for differences in focal sample length, following the methodology of Teichroeb *et al.* (2003; see also Zar, 1999; Hanya, 2004; Prates & Bicca-Marques, 2008; El Alami et
Focal samples from infants were excluded from overall activity budget analysis as infant behaviour was found to be significantly different from other group members, resulting in large skews in activity patterns (see Section 4.3.1 and 4.3.3; Melfi & Feistner, 2002; Hanya, 2004; Li & Rogers, 2004a). Additionally, for captive individuals, focal samples of juveniles were removed as not enough samples could be obtained to provide a reliable representation of this age class, and hence juveniles could not be analysed in any captive/wild comparisons.

**Table 4.1** A breakdown of the five key mutually exclusive behavioural categories used for activity budgets, with sub-category splits included. The ethogram code or group reference (see Appendix I) indicates how behaviours from the focal samples were assigned to sub-categories.

<table>
<thead>
<tr>
<th>Behaviour Category</th>
<th>Sub-category Behaviour</th>
<th>Ethogram reference</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Inactive</strong></td>
<td>Resting</td>
<td>IR, IE</td>
</tr>
<tr>
<td></td>
<td>Scanning</td>
<td>IS, IA</td>
</tr>
<tr>
<td><strong>Feed</strong></td>
<td>Feeding</td>
<td>FC, FF</td>
</tr>
<tr>
<td></td>
<td>Nursing</td>
<td>FN</td>
</tr>
<tr>
<td></td>
<td>Other</td>
<td>FD, FE, FR, FG</td>
</tr>
<tr>
<td><strong>Locomotion</strong></td>
<td>Qudrupedal</td>
<td>LQ</td>
</tr>
<tr>
<td></td>
<td>Jump</td>
<td>LJ</td>
</tr>
<tr>
<td></td>
<td>Climb</td>
<td>LC</td>
</tr>
<tr>
<td></td>
<td>Branchiate</td>
<td>LB</td>
</tr>
<tr>
<td></td>
<td>Bipedal Walk</td>
<td>LW</td>
</tr>
<tr>
<td><strong>Social</strong></td>
<td>Groom</td>
<td>GB, GA, GR, GQ</td>
</tr>
<tr>
<td></td>
<td>Autogroom</td>
<td>GS</td>
</tr>
<tr>
<td></td>
<td>Play</td>
<td>‘Play’ group</td>
</tr>
<tr>
<td></td>
<td>Sexual</td>
<td>‘Sexual’ group</td>
</tr>
<tr>
<td></td>
<td>Dispute</td>
<td>TN, TC, TS</td>
</tr>
<tr>
<td></td>
<td>Threat Display</td>
<td>TD</td>
</tr>
<tr>
<td></td>
<td>Contact</td>
<td>‘Contact’ group</td>
</tr>
<tr>
<td></td>
<td>Infant Cling</td>
<td>‘Cling behaviours’ group</td>
</tr>
<tr>
<td><strong>Other</strong></td>
<td>Vocalisation</td>
<td>‘Vocalisation’ group</td>
</tr>
<tr>
<td></td>
<td>Excretion</td>
<td>EE</td>
</tr>
<tr>
<td></td>
<td>Other</td>
<td>OA</td>
</tr>
</tbody>
</table>
Mann–Whitney U tests were performed to compare the five key behaviour categories between wild and captive groups, looking at any significant differences between the two populations. Additionally, differences were tested between males and females, and between adults and subadults, for both wild and captive populations and within each study group. When three or more study groups were being compared within the same population, a Kruskal-Wallis one-way analysis of variance was used. Non-parametric tests were used as the data violated the assumptions for parametric testing, but all assumptions were met for both Mann-Whitney U tests and Kruskal-Wallis tests, the data being ordinal data that can be ranked (Zar, 1999). The significance level was set at $\alpha = 0.01$ to minimise the chance of Type I errors caused by multiple tests.

All collation, descriptive statistics and graphical work in this chapter was conducted in Microsoft Excel 2010 (Microsoft Corporation, 2010), and all hypothesis testing was conducted in GenStat 14.2 (VSN International Ltd., 2011).

### 4.2.2 Social interactions

Social interactions between captive *T. delacouri* were monitored to investigate the effect of sex and age on these interactions, and the dynamics within study groups. Data were collected via all-occurrence sampling of the three *T. delacouri* cage groups at the EPRC (refer back to Table 3.2), with further detail given in Section 3.6. Thirteen different social interactions were witnessed (refer back to Table 3.5) along with threat display behaviour (see TD in Appendix I) which was also recorded as this frequently related to social interactions within and between the groups. Sampling effort was split evenly between the three cages, but when looking at sex/age classes there was an imbalance due to differences in cage composition. To account for this, values were adjusted where necessary with counts amended to equate to equal observation times between sex/age classes (Teichroeb et al., 2003; Hanya, 2004; Guo et al., 2007; El Alami et al., 2012). Independence of samples was assured by sampling each cage at least three hours apart. In total 110h 9m of sampling was conducted across three cages housing a total of 10 individuals.

As the data collected were collected as counts, they were analysed using chi-square analyses. Tests were conducted on the frequency of both affiliative and antagonistic interactions between cage groups and at the individual level, along with
the effect of age and sex on social interactions. Additionally, descriptive statistics and a sociogram were used to further elucidate any differences or similarities. All assumptions for chi-square testing were met (Zar, 1999), with the significance level set at $\alpha = 0.01$ to allow for multiple testings.

4.2.3 Infant development

A captive male infant, individual 1-25, located in Cage 6B at the EPRC, was monitored from one day old (born overnight 19/20 March 2011) through to three months of age. Focal samples of up to 60 minutes of length were conducted, as described in Section 3.5, following the same methodology used in captive activity budget samples. The study ethogram (see Appendix I) was used with activity budgets split into five categories: inactive, feed, locomotion, social, other, as in Table 4.1, along with the additional ‘cling’ category for infants. To form the cling category, dorsal and ventral clings by the infants, both moving and stationary, were combined into the one group (see Appendix I). In other activity budgets in this thesis, notably wild and captive population comparisons, cling behaviours were grouped into the social category. Additional *ad libitum* notes were taken on any milestone behaviours witnessed and on physical appearance changes. A *T. delacouri* infant is initially born with a bright orange natal coat that slowly changes to full black between four and nine months of age, before the development of ‘white shorts’ begins (refer back to Table 3.1). This process was recorded and photographed for individual 1-25 when possible. In total 60h and 32m of infant data were collected, split across 62 focal samples.

Raw figures from the focal samples were converted to proportions for statistical analysis in the same method used for activity budgets as outlined in Section 4.2.1. Independence of samples was maintained by all samples occurring on separate days, with one sample per day conducted whenever possible. Samples were split into three groups based on the age of the infant, in order to examine changes to behavioural patterns that occurred as the infant aged, with groups reflecting the first, second and third month of life. Along with descriptive statistics, a Kruskal-Wallis one-way analysis of variance significance test was used to compare behavioural difference between the three age groups. All assumptions of the test were met, with a non-parametric test being used as data violated the assumptions for parametric testing (Zar, 1999). Additionally, Chi-square analyses were utilised for count data to look at
the relationship between infant age and the frequency of different play behaviours and allomothering. The significance level was set at $\alpha = 0.01$ to minimise the chance of Type I errors caused by multiple tests.

### 4.3 Results

#### 4.3.1 Activity budgets

All individuals from the wild groups were combined to represent one population, as were all individuals from the captive groups, with the exception of infants which were removed for previously stated reasons. When comparing these populations, inactivity was the most prominent behaviour for both groups, representing 75.0% of wild individuals’ time and 61.9% for captive individuals (see Figure 4.1).

When each of the five behavioural categories was compared between wild and captive populations, there was a significant difference in all activities at the $\alpha = 0.01$ level (Inactive: $U = 4034.5$, $p < 0.001$, $n_C = 115$, $n_W = 102$; Feed: $U = 4676.5$, $p = 0.010$; Social: $U = 2285.5$, $p < 0.001$; Other: $U = 1971.5$, $p < 0.001$) apart from locomotion ($U = 5228.5$, $p = 0.168$). Captive individuals engage in a higher proportion of feed, social and other behaviours, whilst wild individuals were more frequently inactive.

![Activity Budget](image.png)

**Figure 4.1** Activity budget for wild compared with captive *T. delacouri* with all sex/age classes combined, except infants were removed. Categories which were not significantly different from one another are marked with a *. 

75
A sub-category breakdown of each of the five activity budget categories (refer back to Table 4.1) gives a clearer picture of how individuals were spending their time. Locomotion and feed sub-category breakdowns between wild and captive populations were fairly comparable; quadrupedal motion was the main locomotor mode in both populations, and straight-feeding all but dominated the feed category (see Table 4.3). In inactive, resting was far more prevalent in captive than wild populations, but there were several sampling biases that could be contributing to this result, and these will be discussed further in Section 4.4. In the social category, the most prominent sub behaviour for wild individuals was play (57.7%), whilst for captive individuals grooming made up 64.7% of social behaviours. Vocalisations accounted for all ‘other’ category behaviours witnessed in wild individuals, but there was a range for captive individuals.
Table 4.3 An overview of the activity budget, with sub-category percentage breakdowns given. All sex/age classes were lumped together except infants, with wild and captive populations compared.

<table>
<thead>
<tr>
<th>Behaviour</th>
<th>Sub-behaviour</th>
<th>Wild (%)</th>
<th>Captive (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inactive</td>
<td></td>
<td>75.0%</td>
<td>61.9%</td>
</tr>
<tr>
<td></td>
<td>Resting</td>
<td>5.7</td>
<td>53.7</td>
</tr>
<tr>
<td></td>
<td>Scanning</td>
<td>94.3</td>
<td>46.3</td>
</tr>
<tr>
<td>Feed</td>
<td></td>
<td>21.3%</td>
<td>29.0%</td>
</tr>
<tr>
<td></td>
<td>Feeding</td>
<td>100</td>
<td>99.8</td>
</tr>
<tr>
<td></td>
<td>Nursing</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Other</td>
<td>0</td>
<td>0.2</td>
</tr>
<tr>
<td>Locomotion</td>
<td></td>
<td>1.8%</td>
<td>1.4%</td>
</tr>
<tr>
<td></td>
<td>Quadrapedal</td>
<td>79.1</td>
<td>88.3</td>
</tr>
<tr>
<td></td>
<td>Jump</td>
<td>13.7</td>
<td>8.5</td>
</tr>
<tr>
<td></td>
<td>Climb</td>
<td>7.2</td>
<td>2.8</td>
</tr>
<tr>
<td></td>
<td>Brachiate</td>
<td>0</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td>Bipedal walk</td>
<td>0</td>
<td>0.2</td>
</tr>
<tr>
<td>Social</td>
<td></td>
<td>1.9%</td>
<td>7.6%</td>
</tr>
<tr>
<td></td>
<td>Groom</td>
<td>19.9</td>
<td>64.7</td>
</tr>
<tr>
<td></td>
<td>Autogroom</td>
<td>11.8</td>
<td>16.3</td>
</tr>
<tr>
<td></td>
<td>Play</td>
<td>57.7</td>
<td>16.7</td>
</tr>
<tr>
<td></td>
<td>Sexual</td>
<td>0.1</td>
<td>1.3</td>
</tr>
<tr>
<td></td>
<td>Dispute</td>
<td>0.02</td>
<td>0.3</td>
</tr>
<tr>
<td></td>
<td>Threat display</td>
<td>1.0</td>
<td>0.7</td>
</tr>
<tr>
<td></td>
<td>Contact</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>Infant cling</td>
<td>9.2</td>
<td>0</td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td>0.001%</td>
<td>0.1%</td>
</tr>
<tr>
<td></td>
<td>Vocalisation</td>
<td>100</td>
<td>66.5</td>
</tr>
<tr>
<td></td>
<td>Excretion</td>
<td>0</td>
<td>33.3</td>
</tr>
<tr>
<td></td>
<td>Other</td>
<td>0</td>
<td>0.2</td>
</tr>
</tbody>
</table>
The activities of all the wild groups (as outlined in Section 3.1.2) were tested, and no significant differences were found for any behaviour category (Inactive: $H = 1.054$, $df = 2$, $p = 0.590$; Feed: $H = 3.536$, $p = 0.156$; Locomotion: $H = 5.201$, $p = 0.074$; Social: $H = 1.653$, $p = 0.410$; Other: not tested due to small samples). As such, all groups were combined into one population for further testing. A comparison of all sex/age classes (adult male, adult female, subadult male, subadult female and juveniles – see Table 3.2 for descriptions) amongst wild individuals showed no significant differences across all five behavioural categories (Inactive: $H = 1.480$, $df = 4$, $p = 0.830$; Feed: $H = 0.9801$, $p = 0.913$; Locomotion: $H = 5.025$, $p = 0.285$; Social: $H = 4.578$, $p = 0.333$; Other: $H = 2.810$, $p = 0.590$). Infants and individuals of unknown sex were removed from this analysis to avoid skewing the results.

For the captive population, with all caged groups combined, adult males, adult females and subadult males were compared (see Figure 4.2). There were insufficient data from juveniles to include in the analysis, and there were no captive subadult females present at the EPRC. For the behaviours of feed and social there was no significant differences between the sex/age classes ($H = 9.063$, $df = 2$, $p = 0.011$ and $H = 2.802$, $p = 0.246$ respectively). For inactive behaviours there was a difference in the distribution ($H = 9.135$, $p = 0.010$), with subadult males spending a significantly smaller proportion of their time engaged in inactive behaviours (AM vs. SM: $U = 458.0$, $p = 0.009$; AF vs. SM: $U = 463.0$, $p = 0.007$). In locomotion there was a significant difference between the groups ($H = 14.20$, $p < 0.001$), with subadult males using a significantly greater proportion of their time for locomotion compared with adult males ($U = 349.0$, $p < 0.001$). For ‘other’ behaviours there was a difference ($H = 26.28$, $p < 0.001$), with adult females using a significantly lower proportion of their time for these behaviours compared with adult males ($U = 329.5$, $p < 0.001$) and subadult males ($U = 332.5$, $p < 0.001$). This can be explained by the low proportion of time spent on vocalisations by adult females, being significantly less than both adult males ($U = 268.0$, $p < 0.001$) and subadult males ($U = 337.0$, $p < 0.001$).
Analyses for sex differences in activity budgets between males and females were conducted (see Figure 4.3), excluding samples from infants, juveniles and any other individuals of an unknown sex. In the wild population there was no significant difference between males and females in any activity budget category (Inactive: $U = 539.5$, $p = 0.395$, $n_{WM} = 35$, $n_{WF} = 35$; Feed: $U = 546.0$, $p = 0.433$; Locomotion: $U = 503.0$, $p = 0.202$; Social: $U = 552.0$, $p = 0.463$; Other: not tested due to small samples). For the captive samples the only significant difference was detected in ‘other’ ($U = 662.0$, $p < 0.001$, $n_{CM} = 75$, $n_{CF} = 40$) with 0.16% of a captive male’s activity budget represented by other behaviours, against 0.04% for females. This again reflects the difference in the proportion of time used for vocalisations, as explained previously when looking at all sex/age classes. All other comparisons between the activity budgets of captive males and females for the remaining behavioural categories showed no significant differences (Inactive: $U = 1256.5$, $p = 0.153$; Feed: $U = 1208.5$ $p = 0.087$; Locomotion: $U = 1468.5$, $p = 0.853$; Social: $U = 1220.0$, $p = 0.101$).

Comparisons between wild males and captive males show a significant difference in the distribution of inactive behaviours ($U = 733.5$, $p < 0.001$, $n_{WM} = 35$, $n_{CM} = 75$); wild males spent 76.3% of their activity budget inactive compared with 59.4% for their captive counterparts. Wild males also spent a significantly lower proportion of their activity budget engaged in social behaviours at 1.2%, compared with 6.9% ($U = 612.5$, $p < 0.001$, $n_{WM} = 35$, $n_{CM} = 75$).
405.0, p < 0.001) for captive males. There was also a significant difference for ‘other’ behaviours (U = 474.0, p < 0.001), with 0.004% of the activity budget for wild males and 0.157% for captive, which was likely due to the lack of vocalisations heard at a distance from wild individuals. Feed and locomotion behaviours were not significantly different (U = 981.0, p = 0.034; U = 1251.5, p = 0.695 respectively).

When looking at wild females versus captive females, no significant difference was found in feeding or locomoting behaviours (U = 495.0, p = 0.029, n_{WF} = 35, n_{CF} = 40; U = 525.0, p = 0.063), but there was a significant difference in the distribution of inactive, social and other behaviours (U = 459.0, p = 0.010; U = 331.0, p < 0.001; U = 227.5, p < 0.001). Wild females spent 76.8% of their time inactive compared with 66.6% for captive females, but captive females were more involved in social behaviours, which accounted for 9.0% of their activity budget against just 1.8% in wild females. For ‘other’ behaviours there were no occurrences recorded for wild females, and they accounted for just 0.04% of captive females’ budget.

Figure 4.3 Activity budget for Wild male and female individuals compared with Captive male and females. All infants, juveniles and individuals of unknown sex were removed from this analysis. Categories which were not significantly different from one another in any of the comparisons are marked with a *.

Analyses were conducted to look for any age specific differences in activity budgets (see Figure 4.4). For wild individuals, adults, subadults, and young (juveniles and infants) were compared and showed a significant difference for social activities (H = 25.99, df = 2, p < 0.001), with young spending a significantly greater
proportion of their time conducting social behaviours (Young vs. Adult: $U = 220.0$, $p < 0.001$, $n_{WA} = 55$, $n_{WY} = 24$; Young vs. Subadult: $U = 160.0$, $p < 0.001$, $n_{WS} = 37$; Adult vs. Subadult: $U = 1000.0$, $p = 0.884$). The remaining activities showed no significant differences across age groups for wild individuals (Inactive: $H = 7.993$, $df = 2$, $p = 0.018$; Feed: $H = 6.937$, $p = 0.031$; Locomotion: $H = 1.372$, $p = 0.504$; Other: $H = 1.109$, $p = 0.574$). In captive populations, only adults and subadults were able to be compared as there were insufficient data to include young. A significant difference was detected in inactive ($U = 921.0$, $p = 0.003$, $n_{CA} = 79$, $n_{CS} = 36$), feed ($U = 925.0$, $p = 0.003$) and locomotion ($U = 864.0$, $p < 0.001$) behaviours; adults spent a significantly greater proportion of their activity budget engaged in inactive behaviours, at 66.3% compared with 52.4% for subadults. Subadults, on the other hand, spent more time feeding (38.4%) and locomoting (2.1%). There were no significant difference between captive adults and subadults for social ($U = 1242.5$, $p = 0.279$) or other ($U = 1165.5$, $p = 0.122$) behaviours.

Comparing wild and captive populations, there was a significant difference in the distribution of activity budgets between wild and captive adults across all behaviours (Inactive: $U = 1405.0$, $p < 0.001$, $n_{WA} = 55$, $n_{CA} = 79$; Feed: $U = 1594.5$, $p = 0.009$; Social: $U = 781.5$, $p < 0.001$; Other: $U = 774.0$, $p < 0.001$) except locomotion ($U = 1820.0$, $p = 0.111$). Wild adults used a greater proportion of their activity budget to engage in inactive behaviours (76.3% compared with captive adults at 66.3%), whereas captive adults dedicated a higher proportion of their activity budgets to feed (24.7% compared with 20.5% for wild adults), social (7.9% versus 1.9%), and other behaviours (0.1% versus 0.002%). With subadults there was no significant difference in the distribution of activity budget behaviours between wild and captive subadults for inactive ($U = 491.5$, $p = 0.054$, $n_{WS} = 37$, $n_{CS} = 36$), feed ($U = 600.0$, $p = 0.470$) and locomotion ($U = 660.5$, $p = 0.954$) behaviours. Captive subadults did spend a significantly greater proportion of their activity budget engaged in social behaviours (7.0% versus 1.9% for wild subadults). For ‘other’ behaviours there were no occurrences recorded in wild subadults, and the activities makeup just 0.2% of a captive subadult’s activity budget.
Figure 4.4 Activity budget for wild adult, subadult, and young (juvenile and infant) individuals compared with captive adult and subadults. There was not sufficient data to include captive young in this analysis. All categories were found to be significantly different from one another.

4.3.2 Social interactions

Of the 280 social interactions witnessed between captive individuals during the study period (refer back to Table 3.5), 73.2% of them were affiliative interactions. Hold/cling of infants or other individuals (24.3%) and grooming (21.1%) were the most common interactions (see Figure 4.5). Of antagonistic interactions, there were only three types witnessed, aggression involving physical contact being the most common (6.8%).
Figure 4.5 Social interactions seen to occur in captive *T. delacouri*, with their percentage in the total number of interactions noted. Antagonistic interactions are marked in light grey, and affiliative in dark grey.

The three captive family groups (refer back to Table 4.1) were watched for approximately equal periods of time (about 36 hours per cage), but the interactions were not split evenly amongst the groups ($\chi^2 = 44.62$, df = 2, $p < 0.001$ at the significance level of $\alpha = 0.01$; see Figure 4.6). Whilst cage 3B had significantly fewer interactions overall (15.4% of the total compared with 37.5% in 2B and 47.1% in 6B), they had the highest number of antagonistic interactions, with 56.8% of all antagonistic interactions witnessed occurring in cage 3B. This finding was supported by a chi-square test showing there was a significant association between the number of antagonistic versus affiliative interactions and which cage group was being looked at ($\chi^2 = 58.71$, df=2, $p < 0.001$).
When considering the pairs involved in interactions within each cage, in 2B antagonistic interactions occurred between all individuals, with 1-10 (adult male) the most dominant during these interactions followed by 1-09 (adult female, see Figure 4.7). Individual 1-09 was the most involved in the group, taking part in 45.5% of all social interactions that occurred in cage 2B. In cage 3B all individuals were involved in antagonistic interactions, with the elder individual in the pairing typically being the dominant in each interaction. The father (individual 1-04) was involved in comparatively few affiliative interactions (only 7% of 3B’s total interactions), which was due to his lack of involvement in play, which 1-16 and 1-18 frequently engaged in together. In cage 6B, the adults and juvenile all engaged in antagonistic interactions but the infant 1-25 was spared from these. The adult male was the dominant individual following the expected pattern, but the juvenile 1-21 frequently appeared dominant over her mother (1-13) although this may be caused by interactions being more of a ‘play fight’ than was obvious to the observer. The proportion of affiliative interactions in cage 6B was higher than the other two groups (refer back to Figure 4.6), likely in part due to the presence of an infant which attracted a lot of grooming and clinging behaviours and was involved in 36.7% of the group’s interactions. The adult male was rarely involved in affiliative interactions, featuring in just 4.0% of them.
Figure 4.7 A sociogram for each cage’s interactions, with each individual named and their sex indicated by a square (male) or circle (female). Both antagonistic (dashed line) and affiliative (solid line) interactions are shown, with arrows directed from the initiator to the receiver. The arrow thickness of each interaction reflects the percentage of the total interactions observed in that cage.

Among adults and subadults, sex significantly affected the expected number of affiliative and antagonistic interactions ($\chi^2 = 31.81$, df = 1, $p < 0.001$; see Figure 4.8). There was a significant difference in the number of affiliative social interactions expected to be performed by a male compared with a female ($\chi^2 = 81.90$, df = 1, $p <$
Of all affiliative interactions witnessed, females were involved in 73.3% with males involved in just 26.7%. Nearly all interactions females participated in were affiliative (94.8%) compared with only 76.2% for males. Males were involved in 67.4% of all antagonistic interactions witnessed, with females involved in only 32.6%. Overall, antagonistic interactions make up 23.8% of the total interactions in which males were involved, compared with just 5.2% for females, but the differences were not statistically significant ($\chi^2 = 5.52$, df = 1, $p = 0.019$).

![Figure 4.8](image)

**Figure 4.8** The effect of sex on the proportion of total social interactions that were antagonistic or affiliative, excluding juveniles and infants.

A significant association was found between an individual’s age class and the number of affiliative or antagonistic interactions in which it participated ($\chi^2 = 16.35$, df = 2, $p < 0.001$; see Figure 4.9). However, for antagonistic interactions alone, age has no significant effect on the number of expected interactions ($\chi^2 = 4.61$, df = 2, $p = 0.100$), with a fairly even split in which group accounts for the antagonistic interactions witnessed (Adults = 44.1%, Subadult = 33.4% and Young 22.5%). When considering affiliative interactions, young (juveniles and infants) account for 48.8% of all affiliative interactions witnessed compared with 28.3% by adults and 22.9% by subadults. This was supported by a significant correlation between age groups and the expected number of affiliative interactions performed ($\chi^2 = 59.45$, df = 2, $p < 0.001$), with pairwise comparisons showing young were different from both groups (Adults: $\chi^2 = 28.83$, df = 1, $p < 0.001$; Subadults: $\chi^2 = 49.73$, df = 1, $p < 0.001$).
0.001), but there was no significant difference between adults and subadults ($\chi^2 = 3.07, \text{df} = 1, p = 0.080$). When considering each group independently, of all the social interactions in which young engaged, 94.6% of them were affiliative, with just 5.4% antagonistic. For subadults 84.7% of their interaction repertoire was affiliative, and 83.9% for adults.

![Figure 4.9](image)

**Figure 4.9** The effect of age on the proportion of total social interactions that were antagonistic or affiliative.

When there is a social interaction between individuals, a vocalisation by one or both participants can occur. In this study there was a significant relationship between whether the interaction was antagonistic or affiliative and the likelihood of a vocalisation occurring ($\chi^2 = 155.57, \text{df} = 1, p < 0.001$). Vocalisations occurred in 13.7% of all interactions, which breaks down to 75.7% of antagonistic interactions and just 2.9% of affiliative. Among these vocal antagonistic interactions, 53.6% of vocalisations were performed by the ‘non-dominant’ participant, 17.9% by the dominant, and in the remaining 28.6% both individuals vocalised, although these differences were not significant ($\chi^2 = 5.64, \text{df} = 2, p = 0.06$). *T. delacouri*’s vocalisation behaviour will be further explored in Chapter 5.

A total of 52 distinctive bounding threat displays were witnessed during the social interaction study, 42% of them being attributable to adult males. Displays frequently occurred in response to another individual (either within the same cage or located elsewhere within the EPRC) performing a threat display, with an apparent domino
effect. Displays could also occur in response to external events, such as when airforce jet planes passed overhead. Vocal hoots typically accompanied the display if the performer was an adult male (see Chapter 5 for further discussion), and females and subadult males also regularly performed silent displays. Young were never seen to attempt a threat display in anything more than a form of play. Age significantly affected the frequency of threat displays ($\chi^2 = 16.71$, df = 2, $p < 0.001$), with adults accounting for 55.2% of displays and subadults 40.8%, but pairwise comparisons showed no significant difference between these two groups ($\chi^2 = 0.90$, df = 1, $p = 0.343$). Young only performed 4.0% of threat displays, and pairwise comparisons show this frequency of displays was significantly different from both adults ($\chi^2 = 17.64$, df = 1, $p < 0.001$) and subadults ($\chi^2 = 11.84$, df = 1, $p < 0.001$). There was no significant difference between the frequency that males, compared with females, perform threat displays ($\chi^2 = 6.43$, df = 1, $p = 0.011$).

### 4.3.3 Infant development

A captive male *T. delacouri* infant, born overnight on the 19/20 March 2011, was monitored from birth to three months of age to look at infant development. The infant, individual 1-25, was born with a bright orange natal coat as is customary for *T. delacouri* infants. The skin was fair with a white/pinkish colouration on the face, hands, and feet, all digits being hairless. The tail was thin with a black tip fading to orange at the base. As the infant was constantly nestled in his mother’s arms as a new-born, there were initially no clear photos of the infant’s appearance available. By two weeks of age there was a slight blackening of fur on the dorsal side with the tail predominantly black (see Figure 4.10).
Figure 4.10 Delacour’s male infant 1-25 at two weeks of age. Note the appearance of the tail in the image on the right.

At one month of age the tail was starting to become bushier, developing the ‘carrot’ shape (Workman, 2010b) of thick at the bottom, with a point, and thinning to the top, as seen in adult *T. delacouri*. The infant had a small tuft of fur on the top of the head, which would develop into the ‘mohawk’ of fur seen in adults (see Figure 4.11).

Figure 4.11 Delacour’s infant 1-25 at one month of age
As the infant reached two months of age there were notable changes, the coat becoming dark orange, especially on the infant’s back, hands and feet, while the head and ventral side remained a bright orange colour. The infant’s skin was darkening in colour, with the face taking on a grey colouration. The tail was continuing to thicken and become bushier and blacker in appearance (see Figure 4.12a). At three months the coat was beginning to blacken on the animal’s chest. The dorsal side of the coat was now fully black on the back and lower limbs. Exposed skin was also blacker, notably on the hands and feet, but also around the face and groin (see Figure 4.12b). Although the infant development study ended at three months, I visited and photographed the infant again at five months of age. By this stage 75% of the coat was black in colouration, with orange fur remaining only on the head, shoulders and around the groin. The tail still had an orange tinge to it in parts. The face was a dark grey colour, with the skin on the hands and feet completely black. The infant’s ‘mohawk’ of fur on the top of the head was thickening and becoming more pronounced (see Figure 4.12c).

**Figure 4.12** Delacour’s infant 1-25 at a) two months, b) three months, and c) five months of age.
The infant’s activity budget over time was divided into six key categories, the same as the activity budgets presented in Section 4.3.1, with the addition of the ‘cling’ category to represent infant carrying behaviours (see Figure 4.13). Changes in infant 1-25’s activity budget as he aged showed a significant difference in all behavioural categories between months (Inactive: $H = 28.55$, df = 2, $p < 0.001$; Feed: $H = 9.644$, df = 2, $p = 0.003$; Social: $H = 31.96$, df = 2, $< 0.001$; Cling: $H = 34.16$, df = 2, $p < 0.001$; Other: $H = 23.71$, df = 2, $p < 0.001$), with the exception of Locomotion ($H = 4.737$, df = 2, $p = 0.085$). Between months, pairwise comparisons show that the first month of life differs significantly from the second and third for Inactive (Second: $U = 42.0$, $p < 0.001$, $n_1 = 19$, $n_2 = 15$, Third: $U = 37.0$, $p < 0.001$, $n_1 = 19$, $n_3 = 28$), Social (Second: $U = 14.0$, $p < 0.001$; Third: $U = 27.0$, $p < 0.001$), Cling (Second: $U = 26.0$, $p < 0.001$; Third: $U = 15.0$, $p < 0.001$) and Other behaviour categories (Second: $U = 29.0$, $p < 0.001$; Third: $U = 61.0$, $p < 0.001$). There was however no significant difference between the second and third months for these categories (Inactive: $U = 123$, $p = 0.026$, $n_2 = 15$, $n_3 = 28$; Social: $U = 171.0$, $p = 0.331$; Cling: $U = 129.5$, $p = 0.040$; Other: $U = 194.0$, $p = 0.689$). For Feeding there was a significant difference between the second and third month ($U = 101.5$, $p = 0.002$, $n_2 = 15$, $n_3 = 28$), but no difference for the first month compared with the second ($U = 119$, $p = 0.348$, $n_1 = 19$, $n_2 = 15$) or third ($U = 161$, $p = 0.016$, $n_1 = 19$, $n_3 = 28$).

![Figure 4.13 Activity budget for a captive T. delacouri infant, divided in to a budget for newborn to one month of age, second and third months of life.](image)
Cling behaviours made up the vast majority of the activity budget for the first month of life, accounting for 86.0% with Inactive at 5.3% and Social at 4.8%. For the second month, Cling behaviours still made up the majority (40.7%), but were closely followed by Social (37.5%) and Inactive (20.3%) behaviours. In the third month of life, infant 1-25 most frequently displayed Social behaviours (40.7%), followed by Inactive (27.6%) and Cling (25.8%). For ‘Other’ behaviours the decrease in frequency over time can be attributed to the decrease of vocalisations, which were very prominent in the first month of life (1.7% of activity budget) but tailed off as the infant aged (0.2% and 0.1% respectively). Social behaviours were dominated by play, making up 86% of the Social category in the first month, then increasing to 99% and 98% in the latter two stages. An increase in these play behaviours, along with grooming, contributed to the increase in Social behaviour over time. Feeding behaviour increased as the infant aged and began to forage on leaves, making up 5.4% of the total activity budget in the third month of life. Initially nursing dominated feeding behaviour, although the low levels of nursing recorded, observed in just 13% of all focals, may not be a true representation because of difficulty in identifying the behaviour. The infant was often held close to the mother’s chest for prolonged periods, and the mother’s nipples were not clearly visible through her fur, making identification of when the infant was feeding and when it was simply resting extremely challenging. At four weeks of age 1-25 was seen to begin foraging on leaves, but initial ‘foraging’ appeared to be more in play, with little food consumed.

Whilst Play behaviour (encompassed in ‘Social’ within the activity budget, see the full ethogram in Appendix I for definitions), made up only 4.1% of the activity budget in the first month of life, this rapidly rose to 37.3% and 40.0% in the second and third months. Within the Play subgroup, there were three types of play recorded – object play, locomotive play and social play, i.e. play with another individual (see Figure 4.14). There was a significant relationship between the type of play performed and the infant’s age ($\chi^2 = 19185.22$, $df = 4$, $p < 0.001$), and this holds across all three play types when looked at individually (Object: $\chi^2 = 12975.88$, $df = 2$, $p < 0.001$; Locomotive: $\chi^2 = 5259.43$ $df = 2$, $p < 0.001$; Social $\chi^2 = 949.68$ $df = 2$, $p < 0.001$). The infant was first witnessed to engage in social play at four weeks of age, and this increased to 6.7% by the third month of life. Object play was initially
the main type of play at 64.6%, but this value steadily decreased. In contrast, locomotive play steadily increased to become the most performed play type making up 87.5% of all play activity by the third month. The infant, once mobile, rarely stayed in one place and was constantly running back and forth in locomotive play.

Infant 1-25 was first seen to be allomothered by his two and a half year old sister (individual 1-21) at just four days old. The infant protested against initial allomothering attempts, wriggling and vocalising loudly. Initial bouts were kept short at a maximum of 17 seconds, the mother (individual 1-13) remaining beside 1-21 and occasionally touching the infant. In the first two weeks allomothering occurred for just 10.6% of all clinging time, but as the infant aged allomothering frequency increased (see Figure 4.15). This was supported by a significant difference in the frequency of allomothering that occurred as the infant aged ($\chi^2 = 1660.09$, df = 2, $p < 0.001$), peaking at 28.6% in the second month of life, and 24.1% in the third. Nearly all clinging witnessed during the three months was ventral, with dorsal clinging only observed on three occasions (both with individuals 1-13 and 1-21), making up less than 0.01% of the total clinging behaviour. The infant’s father (individual 1-07), the only other animal in this cage group, was never seen to hold the infant.
Throughout the three month period, the infant progressed to independent movement. In the first two days of life 1-25 was held in his mother’s arms in a ventral cling, occasionally approached by his sister, with few other behaviours other than frequent vocalisations. The infant’s squeal appeared to function much like a baby’s cry, often squealing when losing grip on his mother, prompting her to readjust the hold, or when the mother began to move. Independent movement was first witnessed at 15 days old, with 1-25 clinging to the fence next to his mother and making attempts at quadrupedal locomotion. By one month of age the infant had grown bolder, and was frequently moving independently. At seven weeks I witnessed attempts by 1-13 and 1-21 to ‘push off’ the infant whilst he was clinging to them, in what appeared to be an attempt to dissuade and to encourage independence. The infant was now playing independently, but always within five metres of his mother. At nine weeks of age 1-25 was seen to independently move himself in to the holding cage at feeding time for the first time, having always previously been collected by 1-13 or 1-21.

Wild infants in general appear to show the same behavioural changes as the captive infant, mimicking the same pattern of increasing independence. However, focal hours for samples of wild infants were low, at just under 10 hours of data, so no statistical testing was possible, with only descriptive comparisons utilised.
Orange infants (aged 0 – 4 months, refer back to Table 3.2) spent 80% of their time engaged in cling behaviour, whilst Black infants (aged 5 – 9 months) spent just 4% of their time in cling behaviours. Wild Black infants spent most of their time either Inactive (59%) or engaged in Social activities (33.6%). As in the captive setting, play behaviour accounted for 99% of the Social behaviours witnessed in both Orange and Black infants.

4.4 Discussion

4.4.1 Activity budgets

An animal’s activity budget can be affected by a variety of factors, including population size, food availability, seasonality, human activities, and the individual’s sex and age (Clutton-Brock, 1977b; Saj et al., 1999; Steenbeek & Van Schaik, 2001; Zhou et al., 2007b; Jaman & Huffman, 2008; Prates & Bicca-Marques, 2008; Xiang et al., 2010). By comparing the activity budget of captive T. delacouri with that of wild individuals, we can gain an understanding of how ‘natural’ the behavioural profile of the captive animal is (Melfi & Feistner, 2002; McPhee, 2004; Hosey, 2005; Kerridge, 2005; Jaman & Huffman, 2008; Yamanashi & Hayashi, 2011). This has potential importance when the ultimate aim is, as is the case with the EPRC, to release the animals back into the wild, and could provide an indication of how well the animals may cope in a wild environment.

Wild T. delacouri spent significantly more time inactive than their captive counterparts (75.0% compared with 61.9%), but spent less time involved in feeding (21.3% versus 29.0%), social (1.9% versus 7.6%) and other (0.001% versus 0.1%) behaviours, with locomotion (1.8% versus 1.4%) not statistically different between the two groups. The only previous findings on T. delacouri activity budgets (Workman, 2010b), also conducted at Van Long, showed that the animals spent less time resting (just 61.3%) when compared with the wild results of this current study, and more time conducting the remaining other activities (feeding 28.2%, socialising 6.3% and travelling 4.2%). The reasons for these differences in findings is unclear – Workman used a similar methodology of focal animal full day follows, with data collected across the year as in this study, although it is probable that different groups of T. delacouri within the Dong Quyen area were studied. Some differences may
have been caused simply by the different makeup of the groups studied, and continuing changes in the Dong Quyen environment in the three years between the two studies. Additionally, differences in results could be attributed to the level of detail in recordings – in the current study behaviours were recorded according to a comprehensive ethogram (see Appendix I), and then later simplified into the five key categories to give an overall view of the activity budget whilst still allowing a detailed look at the finer points of the animals’ behaviour, whilst Workman’s focus was on feeding ecology with just the basic behaviour recorded. There may also be differences in observer interpretation of the different behaviours, despite similar definitions.

When comparing wild *T. delacouri* to other limestone langurs, *T. poliocephalus* showed similarly high levels of inactive behaviour, spending 66% of the day resting, 15% foraging, 11% moving and 8% engaged in social activities (Schneider et al., 2010). High levels of inactivity are expected for this group of highly folivorous colobines, as not only do they require a large amount of time to digest their fibrous leaf diet, but this diet also provides them with a relatively low energy intake, meaning that they cannot be particularly active (Davies & Oates, 1994; Huang et al., 2003; Hu, 2007; Workman, 2010b; Harding, 2011; Hadi et al., 2012). *T. leucocephalus* have been found to have inactivity levels ranging from 50% (Li & Rogers, 2004a) to 84% (in the summer/autumn; Huang et al., 2003); Li recorded feeding at 13%, moving 18%, social 19% and other 1%. For *T. francoisi*, inactive behaviour has been reported to make up 35.4% (Yang et al., 2007), 41% (Hu, 2007), and 51.5% (Zhou et al., 2007b) of the activity budget across a variety of studies, all conducted in China. Hu found feeding to made up 25% of the budget, a similar proportion to the current study, as did Zhou at 23.1%, whilst Yang reported a ‘foraging’ category at 31.7%. Locomotion (14.4% (Yang et al., 2007) to 17% (Hu, 2007)) and social (7.5% (Zhou et al., 2007b) to 17% (Hu, 2007)) levels were much higher than for *T. delacouri*, presumably linked to the lower level of resting recorded in the *T. francoisi* studies.

Differences in the activity budget of captive *T. delacouri* compared with their wild conspecifics were expected, as the animals live in vastly different environments. Animals housed at the EPRC live in basic wire fenced cages with concrete floors and bamboo climbing frames, are free of predator risks, and do not need to forage for
food. Previous studies of the activity budget of captive compared with wild primates have found that the captive group typically spend less time feeding and moving, and more time engaged in social and inactive behaviours (Melfi & Feistner, 2002; Kerridge, 2005; Yamanashi & Hayashi, 2011). It is presumed that these differences are linked to captive groups not needing to search for food, and hence having more time to spend on other activities. However, *T. delacouri* in this study did not always follow this trend; the captive individuals actually spent less time resting and more time feeding (refer back to Figure 4.1). It is possible that this unexpected finding may have been caused in part by sampling limitations – *T. delacouri* on Dong Quyen are thought to feed predominantly in the valleys between the cliffs (Workman, 2010b), which are largely out of sight of any observer, meaning that a lot of feeding behaviour may have been unavoidably missed. Additionally, the distance at which wild individuals were observed means that behaviours may not have been differentiated in such detail as in the captive environment. Alternatively, it could be a function of the captive environment where a set diet is fed and there are no ongoing foraging opportunities, meaning animals may be overeating to try and reach nutritional goals, as opposed to foraging throughout the day on a variety of sources as they would in the wild.

When looking at the sub-category breakdown of captive versus wild behaviour (refer back to Table 4.3), it can be seen that, whilst inactive behaviour for captive individuals was split between resting and scanning, for wild individuals 94.3% of their inactive budget was taken up by scanning. The need for frequent vigilant scanning behaviour for threats in the wild may explain why the wild individuals spent a greater proportion of their activity budget inactive than their captive conspecifics. Additionally, wild resting behaviour often takes place out of view of the observer, in the shade of the valleys or in caves, and hence may have been underrepresented, allowing scanning behaviour to make up the majority. Captive individuals may have been able to devote more time to social activities because of the lack of foraging pressures, and spent the majority of this time involved in grooming, whilst wild individuals seemed to predominantly use their social time for play – although this may be a construct of play being a highly visible activity to observe at distance, and grooming being more difficult to detect and potentially taking place out of view during resting times.
There were very few differences in the overall activity budget of male compared with female T. delacouri, with only ‘other’ behaviours in captive animals showing a statistical difference – which can be explained by males vocalising more frequently than females (discussed further in Chapter 5). Although not statistically different, both captive and wild females were more social than their male counterparts and were particularly active in grooming (discussed further in Section 4.4.2), whilst males took on the majority of scanning and vigilance behaviour, this finding being backed by Workman (2010b). Any differences between wild males compared with captive males, and wild females compared with captive females, are simply reflective of those already described in this study (refer back to Section 4.3.1) between the wild and captive populations. Hu (2007) reported that male T. francoisi spent more time resting and engaged in ‘other’ activities such as territorial behaviours than their female conspecifics, and Li and Rogers (2004b) also noted that male T. leucocephalus were responsible for the majority of territorial behaviour. Sex differences can be driven by biology, male primates typically spending less time feeding and more time resting than females, which could be due to male dominance meaning that they have access to higher quality food sources, and do not suffer the reproductive costs of pregnancy and lactation like females (Clutton-Brock, 1977b; Symington, 1988; Melfi & Feistner, 2002; Prates & Bicca-Marques, 2008; Li, 2009). Alternatively, such sex differences could also be a function of body size, with larger animals able to eat different amounts of different quality food items to meet their nutritional requirements (Clutton-Brock, 1977a; Melfi & Feistner, 2002; Otto, 2005).

When considering age class differences, wild young spent a significantly greater proportion of their activity budget on social behaviour (predominantly play) than adults or subadults, but no other differences were found. For the captive population, adults spent more time inactive, and less time involved in feeding and locomotion than subadults. It has been well documented that young tend to engage in more play behaviour, as part of their development, than adults or subadults (Hu, 2007; Zhou et al., 2007b; Schneider et al., 2010), with infant and juvenile T. leucocephalus committing 20.3% of their activity budget to play (Li & Rogers, 2004a), compared with 0.2% for adults (infant behaviour will be discussed further in Section 4.4.3). T. francoisi adults, like T. delacouri, were also found to spend more time resting and less time feeding than their subadult counterparts (Hu, 2007), along with subadults.
spending more time engaged in social play. Like sex differences, this may be linked to dominance positions within the group, with adults obtaining higher quality food sources allowing them more time for resting.

### 4.4.2 Social interactions

Social interactions can provide an important means of communication and relationship building amongst primates, along with giving assistance in necessary daily tasks, such as grooming (Poirier, 1970; Clutton-Brock, 1977b; Hinde, 1983; Strier, 2007; Ren *et al.*, 2010). The types of social interactions performed can differ between species, but generally they involve a number of affiliative interactions such as embracing, grooming and sexual behaviours, along with some aggressive interactions (Poirier, 1970; Leinfelder *et al.*, 2001; Strier, 2007; Klass & Cords, 2011; Lu *et al.*, 2013; Roberts & Cords, 2013). Over the course of this study, ten affiliative and three antagonistic social interaction types were witnessed amongst *T. delacouri*.

When comparing the three caged groups of *T. delacouri*, there were distinct differences in the level and type of interactions within each cage. The all-male cage group showed a high proportion of antagonistic interactions with very little reciprocal grooming. This high level of aggression is probably a function of cage composition, with a group of three males more likely to be aggressive to one another, combined with the ongoing battle for dominance between the two sons. Some apparent hierarchies within groups could be seen when comparing their interactions (refer back to Figure 4.7), age being the determining factor in the all-male group - with the oldest male, the father, not receiving any antagonistic interactions towards him. In the mixed-sex family groups, the adult males typically showed little interaction with their offspring, with only the occasional antagonistic interaction towards them. The majority of interactions occurred between the male-female pair, which were generally affiliative interactions, although the male appeared dominant with some antagonistic behaviours directed towards the female. The female frequently engaged with her offspring, predominantly in an affiliative manner. Li and Rogers (2004b) found no obvious social hierarchies amongst adults in wild *T. leucocephalus*, with only one observation of males showing dominance over females during feeding. This is not surprising, as instances of antagonistic behaviour of *T. delacouri* males towards females were uncommon in this study, and could be hard to
detect in a wild setting. In some species, dominance hierarchies are very obvious and can greatly affect an individual’s opportunities. Baboons, for example, have a strong matrilineal hierarchy, where high ranking animals are more frequently groomed, get better access to high quality food sources, and have increased mating opportunities (Rowell, 1967; Hamilton & Busse, 1982; Leinfelder et al., 2001; Bergman et al., 2003).

The sex/age class of an individual had an effect on its social interaction behaviour. Females were involved in 73.3% of all affiliative interactions witnessed, whilst males were more frequently involved in antagonistic interactions (67.4%). Age did not impact on the likelihood of being involved in an antagonistic interaction, but young were most likely to be involved in an affiliative interaction (48.8%), followed by adults (28.3%) and subadults (22.9%). Rowell (1967) also found, when looking at captive baboons, that males were involved in a higher proportion of antagonistic approach-retreat interactions than females or young, and that females were involved in the highest number of affiliative interactions.

4.4.3 Infant development

As a primate infant develops, it quickly moves through a series of both physical and behavioural changes, which can provide an interesting insight into the species and its evolutionary path (Hinde, 1983; Thierry, 1985; Hosey, 2005; Hu, 2007; Strier, 2007). Changes from being carried by a parent to independent movement, nursing to consumption of solid foods, and gradual transformations in appearance to take the adult form, mark significant biological changes in an individual (Davies, 1994; Hu, 2007). By closely studying an infant in a captive setting one can determine when these milestones occur, and how an infant’s activity budget changes as it ages to give a fuller picture of the species’ behaviour.

The captive T. delacouri infant (individual 1-25) was followed from birth to three months of age, and in this time underwent significant physical changes as his orange natal coat progressively blackened, as is typical for all limestone langur species (Rowe, 1996; Nadler et al., 2003; Groves, 2004; Nguyen Manh Ha, 2006; Hu, 2007; Bleisch et al., 2008c; Timmins & Boonratana, 2008; Xuan Canh et al., 2008; Schrudde et al., 2009; Workman, 2010b; Harding, 2011). There were also significant changes in the infant’s activity budget, with all behaviours except
locomotion showing significant differences across time (refer back to Figure 4.13). During the first month of life cling behaviours made up the majority of the activity budget as the infant was largely immobile (first independent movement seen at 15 days) and reliant on his mother, but this decreased in the second month as social (predominantly play) and inactive behaviours became increasingly utilised. By the third month of life social behaviours made up the biggest proportion of the activity budget, the infant principally engaging in locomotive play although inactive and cling behaviours still featured largely. When compared to the activity budget of the other captive T. delacouri age classes (refer back to Figure 4.1), the infant showed considerably higher levels of social behaviour, peaking at 40.7% at three months of age, compared with an average 7.6% for the captive group in Section 4.3.1. The infant spent less time engaged in feeding and inactive behaviours than the rest of the captive population, although the lack of inactivity is in part compensated for by the presence of the cling behaviour category, which when combined for the third month of life give an inactivity level of 53.4% (compared with an average 61.9% for the captive group). The low reported levels of feeding, which peaked at 5.4% at three months of age compared to 29.0% for the captive group, may to an extent be caused by the difficulty in detecting infant feeding, as it was hard to discern when the infant was simply being held to his mother’s chest rather than nursing. Of course, with a smaller body size infants have lower nutritional requirements so one may expect decreased feeding levels compared to adults, however infants are likely to feed at a slower rate (Clutton-Brock, 1977a; Nadler et al., 2003; Hu, 2007; Prates & Bicca-Marques, 2008).

Hu (2007) found that wild T. francoisi infants followed a relatively similar pattern of behavioural development to that reported here. Hu also reported that play became a prominent behaviour from one month of age, and gradually increased, representing 35% of the activity budget at three months (T. delacouri in this study = 37%). Infants were initially transported by ventral cling, as in T. delacouri, and independent locomotion increased sharply from two months of age, with more than half of movement being independent by six months of age. Allomothering was seen from two weeks of age with other adult females, progressing to allomothering by juveniles at five weeks, the infants initially protesting against any allomothering attempts, hence the bouts were short. Comparatively the T. delacouri infant was allomothered
from just four days of age by his juvenile sister (individual 1-21), although again with the same pattern of initial infant protest and short duration. This apparently early onset of allomothering may be a construct of the captive environment, or could be related to the allomotherer being a full sibling. Overall infant 1-25 spent about a quarter of his cling time being allomothered in the arms of his sister. Hu also noted allomaternal nursing in wild *T. francoisi*, but this was not possible for *T. delacouri* as there was only one nursing adult female present in the cage. *T. francoisi* infants were exclusively nursed for the first month of life and were seen to begin trying solid food from 34 days of age, with mixed feeding of solids and nursing continuing until 12-14 months, although the mothers were seen to occasionally refuse nursing of their infants from about four months of age. Infant 1-25 was also witnessed trying his first solid food at about four weeks of age, and continued to both nurse and feed on leaves throughout the remaining two months of the study.

Studies of the activity budget of other limestone langur infants supported the trend of a prominence of social behaviours compared to other age classes, particularly play. *T. poliocephalus* infants were reported to spend 33% of the day engaged in social behaviours (Schneider et al., 2010), and also spent a lower proportion of time resting compared with their adult and juvenile counterparts, similar to *T. delacouri*. *T. leucocephalus* immatures (juveniles and infants combined) were reported to spend 20.3% of their activity budget playing, compared to 0.2% for adults, and also followed the pattern of spending less time feeding and resting than adults (Li & Rogers, 2004a). Moving outside the limestone langur group, a study of Sichuan snub-nosed monkeys (*Rhinopithecus roxellana*) also found that infants spent a considerably larger proportion of their time involved in social behaviours, and less time feeding and inactive than other sex age classes (Li, 2009). On the other hand, whilst a study of black-and-gold howler monkeys (*Alouatta caraya*) found that infants spent more time moving around to explore their environment and less time resting than adults, they did not show a considerably greater level of socialising than the other age classes (Prates & Bicca-Marques, 2008).

When comparing the results of captive infant 1-25 with the observations of wild *T. delacouri* at Dong Quyen, they appeared to show roughly the same pattern of behavioural development, graduating from predominantly clinging behaviours to independent activities as they aged, with play forming a major component of their
behavioural repertoire. This indicates that whilst the study of infant 1-25 is limited by his captive setting and the small social group of immediate family members, broadly speaking it is likely that he has shown a typical picture of behavioural development in T. delacouri infants, and that a wild study (although logistically very difficult) would show similar patterns.

4.5 Summary

T. delacouri showed significant differences in the activity budget between wild and captive populations, along with some differences between age classes, but there were minimal sex class differences. Thirteen different social interactions were identified, with an individual’s sex and age class affecting the types of interaction they were likely to be involved in. A captive T. delacouri infant showed significant changes in his behaviour and appearance as he aged, becoming progressively more independent and social.

Potential bias during the data collection for this study was caused by the differing observation conditions in the captive versus wild environment. In the wild it is probable that, when the animals retreated to the shaded valleys of the cliffs, they tended to perform certain behaviours (for example feeding, resting, grooming), meaning that these behaviours may have been underrepresented in observations as they were being conducted out of view. This was carefully considered when interpreting results, to avoid drawing false conclusions. Additionally, wild animals were being monitored at distance, and this meant it could occasionally be difficult to accurately determine in detail what behaviour was being conducted, so extra care had to be taken, and focal observations abandoned when it became too difficult. The captive animals’ behavioural repertoire was limited by their confined space within the cage, and the orchestrated social group they had been placed in. Although there were broad similarities found between the two populations, further investigation is needed into the differences identified to determine to what extent these may have been affected by sampling limitations.

This study provided a valuable comparison of how the behaviour of the wild and captive populations differed, which gives an important insight into the likely success of any future releases of captive T. delacouri into the wild, and highlights areas
where behavioural differences in the two populations may cause problems (the first *T. delacouri* release is discussed in Chapters 6 and 7). By having a clear understanding of these differences, there is the potential to attempt to modify and enrich the captive population’s environment so that their behaviour more closely mimics a wild population, which would aid the EPRC’s continuing goal to release endangered primates back into the wild. Additionally, by having a greater understanding of how the species interacts, potential hierarchies within groups, and the time-scales involved in infant development, conservationists have a better idea of how to manage the species’ social groupings in both captive and wild environments for optimal outcomes.
An adult male Delacour’s langur moving across the karst on Dong Quyen, Vân Long Nature Reserve
Vocalisation Behaviour

5.1 Introduction

Vocalisations can be an important form of auditory communication for primates, allowing the transfer of information from one individual to another (Marler, 1967; Byrne, 1982; Davies & Oates, 1994; Hauser, 2000; Manning & Dawkins, 2002; Martin & Bateson, 2007). Animals may vocalise for a variety of reasons, such as to assert their dominance (Salmi et al., 2013), mark their territory (Ramakrishnan & Coss, 2000; Lazaro-Perea, 2001), give a warning/alarm call to their conspecifics (Seyfarth et al., 1980; Ramakrishnan & Coss, 2000; Srivathsan & Meier, 2011), indicate the location of a food source (Dittus, 1984; Gros-Louis, 2004), maintain social bonds (Gros-Louis, 2002; Greeno & Semple, 2009), coordinate group movements (Sabatini & Ruiz-Miranda, 2008), or as part of a mating call sequence (Semple, 2001; Keith et al., 2009). Additional communication behaviours can also be used to convey these messages, with the use of visual signals such as gestures and facial expressions common in primates (Hauser, 2000), although beyond the scope of this study.

By studying an animal’s vocalisations, researchers can gain a greater understanding of how the species interacts and communicates with one another, and how the response of one individual may affect another (Marler, 1967; Hauser, 2000; Manning & Dawkins, 2002). Vocalisation behaviour can provide insight into the animal’s thought processes and their relationship with their environment. Vocalisation studies can be useful to help identify taxonomically different species who may otherwise appear the same, and have been extensively utilised to resolve taxonomic relationships of both *Nomascus* and *Hylobates* gibbons (Konrad & Geissmann, 2006; Groves, 2007; Keith et al., 2009), along with *Tarsius* (Brandon-Jones et al., 2004). In some species, such as killer whales, *Orcinus orca* (Miller & Tyack, 1998), Amazonian manatees, *Trichechus inunguis* (Sousa-Lima et al., 2002), chimpanzees, *Pan troglodytes* (Kojima et al., 2003), and orangutans, *Pongo pygmaeus wurmbii* (Lameira & Wich, 2008), specific individuals can be identified by
their unique call, not only aiding in intragroup communication but also providing researchers with a tool to closely monitor each member of a group. There have also been incidents of geographic ‘dialects’ of vocalisations being recorded in primates, where the calls of one species differ across regions (Byrne, 1982; Maeda & Masataka, 1987; Mitani et al., 1999; Keith et al., 2009). Vocalisations can be a useful signal when conducting surveys in difficult habitats for the presence of a species, not only identifying the species occurrence in the area, but also assisting in estimating the population size (Rawson, 2004; Duckworth et al., 2010).

There have been some studies on the vocalisation behaviour of langurs, predominantly focusing on the *Presbytis* and *Semnopithecus* genera, but there is little concentrated research on the *Trachypithecus* genus or the limestone langur group within this. Wich et al. (2003) showed loud calls in Thomas langurs (*Presbytis thomasi*) in Sumatra differed in their structure to reflect different social contexts, and females in the group responded accordingly depending on the type of loud call given. Vogel (1973) compared the vocal repertoire of Indian langur (*Semnopithecus entellus*) groups located in two different habitats, and found differences in vocalisation functions, which were attributed to the different environmental pressures between the habitats. A study of western purple-faced langurs (*Semnopithecus vetulus nestor*) in Sri Lanka documented the loud calls of males to assist in future population density surveys of this shy species (Eschmann et al., 2008).

This chapter provides a preliminary overview of the different vocalisation behaviours used by captive *T. delacouri* as part of their daily behaviour from an ecological function perspective, identifying the different call types by utilising spectrogram technology to analyse their specific attributes. The influence of sex, age, and the time of day on vocalisation behaviour was also investigated, along with comparing the vocalisation behaviour of *T. delacouri* to that of other limestone langur species.
5.2 Methods

5.2.1 Vocalisation type, use and functions

Seven vocalisation types performed by *T. delacouri* and some of the other five limestone langur species held at the Endangered Primate Rescue Center (*T. ebenus, T. francoisi, T. hatinhensis, T. laotum, and T. poliocephalus*) were identified during my initial weeks at the EPRC. Full descriptions of the call types can be found in Table 5.1, with the name of each call type largely indicative of the sound produced. In addition, for audio clip examples of the vocalisations see Appendix II and the attached DVD.

Table 5.1 The seven vocalisations identified to be used by *T. delacouri* at the Endangered Primate Rescue Center.

<table>
<thead>
<tr>
<th>Vocalisation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Click</td>
<td>Sequence of very soft ‘clicking’ noises, with gap between clicks decreasing as the call tails off; often several calls given in a row, typically by an adult male</td>
</tr>
<tr>
<td>Grunt</td>
<td>Short, deep ‘grunt’ noise, typically by an adult male</td>
</tr>
<tr>
<td>Hoot</td>
<td>Loud and deep ‘hooting’ noise performed during a bounding display</td>
</tr>
<tr>
<td>Meow</td>
<td>Similar in sound to a domestic cat’s meow, a drawling call typically given by sub-adults</td>
</tr>
<tr>
<td>Screech</td>
<td>High pitched ‘screeching’ call, typically given during an aggressive altercation</td>
</tr>
<tr>
<td>Squawk</td>
<td>Short throaty ‘squawk’ of mid pitch, typically given during an aggressive altercation</td>
</tr>
<tr>
<td>Squeal</td>
<td>Used by infants and juveniles; a long and high pitched ‘squealing’</td>
</tr>
</tbody>
</table>

All-occurrence samples of 60 minutes of length (Altmann, 1974) were taken on each captive group, rotating around caged groups in an effort to achieve even sampling effort (refer back to Section 3.7 for further detail). In total, 11 cages were sampled (refer back to Table 3.2), including three *T. delacouri* cage groups (10 individuals), along with *T. ebenus* (1 individual), *T. francoisi* (3 individuals), *T. hatinhensis* (16 individuals), *T. laotum* (1 individual), and *T. poliocephalus* (3 individuals) groups. Any vocalisation witnessed was noted and classified by its vocal type, with the individual who performed the vocal, possible function, vocal length, number of calls in a bout, and time of day recorded. The behaviour of the
performer and other group members at the time of the vocalisation were also noted, using the complete behavioural ethogram (see Appendix I) to classify behaviours. In total 2033 calls were recorded over 150h and 38m of sampling across the 11 cages between May – June 2011, with 73% of this time focused on the target species of this thesis, *T. delacouri*.

Although sampling effort was evenly split where possible amongst cages, the differing composition of each cage resulted in some sex/age classes being sampled much more frequently than others. To account for this, the data were adjusted, when necessary, by translating call numbers into a rate and extrapolating these values out to reflect the expected number of calls if all sex/age classes had been sampled for an even amount of time. It is possible that the sex/age composition of the cage may itself impact on the vocalisation rate, but sample sizes in this study were not large enough to be able to take this into account. Descriptive statistics were used to look at the percentage breakdowns of call frequencies across call types, species, and sex/age classes. When considering call function, only data from *T. delacouri* individuals were analysed, as there were insufficient data to consider each species individually, and pooling all species may have caused bias due to potential interspecific difference. Chi-square analyses were used for hypothesis testing looking at the call frequency between sex/age classes and differing time of day. All assumptions of chi-square testing were met (Zar, 1999), using count data, with the significance level set at $\alpha = 0.01$ to allow for multiple testings.

When looking at the likely use and function of the different call types, only samples from *T. delacouri* individuals were analysed to avoid any potential bias that may result from interspecific differences.

All collation, descriptive statistics and graphics in this chapter were done in Microsoft Excel 2010 (Microsoft Corporation, 2010), and all hypothesis testing in GenStat 14.2 (VSN International Ltd., 2011).

### 5.2.2 Vocalisation spectrograms

Throughout the all-occurrence sampling of limestone langurs’ vocalisations at the EPRC, some vocalisations were opportunistically recorded using a Panasonic HDC-SD60 video camera. Each recording was edited and coded, with field notes surrounding the vocalisations attached, and all callers and call types identified. All
recordings were analysed using Raven Pro 1.4 (Cornell Lab of Ornithology Bioacoustics Research Program, 2011) – an interactive sound analysis software. Spectrograms were created using the software’s inbuilt digital Fourier Transformations system, using a Blackman window type with a size of 50.9ms and a DFT (discrete Fourier Transformation) size of 4096 samples (Elemans et al., 2008; Charif et al., 2010). Spectrograms give a visual representation of the sound, with time (in seconds) along the x-axis and frequency (in hertz) on the y-axis. The colouration of the graph represents the power (in decibels) of the sound, with dark shading indicating greater power. In total 245 recorded vocalisations from six limestone langur species across a variety of sex/age classes were of sufficient quality, once converted into spectrogram format, for analysis.

When analysing spectrograms, seven call attributes were used to help quantitatively define each call and allow for comparisons between call types. Delta Time (1) measures the time in seconds between the start and the end of each call, Low Frequency (2) measures the lowest frequency bound of the call in hertz, High Frequency (3) the highest frequency bound, and Delta Frequency (4) the difference between these last two attributes giving an assessment of the frequency range of the call (Charif et al., 2010). Average Power (5) is calculated by examining the power of the call across its entire spectrum and returning the mean value, in decibels, for the call as a whole; Maximum Power (6) is the most power exerted at any one time during the call which is shown with the darkest shading, with Peak Frequency (7) being the frequency at which Maximum Power occurs during the vocalisation. If a vocalisation produced harmonics, just the fundamental frequency was used for analysis (Geissmann, 2003; Konrad & Geissmann, 2006; Elemans et al., 2008).

All spectrogram attribute data were exported to Microsoft Excel and catalogued, with descriptive statistics for call and species’ groups calculated. Analysis of Variance tests were conducted in GenStat to look at differences among call types within species as well as interspecific differences where possible. If there were fewer than five replicates for a particular group type it was not included in analyses as the sample was considered too small to be representative and may affect statistical power. All assumptions for ANOVA testing were met (Zar, 1999), with data transformed using log or square root transformations when necessary in order to
meet the assumption of equal variances. The significance level was set at $\alpha = 0.01$ to allow for multiple testings.

5.3 Results

5.3.1 Vocal types and functions

Of the seven vocalisation types given by the limestone langurs in this study (refer back to Table 5.1), 60.2% of the 2033 witnessed calls were Grunts (see Figure 5.1).

![Figure 5.1](image.png)

**Figure 5.1** The percentage breakdown for the vocal type of all vocalisations heard from the captive limestone langurs monitored during this study, with all species combined.

When looking at *T. delacouri* alone, the percentages were hardly different from those for the limestone langur sample as a whole, with Grunts making up 61.2% of all *T. delacouri* calls witnessed (see Figure 5.2). Squeals accounted for 16.5% of *T. delacouri* calls, Clicks 8.6% and Hoots 6.8%. For *T.ebenus* and *T. laotum* only Clicks and Grunts were heard (see Figure 5.2), but this is likely due to only adult males of these species being sampled (refer back to Table 5.1). The sex/age class composition of the species sampled should be taken in to consideration when looking at the results, and the impact of a caller’s sex/age on vocal type will be explored later in this chapter.
Figure 5.2 A percentage breakdown, separated according to species, of the vocalisation types performed by the captive study animals.

Vocalisations were often performed in a bout, which is a series of one call type with a gap of five seconds or less between calls, and the average number of calls per bout differs depending on call type. A Hoot bout typically contains the largest number of calls, with an average of 4.9 per bout (see Table 5.2). Squawks, Meows and Screeches more commonly occur as a single one-off call. Click bouts were characteristically the longest, at an average of 16.5 seconds, whilst Squawks last only 3.2 seconds on average.
Table 5.2 Across all species sampled in this study, the average number of calls in a bout for each vocal type and the average bout length (in seconds) is presented.

<table>
<thead>
<tr>
<th>Vocal Type</th>
<th>Average # of Calls in Bout</th>
<th>Average Bout Length (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Click</td>
<td>3.5</td>
<td>16.5</td>
</tr>
<tr>
<td>Grunt</td>
<td>1.8</td>
<td>4.7</td>
</tr>
<tr>
<td>Hoot</td>
<td>4.9</td>
<td>13.7</td>
</tr>
<tr>
<td>Meow</td>
<td>1.4</td>
<td>4.4</td>
</tr>
<tr>
<td>Screech</td>
<td>1.5</td>
<td>5.5</td>
</tr>
<tr>
<td>Squawk</td>
<td>1.5</td>
<td>3.2</td>
</tr>
<tr>
<td>Squeal</td>
<td>3.1</td>
<td>10.4</td>
</tr>
</tbody>
</table>

When considering the likely use and function of the different call types for *T. delacouri*, Click vocalisations were noted to be typically given whilst the animal was engaged in inactive behaviour: 97% of Clicks occurred with the caller in a stationary sitting position (see ‘IS’ in the ethogram, Appendix I). The function remains unclear, with only 3% of calls being recognised as ‘response’ behaviours and 8% to show ‘distress’ – typically involved with territorial vigilance behaviour, leaving the remaining 89% listed as ‘unknown’.

Grunt vocalisations, like Clicks, were typically emitted whilst the animal was in an inactive stationary sitting position (IS), with 90.4% of calls occurring during this behaviour. Grunts were, however, also used in a variety of other behaviours including locomotive play (PL = 4.8%), quadrupedal locomotion (LQ = 3.2%), concentrated feeding (FC = 1.0%) and one-off instances during standing scans (IA), contact aggression (TC) and rump holding (SH, all 0.2%). For the majority of calls the function was recorded as ‘unknown’ (76.1%), although there were cases where a Grunt was used as a ‘response’ (12.9%) to another animal’s vocalisation, as well as in excitement (8.0%) - primarily at feeding time. It was also identified to function in ‘distress’ (1.8%), ‘aggression’ (0.6%) and as a ‘request’ (0.6%).

Hoot vocalisations were the most distinctive calls given by *T. delacouri*, and were used as part of a territorial ‘bounding display’ performed by adult males. Hoots were utilised exclusively for this purpose with all recorded instances of the vocalisation occurring during threat display (TD) behaviours, presumably functioning to show ‘aggression’ towards other groups.

Meow vocalisations, so named as they sounded similar to a cat’s meow, were observed only in *T. delacouri* subadult males. They were performed whilst the
animal was inactive (IS = 95.8%, IR = 4.2%) but the function was listed as ‘unknown’ in all instances.

Screech vocalisations were used exclusively during altercations with another individual; 54.5% were identified as having a ‘distress’ function and 45.5% in ‘aggression’. This is reflected by 36.4% of calls being given whilst the performer was engaged in aggressive contact behaviour (TC), 27.3% during submissive behaviour in response to a threat (TS) and 9.1% during aggressive non-contact behaviour (TN).

A Squawk call was typically used during fights, 64.9% of them being given during an altercation between individuals (TS submissive individual = 29.7%, TN aggressor non-contact = 18.9%, TC aggressor contact = 16.2%). Moreover, 35.1% of these calls were identified as having a ‘distress’ function, and 32.4% an ‘aggression’ function. ‘Excitement’ was also identified as a function in 18.9% of calls, while the remaining 13.5% of calls were classed as having an ‘unknown’ function. Other behaviours being conducted by performers included play (locomotion PL = 13.5%, with another PA = 2.7%), inactive scanning (IS = 16.2%) and concentrated feeding (FC = 2.7%).

Finally, vocal Squeals seemed to function broadly as a call performed primarily by infants/young in a variety of situations, similar to a baby’s cry. Considering function, 29.2% of calls seemed to occur due to ‘excitement’ and 28.1% for ‘distress’, with the remaining 42.7% of calls being classed as ‘unknown’. The call was most commonly given whilst the performer was engaged in play behaviour (locomotive PL = 47.2%, with another PA = 5.6%), but it also occurred during quadrupedal locomotion (LQ = 20.2%) and inactive scanning (IS = 18.0%). Other behaviours in which performers were engaged included clinging (ventral hold NV = 3.4%, ventral hanging NH = 2.2%), climb (LC = 1.1%), non-contact aggression (TN = 1.1%), and submissive (TS = 1.1%).

5.3.2 Effect of sex/age class on vocalisations

There was a significant relationship between the sex/age class of an individual, and the frequency at which it would vocalise ($\chi^2 = 1040.17$, df = 5, $p < 0.001$ at the significance level of $\alpha = 0.01$; see Figure 5.3). This significant difference stands across all pairwise combinations when tested independently (df = 1, $p < 0.001$ for all
pairs). All values in this section were adjusted where necessary for unequal watching times between the sex/age classes. When looking exclusively at *T. delacouri*, there was a significant difference in the frequency of vocalisations across the sex/age classes ($\chi^2 = 920.90$, df = 4, p < 0.001), which again held across all pairwise combinations (df =1, p < 0.001 for all pairs).

![Expected % of Total Vocalisations](image)

**Figure 5.3** A breakdown of the percentage of calls each sex/age class performs. Values for all species combined are given, along with *T. delacouri* by itself.

Adult males accounted for the bulk of calls, performing an expected 45.2% of all calls heard, while *T. delacouri* adult males performed an expected 52.6% (see Figure 5.3). When considering this as a rate, *T. delacouri* adult males performed 8.2 calls per hour on average (see Table 5.3). Orange Infants, which means infants aged between 0 – 4 months (refer back to Table 3.1), were the second most prolific callers, making up an expected 28.5% of total limestone langur calls and 32.3% for *T. delacouri*. This equates to an average rate of 5.4 calls per hour for all species, and 5.1 per hour for *T. delacouri* alone. Females made very few calls; the sole subadult female (a *T. hatinhensis*) was never heard to vocalise during the study, and adult females called at an average of only 0.1 per hour.
Table 5.3 Vocalisation rate per hour, broken down in to sex/age classes for all limestone langur species as a whole and *T. delacouri* separately. Classes marked N/A were not available for sampling.

<table>
<thead>
<tr>
<th>Sex/Age Class</th>
<th>Vocalisation rate per hour</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Limestone langurs</td>
</tr>
<tr>
<td>Adult Male</td>
<td>8.5</td>
</tr>
<tr>
<td>Adult Female</td>
<td>0.1</td>
</tr>
<tr>
<td>Subadult Male</td>
<td>1.4</td>
</tr>
<tr>
<td>Subadult Female</td>
<td>0.0</td>
</tr>
<tr>
<td>Juvenile</td>
<td>0.7</td>
</tr>
<tr>
<td>Infant Black</td>
<td>2.7</td>
</tr>
<tr>
<td>Infant Orange</td>
<td>5.4</td>
</tr>
</tbody>
</table>

When looking at all six limestone langur species sampled together as a whole, there was a significant association between the expected number of calls and an individual’s sex ($\chi^2 = 600.87$, df = 1, p < 0.001). With juveniles and infants excluded, males gave 98.6% of all calls. When considering the impact of age, there was a significant association between the expected number of calls and the individual’s age class ($\chi^2 = 353.36$, df = 2, p < 0.001). Subadults performed only 7.6% of all expected calls, whilst adults and young made up the rest at 46.0% and 46.4% respectively. Pairwise comparisons showed that subadults differed significantly from both adults ($\chi^2 = 326.39$, df = 1, p < 0.001) and young ($\chi^2 = 330.19$, df = 1, p < 0.001). As would be expected given the percentage values, there was no significant difference between adults and young ($\chi^2 = 0.02$, df = 1, p = 0.90).

When looking at *T. delacouri* on its own, there was a significant difference between males and females in the rate of vocalisations ($\chi^2 = 558.45$, df = 1, p < 0.001). Excluding juveniles and infants, males were responsible for 97.8% of all calls made by *T. delacouri*. When comparing adults, subadults and young there was again a significant association between age and the number of calls ($\chi^2 = 284.37$, df = 2, p < 0.001). This difference held across all pairwise comparisons (adults vs. subadults $\chi^2 = 293.58$, df = 1, p < 0.001; adults vs. young $\chi^2 = 33.26$, df = 1, p < 0.001; subadults vs. young $\chi^2 = 146.09$, df = 1, p < 0.001). Adults made the majority of expected calls, at 54.0% with young accounting for 36.3% and subadults just 9.8%.
When looking at call types, there were some clear distinctions with some vocalisations being given exclusively by a certain sex/age class. Click and Hoot vocalisations were only performed by adult males throughout the study, across all species. Meow vocalisations were performed only by subadult males, and only by the two *T. delacouri* subadult males. They were not heard from *T. hatinhensis*, the only other species of which subadult males were present (refer back to Table 3.2).

Grunts were predominantly performed by adult males, making up 98.3% for all limestone langur species combined, and 99.6% for *T. delacouri* alone (see Figures 5.4 and 5.5). Adult females and subadult males were sporadically heard to perform the occasional Grunt call. The high amount of adult males in the study (ten individuals in total), and their high frequency of Grunting contributed to the large number of Grunt calls heard throughout the study – making up 60.2% of all vocalisations heard (refer back to Figure 5.1). Further sections comparing sex and age classes used adjusted values accounting for the unequal sampling times between sex/age classes.

Screech calls were performed by several classes – males and females, adults and subadult, along with juveniles. Subadult males were the most prominent performer making up 46.3% of Screech calls for limestone langurs and 55.9% for *T. delacouri* (see Figures 5.4 and 5.5). These results should be viewed with caution as this was the least common vocal type during the study, so results were taken from a very small sample size.

Squawk vocalisations, like Screeches, were used by a wide range of individuals (see Figures 5.4 and 5.5). They were most frequently utilised by juveniles, at 40.8% for limestone langurs and 41.3% for *T. delacouri*. Again, there was a relatively small sample size for this call type so results should be interpreted with caution.

Infants dominated Squeal vocalisations, making up 88.9% (black and orange infants combined) of all performers for limestone langurs and 82.8% for *T. delacouri* (see Figures 5.4 and 5.5). Juveniles and subadults made up the rest of the callers, whilst adults were never witnessed to perform this call.
Figure 5.4 The breakdown of performers by sex/age class for the different vocalisation types, with percentages given, when looking at all six limestone langur species combined. Hoot, Click and Meow calls are excluded from this figure as they were performed only by one sex/age class.

<table>
<thead>
<tr>
<th></th>
<th>Adult Male</th>
<th>Adult Female</th>
<th>Subadult Male</th>
<th>Juvenile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grunt</td>
<td>0.6%</td>
<td>1.1%</td>
<td>98.3%</td>
<td></td>
</tr>
<tr>
<td>Screech</td>
<td>8.4%</td>
<td>27.1%</td>
<td>18.2%</td>
<td>46.3%</td>
</tr>
</tbody>
</table>

Figure 5.5 The breakdown of performers by sex/age class for the different vocalisation types, with percentages given, when looking at *T. delacouri* alone. Hoot, Click and Meow calls are excluded from this figure as they were only performed by one sex/age class.

<table>
<thead>
<tr>
<th></th>
<th>Adult Male</th>
<th>Adult Female</th>
<th>Subadult Male</th>
<th>Juvenile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Squawk</td>
<td>7.1%</td>
<td>40.8%</td>
<td>21.1%</td>
<td>8.4%</td>
</tr>
<tr>
<td>Squeal</td>
<td>7.4%</td>
<td>59.8%</td>
<td>29.1%</td>
<td>3.7%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Adult Male</th>
<th>Adult Female</th>
<th>Subadult Male</th>
<th>Juvenile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grunt</td>
<td>0.4%</td>
<td>99.6%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Screech</td>
<td>11.0%</td>
<td>55.9%</td>
<td>33.1%</td>
<td></td>
</tr>
<tr>
<td>Squawk</td>
<td>41.3%</td>
<td>23.5%</td>
<td>12.4%</td>
<td>14.0%</td>
</tr>
<tr>
<td>Squeal</td>
<td>12.4%</td>
<td>82.8%</td>
<td>4.8%</td>
<td></td>
</tr>
</tbody>
</table>
Given that there was a clear association between a performer’s sex/age class and vocalisation, a presentation of the frequency of different vocalisations adjusted for unequal watching times between sex/age classes is necessary to avoid potential bias in the sampling. Figure 5.6 shows the expected percentage breakdown of the call types, and when looking at all limestone langurs sampled as a group. Grunts were still the most prominent call type at 41.1% closely followed by Squeals at 39.1%. This was a drop for Grunts from the initially reported level of 60.2% of all calls, which was caused by the high number of adult males in the sample who have been shown to be prolific Grunters. On the other hand, the percentage of Squeal calls has risen from 18.8%, as this call was predominantly performed by infants and there were only four infants available for sampling in the study, meaning they were underrepresented. When looking at *T. delacouri* alone, Squeals were the majority at 47.6%, followed by Grunts at 35.8%. The five other call types remained as a minor feature in the species’ vocal repertoire.

![Figure 5.6](image.png)

**Figure 5.6** The adjusted percentage breakdown by vocal type of all vocalisations, allowing for unequal watching times between the different sex/age classes. These adjusted figures present a more accurate view of the occurrences of the species’ full vocal repertoire. Figures for all six limestone langur species combined, along with *T. delacouri* on its own, are given.

### 5.3.3 Effect of time of day on vocalisations

There was an even spread of vocalisations performed across the day, with time of day (morning, noon or afternoon) having no significant effect on the frequency of vocalisations either for *T. delacouri* ($\chi^2 = 3.20, \text{df} = 2, p = 0.202$) or for all limestone langur species grouped ($\chi^2 = 3.48, \text{df} = 2, p = 0.176$). Analyses to look at the use of
the different call types throughout the day were not possible due to insufficient sample sizes.

There was a notably large increase in vocal activity preceding and during feeding times (which occurred on a regular schedule at the EPRC, refer back to Section 3.2.2), which were accompanied by heightened ‘excitement’, and ‘anticipation’ of being fed. Small fights often took place during feeding, frequently resulting in Screech, Squawk or Squeal calls. This was a major disadvantage of conducting this study in a captive setting, and was a contributing factor to why further analyses looking at how time of day effects vocal behaviour were not conducted.

5.3.4 *T. delacouri* spectrogram analysis

For *T. delacouri*, 123 vocalisations were converted into spectrograms for analysis (see Figure 5.7). For each call identified, its length (delta time), low frequency, high frequency, frequency range (delta frequency), peak frequency, average power and max power were calculated using Raven Pro 1.4 software (Cornell Lab of Ornithology Bioacoustics Research Program, 2011). Sixteen Click calls, 43 Grunts, 17 Hoots, 10 Meows, 3 Screeches, 3 Squawks, and 31 Squeals were analysed (see Table 5.4). All results from call types with less than five replicates should be viewed with caution as data may not be representative.
a) Click

b) Grunt

c) Hoot

d) Meow
Figure 5.7 Spectrogram examples for all seven identified *T. delacouri* call types, with the call marked out in a dotted line. Time in seconds is on the horizontal axis, frequency in kHz on the vertical axis, and power in decibels represented by the shading (dark colouration = greater power). Scales between spectrograms are not all equal due to differences in call type attributes, so care should be taken when comparing different calls. Due to the captive setting of these recordings there is interference visible (e.g. cage rattles in Hoot calls as the animal completes bounding display, or people’s movements/actions) along with natural interferences (e.g. insect calls visible as dark constant lines and bird/squirrel vocalisations). All spectrograms were produced using digital Fourier Transformations in Raven Pro 1.4.
Table 5.4 Values, from the fundamental frequencies, $F_0$, for the seven attributes analysed for each *T. delacouri* call type from their spectrogram transformations, along with the number of harmonics identified. The average value from the replicates is given, along with the minimum and maximum values identified. Vocalisations marked with * show call types with low replicate numbers.

<table>
<thead>
<tr>
<th>Call Type</th>
<th>Delta Time</th>
<th>Low Freq</th>
<th>High Freq</th>
<th>Delta Freq</th>
<th>Peak Freq</th>
<th>Average Power</th>
<th>Max Power</th>
<th>Number of Harmonics</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Click</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>1.70</td>
<td>208</td>
<td>633</td>
<td>425</td>
<td>387</td>
<td>63</td>
<td>79</td>
<td>0</td>
</tr>
<tr>
<td>Minimum</td>
<td>1.40</td>
<td>123</td>
<td>470</td>
<td>470</td>
<td>293</td>
<td>-</td>
<td>73</td>
<td>0</td>
</tr>
<tr>
<td>Maximum</td>
<td>3.13</td>
<td>412</td>
<td>1330</td>
<td>918</td>
<td>492</td>
<td>-</td>
<td>83</td>
<td>0</td>
</tr>
<tr>
<td><strong>Grunt</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>0.20</td>
<td>335</td>
<td>1567</td>
<td>1233</td>
<td>914</td>
<td>64</td>
<td>79</td>
<td>0.68</td>
</tr>
<tr>
<td>Minimum</td>
<td>0.11</td>
<td>44</td>
<td>885</td>
<td>366</td>
<td>199</td>
<td>-</td>
<td>68</td>
<td>0</td>
</tr>
<tr>
<td>Maximum</td>
<td>0.36</td>
<td>3297</td>
<td>4495</td>
<td>3499</td>
<td>3844</td>
<td>-</td>
<td>93</td>
<td>5</td>
</tr>
<tr>
<td><strong>Hoot</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>0.38</td>
<td>168</td>
<td>449</td>
<td>282</td>
<td>325</td>
<td>88</td>
<td>102</td>
<td>0</td>
</tr>
<tr>
<td>Minimum</td>
<td>0.16</td>
<td>113</td>
<td>366</td>
<td>166</td>
<td>281</td>
<td>-</td>
<td>88</td>
<td>0</td>
</tr>
<tr>
<td>Maximum</td>
<td>0.63</td>
<td>202</td>
<td>538</td>
<td>397</td>
<td>352</td>
<td>-</td>
<td>111</td>
<td>0</td>
</tr>
<tr>
<td><strong>Meow</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>0.55</td>
<td>242</td>
<td>1166</td>
<td>924</td>
<td>642</td>
<td>63</td>
<td>77</td>
<td>2.70</td>
</tr>
<tr>
<td>Minimum</td>
<td>0.42</td>
<td>99</td>
<td>281</td>
<td>171</td>
<td>223</td>
<td>-</td>
<td>64</td>
<td>0</td>
</tr>
<tr>
<td>Maximum</td>
<td>0.93</td>
<td>494</td>
<td>3061</td>
<td>2839</td>
<td>1887</td>
<td>-</td>
<td>101</td>
<td>8</td>
</tr>
<tr>
<td><strong>Screech</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>1.31</td>
<td>1105</td>
<td>12161</td>
<td>11056</td>
<td>4227</td>
<td>71</td>
<td>96</td>
<td>1.97</td>
</tr>
<tr>
<td>Minimum</td>
<td>0.51</td>
<td>549</td>
<td>4667</td>
<td>3294</td>
<td>3879</td>
<td>-</td>
<td>92</td>
<td>0</td>
</tr>
<tr>
<td>Maximum</td>
<td>2.55</td>
<td>1394</td>
<td>16992</td>
<td>15598</td>
<td>4441</td>
<td>-</td>
<td>99</td>
<td>5</td>
</tr>
<tr>
<td><strong>Squawk</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>0.47</td>
<td>351</td>
<td>9107</td>
<td>8756</td>
<td>2914</td>
<td>69</td>
<td>97</td>
<td>0</td>
</tr>
<tr>
<td>Minimum</td>
<td>0.12</td>
<td>153</td>
<td>1922</td>
<td>1647</td>
<td>1102</td>
<td>-</td>
<td>86</td>
<td>0</td>
</tr>
<tr>
<td>Maximum</td>
<td>1.03</td>
<td>625</td>
<td>14112</td>
<td>13487</td>
<td>4500</td>
<td>-</td>
<td>93</td>
<td>0</td>
</tr>
<tr>
<td><strong>Squeal</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>1.18</td>
<td>1631</td>
<td>4702</td>
<td>3070</td>
<td>3686</td>
<td>64</td>
<td>85</td>
<td>1.90</td>
</tr>
<tr>
<td>Minimum</td>
<td>0.22</td>
<td>133</td>
<td>853</td>
<td>265</td>
<td>164</td>
<td>-</td>
<td>67</td>
<td>0</td>
</tr>
<tr>
<td>Maximum</td>
<td>4.33</td>
<td>3364</td>
<td>17121</td>
<td>16630</td>
<td>10969</td>
<td>-</td>
<td>111</td>
<td>5</td>
</tr>
</tbody>
</table>
Click calls were typically a sequence of low frequency clicks, becoming closer together as the call tailed off, as visible in the spectrogram, with the average maximum frequency of a call being 633Hz. The call also had a narrow average frequency range of just 425Hz, which is larger than only one other call type, Hoots. They were the longest call type identified at an average of 1.70s, owing to the sequence nature of the call. The peak frequency was reached, on average, at 387Hz.

Grunts were the shortest call at just 0.20s length on average, with a relatively wide frequency range of 1233Hz visible by the wide vertical breadth in Figure 5.7(b). They ranged on average from 335Hz to 1567Hz, putting their frequency range in roughly the middle of the seven identified calls.

Hoot calls were the loudest with the largest average power (88dB) and maximum power (102dB) readings, which was to be expected as they were the only call type which I regularly heard at a distance in the wild. This was shown by the dark colouration of the calls in the spectrogram, although this was somewhat marred by the background noise of the animal bounding around the cage. They were also the shortest calls after Grunts at 0.38s in length, with the smallest frequency range of 282Hz. They were the lowest frequency call recorded with an average maximum of just 449Hz, making them a distinct and easily recognised call type.

Meow calls were of medium length at 0.55s, with an average peak frequency of 642Hz. They had a low-to-medium frequency with a maximum average of 1166Hz. As shown in Figure 5.7(d), they followed a typical pattern of starting at a high pitch followed by a slowly tailing lower pitched portion, in a similar noise to a domestic cat’s meow.

Screech calls showed the largest average frequency range, at 11056Hz, with the call also the second longest at 1.31 seconds in length. It should be noted that, due to the infrequency of this call being performed, spectrogram analysis is taken from a small sample size so may not be representative.

Squawk calls, also analysed from a small sample size which may not be representative, showed the second greatest frequency range at 8756Hz with an average maximum frequency of 9107Hz, topped only by Screech calls. The calls
were shorter and harsher than Screeches, at just 0.47s in length with a typical peak frequency of 2914Hz.

Squeals, the hallmark of infants, were very defined on the spectrograms as a long sharp line, as shown in Figure 5.7(g). On average they were long calls at 1.18s, with a wide frequency range of 3070Hz. They could reach a max power of 85dB, with an average top frequency of 4702Hz. This call type was one of the most variable in structure, and could take many forms, which is represent by the large range in attribute values.

Analysis of variance testing (with transformations when required) was used to compare the attributes of the different call types. The attributes of Screech and Squawk calls were not analysed due to their small sample sizes. When looking at the attributes across the five remaining call types, there was a statistically significant difference between call types for all attributes (Delta Time: $F_{(6, 115)} = 13.08, p < 0.001$; Low Frequency: $F_{(6, 115)} = 23.60, p < 0.001$; High Frequency: $F_{(6, 115)} = 22.86, p < 0.001$; Delta Frequency: $F_{(6, 115)} = 16.10, p < 0.001$; Peak Frequency: $F_{(6, 115)} = 42.13, p < 0.001$; Average Power: $F_{(6, 115)} = 31.57, p < 0.001$; Max Power: $F_{(6, 115)} = 19.42, p < 0.001$). Least square differences tests were conducted to carry out pairwise comparisons between call types, with results presented in table format (see Table 5.5) and graphical representations of the numerical differences shown in box and whisker plots (see Figure 5.8).
Table 5.5 Least square difference comparisons between *T. delacouri* call types across the seven attributes measured, with ‘X’ indicating a difference and ‘=’ showing no significant difference. Each comparison is made under the call type heading to allow for a clear interpretation, but note that this means there are repetitions in pair comparisons.

<table>
<thead>
<tr>
<th>Call Type</th>
<th>Delta</th>
<th>Low</th>
<th>High</th>
<th>Delta</th>
<th>Peak</th>
<th>Average</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Time</td>
<td>Freq</td>
<td>Freq</td>
<td>Freq</td>
<td>Freq</td>
<td>Power</td>
<td>Power</td>
</tr>
</tbody>
</table>

### Click vs.
- **Grunt**: X = X X X = = =
- **Hoot**: X = = = = = X X
- **Meow**: X = = = = = =
- **Squeal**: = X X X X X =

### Grunt vs.
- **Click**: X = X X X = = =
- **Hoot**: X = X X X X X =
- **Meow**: X = X X X X X =
- **Squeal**: X X X X X X X =

### Hoot vs.
- **Click**: X = = = = = X X
- **Grunt**: X = X X X X X =
- **Meow**: = = X X X X X =
- **Squeal**: X X X X X X X =

### Meow vs.
- **Click**: X = = = = = = =
- **Grunt**: X = X X X X X =
- **Hoot**: = = X X X X X =
- **Squeal**: X X X X X X X =

### Squeal vs.
- **Click**: = X X X X X = X
- **Grunt**: X X X X X X X =
- **Hoot**: X X X X X X X =
- **Meow**: X X X X X X X =

![Delta Time Graph]

---

127
Figure 5.8 Box and Whisker Plots of the seven call attributes measured across five call types for *T. delacouri* (Screech and Squawk excluded due to low sample sizes), with differences analysed using analysis of variance. Refer back to Table 5.5 to look at which call types are significantly different from one another.
When looking at differences between the call types for *T. delacouri*, Squeal calls were quite distinct, sharing a maximum of two similar attributes with any of the other four call types (see Table 5.5). Notably, Squeal calls were statistically different from all other call types for low frequency, high frequency, delta frequency, peak frequency and average power attributes. Grunt calls also showed differentiation from the other call types, sharing a maximum of three comparable attributes with the other call types, and were statistically different from all for delta time, high frequency, delta frequency and peak frequency attributes. Click and Meow vocalisations were very similar, with no significant differences found between the two call types on any attributes except delta time. The spectrograms (Figure 5.7) and audio tracks did however demonstrate clear differences in the calls’ appearance and sound, the Click calls having the distinctive structure of a sequence of Clicks tailing off. Click and Hoot calls shared four statistically similar attributes (low, high, delta and peak frequency), indicating that the calls take place in the same frequency range, but show differences in their times and power values. Overall, these results indicate that at least five distinct call types were identified for *T. delacouri* (Click, Grunt, Hoot, Meow, and Squeal), but further samples of Screech and Squawk calls would be needed to confirm that these are also distinct call types.

5.3.5 Limestone langur spectrogram analysis

Aside from *T. delacouri*, spectrograms were created and analysed for the five other limestone langur species at the EPRC (*T. ebenus*, *T. francoisi*, *T. hatinhensis*, *T. laotum*, and *T. poliocephalus*). In total, 122 calls were of sufficient quality for analysis for these remaining limestone langur species, with 14 calls from *T. ebenus*, 49 from *T. francoisi*, 31 from *T. hatinhensis*, five from *T. laotum*, and 23 from *T. poliocephalus*. Recordings were made of Click, Grunt, Hoot and Squeal vocalisations. Spectrograms were created in Raven Pro 1.4 using digital Fourier Transformations, with the same seven attributes calculated for each call (see Figure 5.9 and Table 5.6). When conducting comparisons within species, only *T. francoisi* and *T. hatinhensis* had enough samples across call types for analyses to be run (greater than five samples in two or more call types), hence other species had to be excluded.
Figure 5.9 Spectrogram examples for three *T. francoisi* and two *T. hatinhensis* call types, with the call marked out in a dotted line. Time in seconds is on the horizontal axis, frequency in kHz on the vertical axis, and power in decibels represented by the shading (dark colouration = greater power). Scales between graphs are not always equal due to differences in call type attributes, so care should be taken when comparing different calls. Due to the captive setting of these recordings there is interference visible (e.g. cage rattles in Hoot calls as the animal completes bounding display, or people’s movements/actions) along with natural interferences (e.g. insect calls visible as dark constant lines and bird/squirrel vocalisations). All spectrograms were produced using digital Fourier Transformations in Raven Pro 1.4.
Table 5.6 Values, from the fundamental frequencies, for the seven attributes analysed for each call type from their spectrogram transformations, along with the number of harmonics identified. The average value from the replicates is given, along with the minimum and maximum values identified. Call types with low sample sizes (less than five) are excluded from this analysis.

<table>
<thead>
<tr>
<th>Call Type</th>
<th>Delta Time (s)</th>
<th>Low Freq (Hz)</th>
<th>High Freq (Hz)</th>
<th>Delta Freq (Hz)</th>
<th>Peak Freq (Hz)</th>
<th>Average Power (dB)</th>
<th>Max Power (dB)</th>
<th>Number of harmonics</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>T. francoisi</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Grunt</strong></td>
<td>Average 0.25</td>
<td>378</td>
<td>2871</td>
<td>2493</td>
<td>1385</td>
<td>60</td>
<td>75</td>
<td>0.31</td>
</tr>
<tr>
<td></td>
<td>Minimum 0.20</td>
<td>127</td>
<td>1017</td>
<td>532</td>
<td>633</td>
<td>-</td>
<td>69</td>
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</tr>
<tr>
<td></td>
<td>Maximum 0.39</td>
<td>834</td>
<td>5505</td>
<td>5102</td>
<td>4184</td>
<td>-</td>
<td>86</td>
<td>2</td>
</tr>
<tr>
<td><strong>T. francoisi</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Hoot</strong></td>
<td>Average 0.31</td>
<td>117</td>
<td>557</td>
<td>439</td>
<td>341</td>
<td>85</td>
<td>99</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Minimum 0.23</td>
<td>60</td>
<td>447</td>
<td>361</td>
<td>281</td>
<td>-</td>
<td>94</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Maximum 0.48</td>
<td>176</td>
<td>702</td>
<td>566</td>
<td>410</td>
<td>-</td>
<td>105</td>
<td>0</td>
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<td><strong>T. francoisi</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Squeal</strong></td>
<td>Average 0.83</td>
<td>1122</td>
<td>1969</td>
<td>847</td>
<td>1621</td>
<td>58</td>
<td>76</td>
<td>0.65</td>
</tr>
<tr>
<td></td>
<td>Minimum 0.49</td>
<td>887</td>
<td>1613</td>
<td>444</td>
<td>1254</td>
<td>-</td>
<td>69</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Maximum 1.57</td>
<td>1451</td>
<td>2573</td>
<td>1291</td>
<td>2133</td>
<td>-</td>
<td>83</td>
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</tr>
<tr>
<td><strong>T. hatinhensis</strong></td>
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<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Grunt</strong></td>
<td>Average 0.24</td>
<td>163</td>
<td>1298</td>
<td>1135</td>
<td>543</td>
<td>62</td>
<td>77</td>
<td>0.11</td>
</tr>
<tr>
<td></td>
<td>Minimum 0.15</td>
<td>85</td>
<td>382</td>
<td>233</td>
<td>211</td>
<td>-</td>
<td>69</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Maximum 0.35</td>
<td>329</td>
<td>2217</td>
<td>2064</td>
<td>856</td>
<td>-</td>
<td>88</td>
<td>2</td>
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<td><strong>T. hatinhensis</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Squeal</strong></td>
<td>Average 1.04</td>
<td>1267</td>
<td>3903</td>
<td>2637</td>
<td>2088</td>
<td>62</td>
<td>82</td>
<td>0.60</td>
</tr>
<tr>
<td></td>
<td>Minimum 0.49</td>
<td>432</td>
<td>1778</td>
<td>647</td>
<td>1488</td>
<td>-</td>
<td>67</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Maximum 2.26</td>
<td>1564</td>
<td>15047</td>
<td>14616</td>
<td>3223</td>
<td>-</td>
<td>95</td>
<td>4</td>
</tr>
</tbody>
</table>
Of the three call types analysed for *T. francoisi*, Grunt calls had the largest average delta frequency at 2492Hz, with the shortest length of an average 0.25s. Hoot calls were the loudest, with an average power of 85dB and an average maximum power of 99dB. Squeal calls had an average length of 0.83 seconds, the longest of the three calls, and the highest average peak frequency at 1621Hz.

For *T. hatinhensis*, Grunt calls were short (average of 0.24s) and at a low frequency, with an average of 163Hz. Comparatively, squeals averaged 1.04 seconds in length, with a delta frequency of 2637Hz and an average max power of 82dB.

Analysis of variance testing showed significant differences across all seven attributes at the $\alpha = 0.01$ level, when comparing the three *T. francoisi* call types (Delta Time: $F_{(2, 46)} = 56.95$, $p < 0.001$; Low Frequency: $F_{(2, 46)} = 254.46$, $p < 0.001$; High Frequency: $F_{(2, 46)} = 79.75$, $p < 0.001$; Delta Frequency: $F_{(2, 46)} = 19.75$, $p < 0.001$; Peak Frequency: $F_{(2, 46)} = 135.97$, $p < 0.001$; Average Power: $F_{(2, 46)} = 377.08$, $p < 0.001$; Max Power: $F_{(2, 46)} = 132.79$, $p < 0.001$). Least square differences tests were utilised to look at pairwise comparisons between call types, with results presented in table format (see Table 5.7). This showed that Hoot calls were distinct in all seven attributes from both Grunt and Squeal calls, whilst Grunts shared three attributes (high frequency, average power and max power) with Squeals.

**Table 5.7** Least square difference comparisons between *T. francoisi* call types across the seven attributes measured, with ‘X’ indicating a significant difference and ‘=' showing no difference was found. Each comparison is made under the call type heading to allow for a clear interpretation, but note this means there are repetitions in pair comparisons.

<table>
<thead>
<tr>
<th>Call Type</th>
<th>Delta Time</th>
<th>Low Freq</th>
<th>High Freq</th>
<th>Delta Freq</th>
<th>Peak Freq</th>
<th>Average Power</th>
<th>Max Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grunt vs.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hoot</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Squeal</td>
<td>X</td>
<td>X</td>
<td>=</td>
<td>X</td>
<td>=</td>
<td>=</td>
<td>=</td>
</tr>
<tr>
<td>Hoot vs.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grunt</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Squeal</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Squeal vs.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grunt</td>
<td>X</td>
<td>X</td>
<td>=</td>
<td>X</td>
<td>=</td>
<td>=</td>
<td>=</td>
</tr>
<tr>
<td>Hoot</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

The same Analysis of Variance testing methodology was used to compare the two *T. hatinhensis* call types, Grunts and Squeals. Significant differences were found for
Delta Time ($F_{(1, 28)} = 112.81, p < 0.001$), Low Frequency ($F_{(1, 28)} = 780.14, p < 0.001$), High Frequency ($F_{(1, 28)} = 51.24, p < 0.001$), and Peak Frequency ($F_{(1, 28)} = 131.25, p < 0.001$). Whilst no significant difference was found when looking at Delta Frequency ($F_{(1, 28)} = 2.37, p = 0.135$), Average Power ($F_{(1, 28)} = 0.07, p = 0.798$), and Max Power ($F_{(1, 28)} = 3.64, p = 0.067$).

5.3.6 Spectrogram comparisons between species

Interspecific differences across call types were investigated, with sufficient data being collected to compare species for Grunt, Hoot and Squeal calls. For Grunts, a total of 92 calls were analysed, with 43 from *T. delacouri*, 12 from *T. ebenus*, 13 from *T. francoisi*, 19 from *T. hatinhensis*, and 5 from *T. laotum* (see Figure 5.10 and Table 5.8). Only two recorded grunt calls from *T. poliocephalus* were of sufficient quality for analysis, and these were excluded due to the sample size being less than five.

![Spectrogram examples for Grunt calls from *T. ebenus* and *T. laotum*, with the call marked out in a dotted line. Time in seconds is on the horizontal axis, frequency in kHz on the vertical axis, and power in decibels represented by the shading (dark colouration = greater power). For Grunt call examples from other species refer back to Figure 5.7b for *T. delacouri*, Figure 5.9a for *T. francoisi*, and Figure 5.9d for *T. hatinhensis*. Scales between graphs are not always equal due to differences in call type attributes, so care should be taken when comparing different calls. All spectrograms were produced using digital Fourier Transformations in Raven Pro 1.4.](image)
Table 5.8 Grunt call values, from the fundamental frequencies, for the seven attributes analysed for each species. Values are taken from spectrogram transformations, with the number of harmonics identified. The average value from the replicates is given, along with the minimum and maximum values identified. Species with low sample sizes (less than five) are excluded from this analysis.

<table>
<thead>
<tr>
<th>Grunt Call Species</th>
<th>Delta Time (s)</th>
<th>Low Freq (Hz)</th>
<th>High Freq (Hz)</th>
<th>Delta Freq (Hz)</th>
<th>Peak Freq (Hz)</th>
<th>Average Power (dB)</th>
<th>Max Power (dB)</th>
<th>Number of harmonics</th>
</tr>
</thead>
<tbody>
<tr>
<td>T. delacouri</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>0.20</td>
<td>335</td>
<td>1567</td>
<td>1233</td>
<td>914</td>
<td>64</td>
<td>79</td>
<td>0.68</td>
</tr>
<tr>
<td>Minimum</td>
<td>0.11</td>
<td>44</td>
<td>885</td>
<td>366</td>
<td>199</td>
<td>-</td>
<td>68</td>
<td>0</td>
</tr>
<tr>
<td>Maximum</td>
<td>0.36</td>
<td>3297</td>
<td>4495</td>
<td>3499</td>
<td>3844</td>
<td>-</td>
<td>93</td>
<td>5</td>
</tr>
<tr>
<td>T. ebenus</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>0.20</td>
<td>162</td>
<td>2469</td>
<td>2307</td>
<td>942</td>
<td>64</td>
<td>81</td>
<td>0.83</td>
</tr>
<tr>
<td>Minimum</td>
<td>0.10</td>
<td>63</td>
<td>1110</td>
<td>917</td>
<td>281</td>
<td>-</td>
<td>72</td>
<td>0</td>
</tr>
<tr>
<td>Maximum</td>
<td>0.33</td>
<td>327</td>
<td>8044</td>
<td>7886</td>
<td>1172</td>
<td>-</td>
<td>86</td>
<td>2</td>
</tr>
<tr>
<td>T. francoisi</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>0.25</td>
<td>378</td>
<td>2871</td>
<td>2493</td>
<td>1385</td>
<td>60</td>
<td>75</td>
<td>0.31</td>
</tr>
<tr>
<td>Minimum</td>
<td>0.20</td>
<td>127</td>
<td>1017</td>
<td>532</td>
<td>633</td>
<td>-</td>
<td>69</td>
<td>0</td>
</tr>
<tr>
<td>Maximum</td>
<td>0.39</td>
<td>834</td>
<td>5505</td>
<td>5102</td>
<td>4184</td>
<td>-</td>
<td>86</td>
<td>2</td>
</tr>
<tr>
<td>T. hatinhensis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>0.24</td>
<td>163</td>
<td>1298</td>
<td>1135</td>
<td>543</td>
<td>62</td>
<td>77</td>
<td>0.11</td>
</tr>
<tr>
<td>Minimum</td>
<td>0.15</td>
<td>85</td>
<td>382</td>
<td>233</td>
<td>211</td>
<td>-</td>
<td>69</td>
<td>0</td>
</tr>
<tr>
<td>Maximum</td>
<td>0.35</td>
<td>329</td>
<td>2217</td>
<td>2064</td>
<td>856</td>
<td>-</td>
<td>88</td>
<td>2</td>
</tr>
<tr>
<td>T. laotum</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>0.16</td>
<td>135</td>
<td>1551</td>
<td>1416</td>
<td>736</td>
<td>62</td>
<td>78</td>
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</tr>
<tr>
<td>Minimum</td>
<td>0.13</td>
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<td>1230</td>
<td>1090</td>
<td>375</td>
<td>-</td>
<td>73</td>
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</tr>
<tr>
<td>Maximum</td>
<td>0.21</td>
<td>196</td>
<td>1868</td>
<td>1741</td>
<td>1020</td>
<td>-</td>
<td>82</td>
<td>0</td>
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</tbody>
</table>
Audibly, grunt calls between the five species analysed sounded very similar, and this was reflected in their relatively similar average values for the various attributes. *T. francoisi* has some audible differences from the others, the call sounding more guttural with an emphasis on a higher pitched ending as shown by a higher average peak frequency of 1385Hz (see Table 5.8). *T. hatinhensis* grunts sounded to be of a lower frequency with less sharpness in the call, and this was supported by a low average peak frequency of 543Hz. These differences, however, may be due to the individual rather than interspecific differences, as in the majority of cases only one or two callers were available for sampling.

Analysis of Variance testing of the seven call attributes for grunt calls, comparing between the five species, showed a statistically significant difference for four of the attributes (Delta Time: $F_{(4, 87)} = 3.89$, $p = 0.006$; High Frequency: $F_{(4, 87)} = 6.64$, $p < 0.001$; Delta Frequency: $F_{(4, 87)} = 5.20$, $p < 0.001$; and Peak Frequency: $F_{(4, 87)} = 8.08$, $p < 0.001$). No significant difference was detected for Low Frequency ($F_{(4, 87)} = 3.14$, $p = 0.018$), Average Power ($F_{(4, 87)} = 3.00$, $p = 0.023$) and Max Power ($F_{(4, 87)} = 2.30$, $p = 0.065$). Least square differences tests were used to conduct pairwise comparisons between species, with results presented in Table 5.9. This supported the view that, overall, Grunt calls were relatively similar across species with a minimum of four attributes in common between any two species. In particular, *T. laotum* shared all seven attributes with *T. delacouri, T. ebenus* and *T. hatinhensis*, although this result may in part be a product of the relatively small number of grunt call samples collected for *T. laotum*. Additionally, *T. ebenus* and *T. francoisi* also had no significantly different attributes.
Table 5.9 Least square difference comparisons for Grunt calls between species across the seven attributes measured, with ‘X’ indicating a significant difference and ‘=’ showing no difference was found. A ‘*’ next to the attribute heading indicates that ANOVA testing showed no significant difference for this attribute. Each comparison is made under the species heading to allow for a clear interpretation, but note this means there are repetitions in pair comparisons.

<table>
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<th>Grunt Call</th>
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<th>High</th>
<th>Delta</th>
<th>Peak</th>
<th>Average</th>
<th>Max</th>
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<td>Time</td>
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<td>Freq*</td>
<td>Freq</td>
<td>Freq</td>
<td>Power*</td>
<td>Power*</td>
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<tr>
<td>T. delacouri vs.</td>
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<td>X</td>
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<tr>
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<td>=</td>
<td>X</td>
<td>X</td>
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<tr>
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<td>=</td>
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<td>T. laotum</td>
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<td>X</td>
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<tr>
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</tr>
</tbody>
</table>

For Hoot vocalisations, 17 were recorded from T. delacouri, 16 from T. francoisi and 19 from T. poliocephalus, making a total of 52 for analysis (see Figure 5.11 and Table 5.10). Only one hoot call sequence was recorded from T. hatinhensis, and none from T. ebenus or T. laotum hence they were excluded from this analysis.
Figure 5.11 Spectrogram example for Hoot calls from *T. poliocephalus*, with the calls marked out in a dotted line. Time in seconds is on the horizontal axis, frequency in kHz on the vertical axis, and power in decibels represented by the shading (dark colouration = greater power). For Hoot call examples from other species refer back to Figure 5.7c for *T. delacouri* and Figure 5.9b for *T. francoisi*. Scales between graphs are not always equal due to differences in call type attributes, so care should be taken when comparing different calls. All spectrograms were produced using digital Fourier Transformations in Raven Pro 1.4.

Table 5.10 Hoot call values, from the fundamental frequencies, for the seven attributes analysed for each species. Values are taken from spectrogram transformations, with the number of harmonics identified. The average value from the replicates is given, along with the minimum and maximum values identified. Species with low sample sizes (less than five) are excluded from this analysis.

<table>
<thead>
<tr>
<th>Hoot Call Species</th>
<th>Delta Time (s)</th>
<th>Low Freq (Hz)</th>
<th>High Freq (Hz)</th>
<th>Delta Freq (Hz)</th>
<th>Peak Freq (Hz)</th>
<th>Average Power (dB)</th>
<th>Max Power (dB)</th>
<th>Number of harmonics</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>T. delacouri</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>0.38</td>
<td>168</td>
<td>449</td>
<td>282</td>
<td>325</td>
<td>88</td>
<td>102</td>
<td>0</td>
</tr>
<tr>
<td>Minimum</td>
<td>0.16</td>
<td>113</td>
<td>366</td>
<td>166</td>
<td>281</td>
<td>-</td>
<td>88</td>
<td>0</td>
</tr>
<tr>
<td>Maximum</td>
<td>0.63</td>
<td>202</td>
<td>538</td>
<td>397</td>
<td>352</td>
<td>-</td>
<td>111</td>
<td>0</td>
</tr>
<tr>
<td><em>T. francoisi</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>0.31</td>
<td>117</td>
<td>557</td>
<td>439</td>
<td>341</td>
<td>85</td>
<td>99</td>
<td>0</td>
</tr>
<tr>
<td>Minimum</td>
<td>0.23</td>
<td>60</td>
<td>447</td>
<td>361</td>
<td>281</td>
<td>-</td>
<td>94</td>
<td>0</td>
</tr>
<tr>
<td>Maximum</td>
<td>0.48</td>
<td>176</td>
<td>702</td>
<td>566</td>
<td>410</td>
<td>-</td>
<td>105</td>
<td>0</td>
</tr>
<tr>
<td><em>T. poliocephalus</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>0.24</td>
<td>135</td>
<td>354</td>
<td>218</td>
<td>278</td>
<td>90</td>
<td>102</td>
<td>0.32</td>
</tr>
<tr>
<td>Minimum</td>
<td>0.18</td>
<td>81</td>
<td>323</td>
<td>175</td>
<td>258</td>
<td>-</td>
<td>91</td>
<td>0</td>
</tr>
<tr>
<td>Maximum</td>
<td>0.33</td>
<td>222</td>
<td>397</td>
<td>282</td>
<td>316</td>
<td>-</td>
<td>111</td>
<td>4</td>
</tr>
</tbody>
</table>

When looking at audible differences between species, *T. delacouri* hoot calls sounded somewhat different from *T. francoisi* and *T. poliocephalus*. In *T. delacouri* the hoot is clear and clean, with no breathe sounds audible in-between. In a hoot
sequence the calls were typically placed 1.5 – 2 seconds apart. In contrast, in *T. francoisi* and *T. poliocephalus* the calls were much more rapid, the gap between calls being usually just 0.5 – 1 second in length. Additionally the calls sounded more guttural with a lower frequency (117Hz for *T. francoisi* and 135Hz for *T. poliocephalus*, see Table 5.10), followed by an obvious inhalation sound.

Analysis of Variance testing for interspecific differences in Hoot calls showed a statistically significant difference for five of the call attributes (Delta Time: $F_{(2, 49)} = 9.66$, $p < 0.001$; Low Frequency: $F_{(2, 49)} = 13.09$, $p < 0.001$; High Frequency: $F_{(2, 49)} = 104.95$, $p < 0.001$; Delta Frequency: $F_{(2, 49)} = 84.13$, $p < 0.001$; and Peak Frequency: $F_{(2, 49)} = 31.18$, $p < 0.001$). Only Average Power ($F_{(2, 49)} = 2.73$, $p = 0.075$) and Max Power ($F_{(2, 49)} = 2.09$, $p = 0.135$) showed no difference. Pairwise comparisons were then calculated using Least Square Differences (see Table 5.11), and showed that unlike Grunt calls, there were several interspecific differences. Although in audio clips *T. francoisi* sounds relatively similar to *T. poliocephalus*, actually they shared only three attributes in common (low frequency, average power and max power). Comparatively, *T. francoisi* shared four attributes with *T. delacouri*, but this was still a relatively weak connection, with some *T. delacouri* call types sharing more attributes than this (refer back to Table 5.5). *T. poliocephalus* and *T. delacouri* hoot calls appeared distinct, with only two attributes shared.

Table 5.11 Least square difference comparisons for Hoot calls between species across the seven attributes measured, with ‘X’ indicating a significant difference and ‘=’ showing no difference was found. A ‘*’ next to the attribute heading indicates that ANOVA testing showed no significant difference for this attribute. Each comparison is made under the species heading to allow for a clear interpretation, but note this means there are repetitions in pair comparisons.

<table>
<thead>
<tr>
<th>Hoot Call Species</th>
<th>Delta Time</th>
<th>Low Freq</th>
<th>High Freq</th>
<th>Delta Freq</th>
<th>Peak Freq</th>
<th>Average Power*</th>
<th>Max Power*</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>T. delacouri</em> vs. &amp; <em>T. francoisi</em> &amp; <em>T. poliocephalus</em></td>
<td>=</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>=</td>
<td>=</td>
<td>=</td>
</tr>
<tr>
<td><em>T. francoisi</em> vs. &amp; <em>T. delacouri</em> &amp; <em>T. poliocephalus</em></td>
<td>=</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>=</td>
<td>=</td>
<td>=</td>
</tr>
<tr>
<td><em>T. poliocephalus</em> vs. &amp; <em>T. delacouri</em> &amp; <em>T. francoisi</em></td>
<td>X</td>
<td>=</td>
<td>X</td>
<td>X</td>
<td>=</td>
<td>=</td>
<td>=</td>
</tr>
</tbody>
</table>

A total of 62 squeal calls from young langurs were of quality for analysis, with 31 calls from *T. delacouri*, 20 from *T. francoisi* and 11 from *T. hatinhensis* (see Table
Only one squeal call was recorded from *T. poliocephalus* and hence this was excluded from analysis. Spectrograms of squeal calls have already been included in this chapter; refer back to Figure 5.7g for *T. delacouri*, Figure 5.9c for *T. francoisi* and Figure 5.9e for *T. hatinhensis*.

Table 5.12 Squeal call values, from the fundamental frequencies, for the seven attributes analysed for each species. Values are taken from spectrogram transformations, with the number of harmonics identified. The average value from the replicates is given, along with the minimum and maximum values identified. Species with low sample sizes (less than five) are excluded from this analysis.

<table>
<thead>
<tr>
<th>Squeal Call Species</th>
<th>Delta Time (s)</th>
<th>Low Freq (Hz)</th>
<th>High Freq (Hz)</th>
<th>Delta Freq (Hz)</th>
<th>Peak Freq (Hz)</th>
<th>Average Power (dB)</th>
<th>Max Power (dB)</th>
<th>Number of harmonics</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>T. delacouri</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>1.18</td>
<td>1631</td>
<td>4702</td>
<td>3070</td>
<td>3686</td>
<td>64</td>
<td>85</td>
<td>1.90</td>
</tr>
<tr>
<td>Minimum</td>
<td>0.22</td>
<td>133</td>
<td>853</td>
<td>265</td>
<td>164</td>
<td>-</td>
<td>67</td>
<td>0</td>
</tr>
<tr>
<td>Maximum</td>
<td>4.33</td>
<td>3364</td>
<td>17121</td>
<td>16630</td>
<td>10969</td>
<td>-</td>
<td>111</td>
<td>5</td>
</tr>
<tr>
<td><em>T. francoisi</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>0.83</td>
<td>1122</td>
<td>1969</td>
<td>847</td>
<td>1621</td>
<td>58</td>
<td>76</td>
<td>0.65</td>
</tr>
<tr>
<td>Minimum</td>
<td>0.49</td>
<td>887</td>
<td>1613</td>
<td>444</td>
<td>1254</td>
<td>-</td>
<td>69</td>
<td>0</td>
</tr>
<tr>
<td>Maximum</td>
<td>1.57</td>
<td>1451</td>
<td>2573</td>
<td>1291</td>
<td>2133</td>
<td>-</td>
<td>83</td>
<td>5</td>
</tr>
<tr>
<td><em>T. hatinhensis</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>1.04</td>
<td>1267</td>
<td>3903</td>
<td>2637</td>
<td>2088</td>
<td>62</td>
<td>82</td>
<td>0.60</td>
</tr>
<tr>
<td>Minimum</td>
<td>0.49</td>
<td>432</td>
<td>1778</td>
<td>647</td>
<td>1488</td>
<td>-</td>
<td>67</td>
<td>0</td>
</tr>
<tr>
<td>Maximum</td>
<td>2.26</td>
<td>1564</td>
<td>15047</td>
<td>14616</td>
<td>3223</td>
<td>-</td>
<td>95</td>
<td>4</td>
</tr>
</tbody>
</table>

When considering audio tracks of squeal calls from the three species, there were no obvious differences, with all species’ young making clear high pitched calls. The spectrogram analysis values did however show a variation in frequency values, with average peak frequencies ranging from 1621 Hz for *T. francoisi* to 3686 Hz for *T. delacouri* (see Table 5.12). Furthermore, audibly, there was a lot of variation with squeal calls even at the individual level, in that they can vary in length and randomly go up and down in frequency following no set pattern. It is also possible that squeal calls could vary as the individual ages and their voice box matures, although there is not enough data to examine this.

Analysis of Variance tests showed a statistically significant difference for four attributes when comparing Squeal calls (High Frequency: $F_{(2, 59)} = 9.32, p < 0.001$;
Delta Frequency: $F(2, 59) = 6.83$, $p = 0.002$; Peak Frequency: $F(2, 59) = 7.19$, $p = 0.002$; and Max Power: $F(2, 59) = 5.24$, $p = 0.008$). Whilst there was no difference found for Delta Time ($F(2, 59) = 0.29$, $p = 0.746$), Low Frequency ($F(2, 59) = 2.98$, $p = 0.058$) and Average Power ($F(2, 59) = 3.74$, $p = 0.030$). Breaking this down into pairwise comparisons using Least Square Difference analysis (see Table 5.13), *T. hatinhensis* Squeal calls appeared very similar to both *T. delacouri* and *T. francoisi*, sharing six and five statistically equal attributes, respectively, while *T. delacouri* and *T. francoisi* had only three attributes in common, with differences in frequencies and max power levels setting them apart.

<table>
<thead>
<tr>
<th>Squeal Call Species</th>
<th>Delta Time*</th>
<th>Low Freq*</th>
<th>High Freq</th>
<th>Delta Freq</th>
<th>Peak Freq</th>
<th>Average Power*</th>
<th>Max Power</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>T. delacouri</em> vs. <em>T. francoisi</em></td>
<td>=</td>
<td>=</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>=</td>
<td>X</td>
</tr>
<tr>
<td><em>T. hatinhensis</em></td>
<td>=</td>
<td>=</td>
<td>=</td>
<td>=</td>
<td>X</td>
<td>=</td>
<td>=</td>
</tr>
<tr>
<td><em>T. francoisi</em> vs. <em>T. delacouri</em></td>
<td>=</td>
<td>=</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>=</td>
<td>X</td>
</tr>
<tr>
<td><em>T. hatinhensis</em></td>
<td>=</td>
<td>=</td>
<td>=</td>
<td>=</td>
<td>X</td>
<td>=</td>
<td>=</td>
</tr>
<tr>
<td><em>T. delacouri</em> vs. <em>T. francoisi</em></td>
<td>=</td>
<td>=</td>
<td>=</td>
<td>=</td>
<td>X</td>
<td>=</td>
<td>=</td>
</tr>
<tr>
<td><em>T. francoisi</em></td>
<td>=</td>
<td>=</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>=</td>
<td>=</td>
</tr>
</tbody>
</table>

### 5.4 Discussion

#### 5.4.1 Possible function of vocalisations

Primate vocalisations can have a variety of functions, and can be used as a form of auditory communication (Marler, 1967; Rendall *et al.*, 1999; Manning & Dawkins, 2002; Strier, 2007). One of the clearest examples of the different functions of primate vocalisations is the alarm calls of vervet monkeys, with the three different forms of the call signalling the threat of leopards, eagles or snakes so that their group can respond appropriately (Seyfarth *et al.*, 1980; Hauser, 2000); and Ouattara *et al.* (2009) demonstrated a similar breakdown of alarm calls in Campbell’s monkeys. In order to gain a true understanding of a vocalisation’s function, extensive playback experiments along with behavioural monitoring in a wild setting are required, but by
watching the behaviour of the caller and their group in captivity, along with the context of a call, an idea of the possible function can be deduced (Byrne, 1982). Studying vocalisations in captivity allows for analysis of quieter calls that may not be heard at distance in the wild, as well as closer monitoring of individuals’ behaviour.

Of the seven vocalisation types identified for *T. delacouri*, Grunts were by far the most common making up 61.2% of all calls heard, and were almost exclusively performed by adult males (99.6%). Grunts were predominantly made whilst the caller was displaying inactive behaviours with no response or effect on the behaviour of other individuals. The call was occasionally utilised as a ‘response’ to another animal’s vocalisation or during feeding time, but the call still did not have any noticeable effect on the behaviour of other individuals in the group. It is possible that Grunts function as a type of contact call, and may assist in maintaining intragroup cohesion or in facilitating affiliative social interactions (Boinski *et al.*, 1994; Gros-Louis, 2002; Greeno & Semple, 2009), such as with chacma baboons, *Papio ursinus* (Rendall *et al.*, 2000). Meow calls, performed exclusively by inactive subadult males, may also be a type of *T. delacouri* contact call, although why the call was only performed by subadults is unclear. It is possible that the subadults’ vocal chords are yet to fully mature, but the Meow vocalisation does not appear to represent an immature form of any of the other calls (discussed further in Section 5.4.3).

Squeal calls were the second most utilised of *T. delacouri’s* vocalisations (16.5%), and were predominantly performed by juveniles and infants (87.8%) and appeared to be context dependent. They chiefly functioned as a distress call, and it was often utilised by young as a way to gain their mother’s attention. In a wild setting, it is plausible that infants would use this call when they became separated from their mother (Marler, 1967; Rendall *et al.*, 2000; Rendall *et al.*, 2009), but in the confines of a captive environment this behaviour was not seen. Squeal calls were also heavily used whilst engaging in play, and therefore may be context dependent, indicating that the call serves a variety of functions depending on the social and ecological situation (Salmi *et al.*, 2013), and in this case could function to express ‘excitement’ when interacting with conspecifics.
Two of the identified vocalisations (Clicks and Hoots) were exclusively utilised by adult males. Clicks are most likely a type of intergroup spacing call (Robinson, 1981; Gros-Louis, 2002), and were typically performed whilst the male was inactive. On the other hand, Hoots were part of a dynamic bounding display, functioning as a loud/warning call (Kitchen et al., 2003; Neumann et al., 2010), and were frequently in response to bounding displays performed by other male langurs within the EPRC. In the wild, Hoot vocalisations were most commonly heard due to their high volume, and were often followed by a ‘response’ Hoot and bounding display from the male in an adjoining group.

Screech and Squawk vocalisations were the least defined of the seven vocalisation categories, with low sample sizes and variable structures (discussed further below in Section 5.4.3). However they clearly functioned as alarm/distress calls, and were typically utilised during an altercation with another individual.

5.4.2 Factors impacting on vocalisations

A variety of factors can impact when and how frequently an animal vocalises, and what type of vocalisation the animal performs. In some species individuals increase copulation-cue vocalisations when in oestrus to advertise their sexual availability (Lazaro-Perea, 2001; Semple, 2001). In yellow-cheeked crested gibbons (Nomascus gabriellae), the weather and time of year has been shown to affect the vocalisation rates, with gibbon groups vocalising more during the dry season and very rarely after rainfall the night before (Rawson, 2004).

For T. delacouri, the individual’s sex and age was shown to have a significant impact on vocalisation behaviour. Adult males could be expected to perform the majority (52.6%) of vocalisations, equating to a rate of 8.2 vocals per hour, with orange infants (0-4 months) the next most prolific at 5.1 per hour. Adult females, on the other hand, vocalised very rarely at just 0.1 vocals per hour. Given these findings, males as a group were found to vocalise much more frequently than females, and adults vocalised more than subadults, and at a slightly greater rate than young. However it should be noted that some sex/age classes (infant black, subadult female) were not present to be sampled at the EPRC, and for other classes only a small number of animals were able to be sampled. There was a link between an animal’s sex/age class and the type of vocalisation they were likely to perform – with
Clicks and Hoots performed exclusively by adult males, Meows by subadult males and Squeals most likely to be performed by young. Sex differences in vocalisation behaviour have been shown in several other primate species, such as rhesus macaques where females have been shown to vocalise significantly more than males, and predominantly target their vocalisations towards other females (Greeno & Semple, 2009). Kloss’s gibbons (Hylobates klossii) are unusual among gibbon species in showing a clear sex difference where the male vocalises alone before dawn, and the female vocalises post-dawn, instead of duetting together as is typical for gibbons (Keith et al., 2009). In addition there is a structural difference in the male call compared to female dawn vocalisations. Adult females and juveniles were the most prolific callers in a study of proboscis monkey (Nasalis larvatus) vocalisations (Srivathsan & Meier, 2011), and older marmosets (Callithrix jacchus) perform more “phee” calls than their younger counterparts (Chen et al., 2009). In comparison, no sex or age differences in vocalisation behaviour was found in a study of golden lion tamarins (Boinski et al., 1994).

Many primate species are known to cluster their vocalisations at a certain time of day, usually dawn or dusk, such as gibbons’ who predominantly vocalise in the early morning with a duet between mated pairs (Rawson, 2004; Konrad & Geissmann, 2006). Western purple-faced langurs (Semnopithecus vetulus nestor) vocalise predominantly in the morning, typically during territorial battles with neighbouring groups to assert their dominance (Eschmann et al., 2008). There was no trend found in the frequency of T. delacouri vocalisations across the day, but further studies in a wild setting, including an assessment of the type of vocalisation used at different times of day, may reveal a pattern and warrants further investigation. There was found to be an increase in vocalisations around the regular feeding time within the EPRC, and this highlights the shortcomings of collecting data within a captive environment.

The social situation of an individual on a given occasion may impact on their vocalisation behaviour and frequency; some species are more likely to give territorial or spacing calls if there are other groups nearby (Robinson, 1981; Lazaro-Perea, 2001; Manning & Dawkins, 2002; Eschmann et al., 2008; Neumann et al., 2010), or females may give more contact calls if they currently have young they are caring for (Marler, 1967; Rendall et al., 2000; Strier, 2007; Rendall et al., 2009). The social
grouping situation of *T. delacouri* individuals in this study did have some impacts on behaviour, with some vocalisations seeming to be in ‘response’ to another animal’s call - both other *T. delacouri* within their cage group and other primates within the EPRC. Likewise vocalisations often accompanied social interactions, such as during grooming or an altercation (refer back to Section 4.3.2), so the way an individual related with the rest of its group also impacted on its vocal behaviour.

### 5.4.3 Spectrogram analysis

By recording samples of *T. delacouri* vocalisations, field observation notes were able to be compared with a detailed spectrogram analysis of each call type. Spectrograms can assist in identifying the evolutionary origin of a species, by aiding in the investigation of the mechanical mechanisms of sound production (Hauser, 2000; Geissmann, 2003; Konrad & Geissmann, 2006; Elemans *et al.*, 2008; Lameira & Wich, 2008; Ouattara *et al.*, 2009). Spectrograms often show the finer detail and differentiations of a vocalisation’s structure that is not discernible to the human ear. This can assist in recognising the distinct calls of individuals, aid in differentiating between taxa due to differences in their vocalisations, and generally gives the ability to have a greater understanding of primate vocalisation behaviour.

When combining the information from the visual spectrograms, measured attributes, and audio clips, at least five of the seven call types identified for *T. delacouri* can be judged to be distinct identities. On the quantitative data of measured attributes alone, Squeals, Grunts and Hoots could be distinguished as distinct vocalisations, with at least four out of seven significantly different attributes in comparison to the other call types. Click and Meow vocalisations significantly differ in only one measured attribute, but examination of their visual spectrograms and audio clips confirms that the calls are structurally different, and therefore distinct. Only Squawks and Screeches cannot be deemed as distinct calls in their own right, predominantly due to the lack of samples for analysis. Further sampling of *T. delacouri*’s vocal behaviour would be needed to determine if these are two different call types, or in fact just variations of the one distress call. It is also possible there are other call types that have not been identified in this study, but throughout the duration of fieldwork for this project no other vocalisation types were heard so this is unlikely.
Squeal calls had the highest average peak frequency (3686 Hz), which is presumably linked to this call being predominantly performed by young, who are immature and have a small body size, with studies having shown a negative correlation between high frequency limit and body size (Srivathsan & Meier, 2011). Hoot calls had the highest average power, at 88dB, meaning they were very loud which explains why these calls were the most commonly heard in the wild. In addition to volume, research has shown that vocalisations transmit best over distance at a low frequency, with loud calls’ peak frequency being typically under 500Hz (Byrne, 1982). Sabatini and Ruiz-Miranda (2008) found a significant relationship between frequency and degradation distance in the loud calls of golden lion tamarins (*Leontopithecus rosalia*), the calls degrading more quickly when produced at a higher frequency. Both Hoot and Click calls, which are thought to function as types of loud calls for intergroup spacing/warning, are performed at a low frequency with average peak frequencies of 325Hz and 387Hz respectively meaning that they are likely to transmit well over large distances, as would be expected for an intergroup function. Further research into the rates of transmission and degradation of the different *T. delacouri* calls in their natural environment would be worthwhile.

### 5.4.4 Interspecific differences

Differences in vocalisation behaviour between closely related species can assist in unravelling the evolutionary relationship between species, and in some instances can help resolve taxonomic uncertainties within a group (Brandon-Jones et al., 2004; Konrad & Geissmann, 2006; Groves, 2007). Vocal behaviour between species can be very similar, and there are several examples of primates responding to the alarm calls of other primates (Byrne, 1982; Ramakrishnan & Coss, 2000; Zuberbühler, 2000). Ramakrishnan and Coss (2000) found bonnet macaques (*Macaca radiata*) in India who resided in the same region as Nilgiri langurs (*Semnopithecus johnii*) and Hanuman langurs (*Semnopithecus entellus*), would respond appropriately to the langurs’ alarm calls, as they would their own.

Conducting this study within the EPRC allowed the unique opportunity to compare the vocalisation behaviour of *T. delacouri* with that of some other closely related limestone langurs – namely *T. ebenus*, *T. francoisi*, *T. hatinhensis*, *T. laotum*, and *T. poliocephalus*. There is little published work on the vocal behaviour of this group in English, and no concentrated vocalisation studies. Broadly speaking, the
vocalisation behaviour is relatively similar between the species, and the breakdown of the frequency of utilisation for each call type is comparable between species, when taking the different sex/age class composition of each group within the EPRC into account. The frequency of vocalisation across different sex/age classes along with the call types typically performed by each class was also similar between T. delacouri and the other limestone langur species. Although there were no subadult females or black infants available for sampling for T. delacouri, by looking at the vocalisation behaviour of individuals of these sex/age classes in other species, an idea of their likely behaviour can be gained.

Audibly, it was easy to pick out Grunt, Hoot and Squeal (for groups with young) calls in each species, with Click calls also identified in T. ebenus, T. laotum, and T. poliocephalus adult males. The measured attributes of Grunt calls were similar across all five species analysed; the call was most likely to differ in average peak frequency and high frequency limit, and hence also frequency range (refer back to Section 5.3.6). Hoot vocalisations showed similarities between species, and were accompanied by the same characteristic bounding display as seen in T. delacouri; there was however more distinction in this call between the three species analysed, and audibly the hoot vocalisations of T. francoisi and T. poliocephalus were performed more rapidly and with audible inhalations and exhalations than compared with T. delacouri (see Appendix II). Squeal calls were relatively similar across species, but due to the nature of this call it tends to have a more variable structure and length, and hence there were some differences when comparing measured attributes. Meow calls were performed only by T. delacouri, although T. hatinhensis was the only other species in the study with subadult males, which was the sex/age class known to perform the call. It is possible that Meow calls are unique to T. delacouri, or that its apparent absence in T. hatinhensis is a simple matter of chance, or possibly that an unknown social situation that results in a Meow call did not occur in the T. hatinhensis captive group. It should be noted that any perceived differences between species may in fact be caused by differences in a particular individual, since the number of individuals available for sampling in this study was very small (total n = 34). A more comprehensive study of the vocalisation behaviour of each species in a wild setting is needed, but this study does suggest there may be some differences in
the structure of different call types, although overall the vocalisation behaviour is much the same across the limestone langur species.

5.5 Summary

*T. delacouri* were found to produce five distinct vocalisations, along with two other unconfirmed call types, with likely functions ranging from distress and warning calls to contact and spacing calls. Overall *T. delacouri* vocalisation behaviour was found to be relatively similar to that of other limestone langurs, but there were some measurable differences in the structure and format of calls.

This study was limited by being conducted in a captive environment, which was the only feasible environment for recording *T. delacouri* vocalisations because I was never able to get close enough to individuals in the wild to hear most vocalisations. A full understanding of the different functions for each call would be better gained in a wild environment where animals are not influenced by limited space, set cage companions, feeding times, and so on, and are free to interact with each other. Some sex/age classes were not represented if there were no individuals of this class for a particular species present at the EPRC, and additionally only limited individuals of each class were able to be sampled. Therefore extrapolating results to reflect limestone langur populations as a whole should be done with caution, as results in some instances may also be reflective of an individual performer’s vocalisation behaviour and not necessarily broadly representative of the species. The vocalisation study was not initially planned as part of this project, and as such specialised equipment for recording vocalisations was not available for use, although the equipment that was available still provided high enough quality recordings for later analysis.

As this study provided one of the first overviews of the different vocalisations utilised by *T. delacouri* and other limestone langur species, a further study focusing on each species in its wild environment would build on this work. Further investigation into how *T. delacouri* uses its vocalisations across the day, as well as possible seasonal and weather related differences, such as have been found to occur in some primates, for example gibbons (as discussed above in Section 5.4.2), would be interesting. Additionally, experiments looking at the different uses of distress and
warning calls, and how the group responds to these, could provide a greater understanding of the function and potential benefits of intra and intergroup communication and relationships in *T. delacouri*.
An adult male and subadult male Delacour’s langur, both wearing GPS collars, two days after their release into the wild at Vân Long Nature Reserve
6.1 Introduction

The use of releases in conservation can take many forms (translocation, reintroduction, reinforcement), and has the potential to provide great benefits to endangered species, although it also carries the risk of causing irreversible harm (IUCN, 1987; Griffith et al., 1989; Ounsted, 1991; Stanley Price, 1991; Bright & Morris, 1994; Sarrazin & Barbault, 1996; Fischer & Lindenmayer, 2000; Laidlaw, 2001; Banks et al., 2002). Releases often aim to reintroduce animals into their natural historic range, and may also function to increase numbers and genetic diversity in an area where the population is depleted. For critically endangered species, especially those with fragmented and small populations, release of captive stock into wild populations, translocation of population fragments to safer environments, or movement of groups into existing populations where breeding can more effectively occur can be an appropriate strategy to stem species decline. On the other hand, due to their nature, release programmes tend to be complicated, expensive to implement, and may have long-term implications for any resident animals, therefore a careful assessment of aims and risks must be undertaken before embarking on such a programme.

In August 2011, the Endangered Primate Rescue Center (EPRC), as part of the Frankfurt Zoological Society’s (FZS) ‘Vietnam Primate Conservation Program’, conducted the first-ever release of captive *Trachypithecus delacouri* into the wild. Following on from the EPRC’s goal to establish captive breeding populations, the Center began to move towards releasing some of its primate species (Nadler, 1996a; Nadler, 2007; Nadler, 2011; Frankfurt Zoological Society, 2012; Nadler, 2012a). This was first scheduled to be done with Hatinh langurs (*T. hatinhensis*), when in 2007 eight individuals were transferred to a large semi-wild enclosure at Phong Nga – Ke Bang National Park, with the intention to release them following a monitoring and habituation programme (Nadler, 2008; Vogt & Forster, 2008b; Vogt & Forster, 2008a; Vogt et al., 2008; Vogt & Forster, 2010; Nadler, 2012b). However, the
planned release is yet to take place as attempts to recapture the animals to transfer them from the semi-wild enclosure to the release site have been unsuccessful (Nadler, 2012b). A release of *T. delacouri*, the Center’s flagship species, was an important landmark for the FZS program, although it was not without controversy. Some people within the wider conservation community believed that the release should not have taken place due to concerns over a lack of transparency in planning and the potential risk of disease transmission to the existing Van Long population on Dong Quyen, with the IUCN Primate Specialist Group and Species Survival Commission involved in these discussions. Ultimately, the EPRC’s release project went ahead, with a goal to connect the successful Dong Quyen *T. delacouri* population with the relic population in western Van Long, promoting opportunities for interbreeding and supporting the genetic stability of the Van Long population as a whole (Nadler, 2012c).

This chapter gives a factual description of the processes undertaken in conducting this release, and provides the first indication of what behaviours released *T. delacouri* individuals’ exhibit in the wild, aiming to address questions of their ranging and dispersal pattern and any similarities they may show to captive and wild *T. delacouri*. An evaluation of the release process in comparison to the IUCN guidelines, along with an assessment of its ‘success’, is undertaken in the following chapter.

### 6.2 Description of the release

#### 6.2.1 Preparations

The EPRC, led by Tilo Nadler, has conducted a vast amount of research, including field surveys (with several unpublished works) on *T. delacouri* since the 1990s. A lot of the EPRC’s research has been concentrated in the Van Long area looking at the area’s ecology and existing populations, while other researchers have focused on population genetics (Ebenau *et al.*, 2011), foraging ecology (Workman, 2010b), and behaviour, conservation and ranging patterns (Nguyen Vinh Thanh & Le Vu Khoi, 2006; Nguyen Vinh Thanh, 2007; Nguyen Vinh Thanh, 2008b; Nguyen Vinh Thanh, 2008a; Nguyen Vinh Thanh, 2009). Through this the EPRC
has amassed a considerable amount of knowledge about the area, and drew on this when developing the Delacour’s release project.

Van Long Nature Reserve was chosen as the release site, with the support of the Van Long Management Board, Ninh Binh Forest Protection Department, and the Ministry of Agriculture and Rural Development, as it was considered the only viable site for such a project by the EPRC (Nadler, 2012b; T. Nadler, pes. comm. 2011; see Chapter 7 for further discussion). Recent publications estimate that T. delacouri occurs across 10 isolated subpopulations in northern Vietnam (Ebenau et al., 2011), with Van Long being the only one deemed to be adequately protected with low hunting risks and an increasing monkey population. The EPRC wanted a release to help restore relic populations and stabilise the reserve population as a whole (Nadler, 2012b). Within Van Long, the population on Dong Quyen is doing well (see Figure 6.1), having expanded from an estimated 40 to 70 individuals between 2004 and 2010, and additionally the Hang Tranh outcrop group is considered a stable expanding population, with 10 – 15 individuals (Nadler, 2004a; Workman, 2010a; Workman, 2010b). Meo Cao is predominantly inhabited by Assamese macaques (Macaca assamensis), making it arguably unsuitable for another primate release (T. Nadler, pers. comm. 2011). It is also extremely difficult to access with steep cliffs on all sides giving it poor monitoring potential. Therefore the western portion of Van Long was chosen by the EPRC as the release area, it being the least populated part of the reserve with the most potential for expansion. Ebenau et al. (2011) surveyed the western area in March - June 2010, and reported two - three groups within the reserve’s borders, with a total of six individuals being sighted, and an estimated population of 20 individuals across Van Long’s western block. The EPRC, with assistance from guards and rangers, used their knowledge of the area and the range of existing T. delacouri groups to select a cage site in the Mao Ga area near Da Han village. The cage was placed at 20.4101°N, 105.8556°E (see Figure 6.1) in a small clearing within the forest, approximately 200m from agricultural pastures and 750m from the road. The cage was constructed of 16 metal framed panels with rope netting, creating a cage of approximately 16m², with bamboo poles and leaf foliage from the surrounding area placed inside. The roof was partly covered by a tarpaulin for shelter, with a water trough, and a hinged door in one panel to allow access.
Figure 6.1 The location of the release cage site in the western portion of Van Long Nature Reserve, shown by a green square in a), with the yellow star marking the reserve headquarters and red line the approximate reserve boundary. Additionally the three karst outcrops in the eastern portion (DQ = Dong Quyen, HT = Hang Tranh, and MC = Meo Cao) are marked with the main potential dispersal barriers identified by the EPRC highlighted - a dam (in pink) separating DQ and HT and the road (in grey) running through the reserve which separates the western block (Google Inc., 2012); b) looking down on the cage site in a SE direction.

The release group, a family group of three individuals - was chosen from the captive stock at the EPRC (see Table 6.1), with a VHF radio–GPS collar purchased for each individual. The group, an adult male-female pair and their subadult son, were housed together in Cage 2B within the EPRC prior to their release. The adult pair (1-10 and 1-09) had been born at the EPRC from wild-born parents that were confiscated and placed in the Center’s care following rescue. In late June 2011 individual 1-09 gave birth to a female infant, the pair’s second offspring, but it was removed and hand-raised after suffering an infection that required medical care (T. Nadler, pers. comm. 2011).

Table 6.1 The release group consisting of an adult male-female pair and their subadult son

<table>
<thead>
<tr>
<th>Individual</th>
<th>Class</th>
<th>Date of birth</th>
<th>Origin</th>
<th>Weight on release (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-10</td>
<td>Adult male</td>
<td>04/06/2001</td>
<td>Captive born</td>
<td>8.7</td>
</tr>
<tr>
<td>1-09</td>
<td>Adult female</td>
<td>03/04/2001</td>
<td>Captive born</td>
<td>8.2</td>
</tr>
<tr>
<td>1-20</td>
<td>Subadult male</td>
<td>30/01/2008</td>
<td>Captive born</td>
<td>5.3</td>
</tr>
</tbody>
</table>

Pre-release health checks were conducted by wildlife veterinarian Dr Ulrike Streicher with assistance from Nadler and EPRC staff. Animals were anesthetised
for their health checks using a blowpipe with a ketamine/xylazine mixture at a dose of 0.02 ml/kg, with an antagonist used to bring them out of sedation. The first health check was conducted on 21st April 2011, with the samples being analysed at Benh Vien Medlatec Hospital in Hanoi. Samples were tested for a complete blood count, complete chemistry profile, hepatitis A, B and C, herpes simplex, and cytomegalovirus (for further discussion see Chapter 7). Additionally the animals were checked for ectoparasites and endoparasites, and given an intradermal tuberculin test for avian and mammalian tuberculosis (U. Streicher, pers. comm. 2011). A thorough clinical examination was done, consisting of a dental check, full measurements of limbs, weighing and checking for any injuries or anomalies. The langurs were given a tetanus injection and any required parasitic treatment during this check. Furthermore, all animals were microchipped and serum, EDTA blood and hair samples were banked for further investigation (T. Nadler, pers. comm. 2011).

After the first health checks, with all results being clear, quarantine measures were implemented for 30 days (U. Streicher, pers. comm. 2011). The entire double cage unit (including the adjoining Cage 2A housing a single T. delacouri adult male) was placed in quarantine, with a boot dip placed outside the cage entrance and specific tools and boots assigned for use in only that cage. All staff caring for the quarantined individuals had been checked for tuberculosis and vaccinated against hepatitis (E. Schwierz, EPRC head keeper, pers. comm. 2011).

A second round of health checks was conducted on 23rd May 2011, repeating all tests as outlined above and checking for a clean tuberculosis result. The results once again came back clear (pers. comm. U. Streicher), and the animals remained in quarantine until transportation for the release three months later.

6.2.2 Transportation

The release was originally scheduled to occur in April 2011, but was delayed for several reasons including difficulties in accessing equipment and materials, and concerns by external parties over the release procedures. It eventually took place in August, with transportation to the forest site occurring on 20th August 2011.

On the morning of transportation, I double checked the collars and basestation download system, prior to the GPS collar fitting. The langurs were anesthetised and
transferred to the veterinary room for a final physical check and weighing. The collars were then fitted by Streicher, with care taken to attach them with an approximately three finger gap whilst ensuring that they were not too loose. Any excess collar material was cut off and the collars were turned on using a magnet to start each collar transmitting to the basestation, which was then used to activate the data collection system. Each animal was then moved to a transportation crate and given an antagonist to bring them out of sedation before being loaded in to the back of a truck and transported by road to Van Long.

On arrival at the Reserve, we found that recent heavy rainfalls had caused severe flooding, so a longer route round the Reserve border had to be taken before abandoning the vehicles to use a boat to cross a ford on the farm road near the release site (see Figure 6.2). The crates and equipment were then carried the remaining 600m to the cage, with an approximate 50m climb, by EPRC staff and Van Long guards. The animals were released into the forest cage at approximately 4pm, roughly four hours after having been crated. The transportation of the animals was filmed by a Vietnamese TV channel as part of a documentary, and several Vietnamese officials from the Ninh Binh province were also present.

![Figure 6.2 Transfer of the langurs across a flooded ford in Van Long on route to the forest cage site.](image)
6.2.3 Release

The animals remained in the forest cage for 40 hours (including two nights), prior to the release. During this time they all appeared calm and were exhibiting typical behaviours consistent with their behaviour in the EPRC. They showed some curiosity to their new surroundings and forest sounds. Both 1-10 and 1-09 frequently sat on and moved across the natural substrate floor, whilst 1-20 kept to the bamboo perches placed within the cage. Individual 1-09 was seen to tug and play with her collar on a few occasions, whilst the males appeared unaware of their collars’ presence. Fresh leaf bundles were placed in to the cage three times daily, and the water was topped up as necessary. During this period each collar’s radio signal and GPS download function were again checked to ensure functionality.

On the morning of the release (August 22nd 2011), the langurs were provisioned with fresh leaves at 6am. The weather was fine and clear, with light winds. By 8am approximately 25-30 people had arrived to witness the release, with people arranged on either side of the cage to try and form barriers to direct the animals into the forest. The cage door was opened by Nadler at 8.15am, and individual 1-10 immediately exited the cage and approached Nadler for food. All three individuals then moved in and out of the cage several times before moving to a nearby tree after about three minutes. After approximately ten minutes, the group was led deeper into the forest in an effort to move them away from the observers; their movements past this point are described in the following section. Remaining fresh leaf bundles were left in the cage following release, but the langurs were never observed to feed on the supplied food.

6.3 Methods

This section explains how collar data were analysed; refer back to Section 3.8 for a description of the radio-GPS collars that were fitted to each of three released langurs and the tracking schedule, including the collection of ad libitum behavioural notes in the first days post release.

6.3.1 Data mapping and day journey length

Data from the three Global Positing System (GPS) collars were systematically downloaded on to a computer, producing outputs in both Microsoft Excel and
Google Earth (Google Inc., 2012) formats. Spreadsheet data were then converted and uploaded into ArcMap 10.0 (ESRI, 2010), with the time and date in the local time zone for each GPS fix, along with the latitude, longitude and height above ellipsoid if the fix was successful. All data were overlaid on a base map of the reserve (supplied by Nadler, map author unknown), and connected using the Point to Line function to show each individual’s journey. Day journey length was calculated by joining the 12 successive GPS fixes for each day and summing the straight line distance between each, with the height of each point included to give a basic 3D day journey length. An Analysis of Variance test was conducted in GenStat, with the assumptions of normally distributed variables, independent samples and equal variances met (Zar, 1999), to look at differences in journey length between individuals. Seasonal and monthly differences in day journey length were analysed using Excel, and independent two sample t-tests looking at individual differences were calculated, with significance levels set at $\alpha = 0.01$.

To assess patterns in travel distances throughout the day, the length of each individual 1.5 hour leg (between GPS fixes) was also analysed, to look at patterns in travel distances across the day. Distances were calculated by converting the GPS points into Universal Transverse Mercator (UTM) values, and then utilising Euclidean distance mathematics to calculate each leg length in Excel. Distances measured using UTM values have a small error associated to the ellipsoid curvature of the earth’s surface (Shortis & Seager, 1994), but across this comparatively small scale the error is insignificant. All graphical work and summary statistics were conducted in Excel.

### 6.3.2 Ranging patterns

Individuals’ ranging patterns were described with the assistance of ArcMap 10.0 and Google Earth. When considering the area that each individual covered, minimum convex polygons (MCP) were constructed in ArcMap 10 (ESRI, 2010) using the Minimum Bounding Geometry tool, which gave an estimation of their total ranging area. It should be noted that MCP’s tend to overestimate area sizes as they can include large chunks of space that the animal never entered, but were simply included due to the geometrical constructions of the shapes (Boyle et al., 2009; Grueter et al., 2009). A quadrant system to estimate home range area was also utilised (Hu, 2007; Zhou et al., 2007a; Grueter et al., 2009; Palma et al., 2011), with
a grid of 1102 200m x 200m cells covering the entire study site constructed using the Create Fishnet tool. This cell size was chosen so as to cover the large area in which the langurs travelled, whilst still providing fine detail on movements. The number of GPS points for each individual in each cell was then calculated, allowing an indication of the amount of time individuals spent in different areas. Home range area was then calculated by counting the number of 4ha cells in which the individual appeared, both across each month as well as for the duration of their tracking period, which was 283 days for individual 1-10, 147 days for 1-09, and 409 days for 1-20.

Additionally, the grid was used to show areas of overlap between individuals, with any cell that was visited >10 times by two or more individuals mapped, with colour coding indicating which individuals visited the site.

6.3.3 Proximity of individuals

The proximity of individuals to one another at any given time and day was calculated by again utilising UTM values and Euclidean distance mathematics. The distance between a pair of released individuals was graphed against the number of days since release, and linear regressions were conducted in Genstat with coefficient of determination values also given. Mann-Whitney U tests were utilised to look at differences in the proximity within which one individual moved compared with another. Non-parametric tests were used as data violated the assumption of equal variances for parametric testing (Zar, 1999).

6.3.4 Accuracy of equipment

Values on the effectiveness of radio and download signals were calculated from field notes validated with Google Earth to measure distances between the animal and the observer. Data on collar GPS fix success rates and time to fix were extracted from the downloadable data spreadsheets off each collar. All descriptive statistics were calculated in Excel.
6.4 Results

6.4.1 Initial post release dispersal and behaviour

Following release, I, with the assistance of Nguyen Hong Chung and Nguyen Van Linh, closely tracked the langurs for nine days, and took ad libitum notes, by which time visual sightings of the group had ceased (for methods refer back to Section 3.8).

Day 1 - 22nd August: Following release at 8.15am, the group remained resting and feeding in trees within 50m SW of the cage, with some vocalisations (grunts and meows) heard (see Figure 6.3). At 10:20am individual 1-10 approached the cage, before returning back into the undergrowth. He again approached the cage at 12:20pm and was within 10m of me; he spent 10 minutes around the cage area, often climbing on the outside of the cage, before moving off in an easterly direction. At 2:40pm, 1-10 returned to the cage and entered it, resting in the shade for 20 minutes but not approaching the leaves or water. Throughout this time individuals 1-09 and 1-20 remained within the forest area 50-100m from the cage. At 4:30pm 1-10 again returned to the cage, while 1-09 and 1-20 were spotted on the forest edge 20m from the cage, where 1-10 joined them after 10 minutes. By 6:00pm the group appeared to have settled in the forest for the night within 50-100m of the cage in a SW direction (see Figure 6.4).

Figure 6.3 Individuals 1-20 (left) and 1-09 (right) with their GPS collars visible, approximately one hour after release into the wild.
**Day 2 - 23rd August:** At 5:30am a series of vocal grunts began to be heard, but the group was not visually sighted until 6:10am when they began feeding in a tree canopy. The group continued to feed in the forest area in front of the cage until 9:00am, when 1-10 and 1-20 moved in an easterly direction to within 10m of me, crossing a small forest trail NW of the cage. The group remained relatively inactive for the rest of the day, a noticeable difference from day 1, staying within this area. They were not sighted at all during the afternoon, but GPS data showed that they did not move out of the area. It was a very hot day (over 30°C) and this may have contributed to their inactivity.

**Day 3 – 24th August:** Overnight there was heavy rain and thunder, but the group spent the night in the forest and did not return to the cage for shelter. At 7:20am, individual 1-20 was spotted feeding in a tree approximately 200m west of the cage, and at 7:55am 1-10 and 1-09 were also sighted, resting in the same tree. At 10:45am the two males entered the cage but did not approach the leaves or water trough, with 1-10 resting inside and 1-20 playing, both remaining in the cage for 45 minutes. Led by 1-10, they headed back to the forest SW of the cage, following a forest trail towards the last sighted position of 1-09. During the afternoon several vocal grunts were heard from the forest basin but there were no further visual sightings. During the day several explosions were heard from the limestone quarries but none of the group seemed to react, possibly as they were acclimatised to the noisy environment of the EPRC.

**Day 4 – 25th August:** At 7:00am all three individuals were visible feeding in trees in the forest basin, and at 7:35am they approached the cage, with 1-09 and 1-20 entering. At 7:50am, 1-10 approached the observers (myself and two field assistants), possibly expecting food, and the group began to follow us as we attempted to move away from them, until the langurs eventually lost interest and moved back towards the cage after we hid behind undergrowth. By 9:00am the radio signal indicated that the group had begun to move, for the first time since release leaving the forest basin immediately in front of the cage, and moving 150m in a SE direction down the ‘cage hill’. They spent the remainder of the day on this hillside, occasionally feeding and vocalising (grunts) but predominately resting.
Day 5 – 26th August: The group began to move around the base of the cage hill in a SW direction, covering a distance of approximately 100m during the day. No visual sightings were made, but movements in the trees were seen. GPS data showed that the group slept in different sites for the first time, about 200m apart from one another.

Day 6 – 27th August: No visual sightings were made, but radio signal indicated that the langurs were still in roughly the same area. GPS data later showed the group had begun to range more widely, exploring surrounding valleys and the nearby ‘central hill’. Individual 1-10 had separated from the group and moved 450m up a valley. Again all individuals overnighted separately, with 1-10 returning to the same position as the night before.

Day 7 – 28th August: Brief sighting of one unidentified individual (thought to be 1-09) on the central hill, but no other visual sightings. Individual 1-10 remained in the valley to the south of the central hill, whilst 1-09 explored a smaller valley to the north of central hill. Individual 1-20 remained in the same region on the cage hill, his location since Day 5, 250m away from 1-09.

Day 8 – 29th August: Again no visual sightings were recorded, although radio signals were tracked, with the langurs moving within the same general area as previous days. Once again all individuals settled overnight in separate areas, having not spent the night in the same area since Day 4, possibly indicating a separation among members of the group although they were still moving within 600m of each other.

Day 9 – 30th August: Whilst tracking the radio signal of 1-09 through the forest in a small valley west of the cage hill, individual 1-20 sprang out from behind a rock and ran off – this was to be the last visual sighting of any of the group for three months. Individual 1-10 remained in the valley, whilst 1-20 remained 450m away on the south face of the cage hill. Individual 1-09 had moved northwards round the side of cage hill heading back towards the forest basin in front of the cage, approximately 650m away from 1-10 and 350m from 1-20. Tracking from this point onwards was limited to radio signals and analysing GPS data.
Figure 6.4 Map showing the movement of the released langurs over the first 9 days, post release. Numbers indicate each of their positions at the first GPS fix of each day post release (4:00am), with some numbers unavoidably obscured due to being placed near one another.

6.4.2 Total tracking period

Following the release on 22 August 2011, each individual was tracked and all GPS data downloaded until its collar was no longer functioning or it could not be found. Individual 1-10 (adult male) was tracked for a total of 283 days, collecting 2798 GPS fixes during this time; the last recorded point was at 4am on 30 May 2012 (see Figure 6.6 and 6.7). At this point, despite several efforts by field assistant Nguyen Hong Chung over the following weeks, no further signal could be found for 1-10 indicating that either the collar had failed, he had moved well out of the expected ranging area, or he was in an area (such as a valley) where the signal could not transmit. As there were no further sightings of this individual, the survival of 1-
10 past this time remains unknown, however it is thought that a fault with the collar is the most likely explanation for his apparent disappearance, as the battery was expected to last till mid-July 2012 and no signal for 1-10 was ever detected during the following two months of tracking.

Individual 1-20 (subadult male) was tracked for a total of 409 days, collecting 3827 GPS fixes, the last recorded point being at 5.30pm on 3 October 2012, making 1-20 the only individual to be monitored for over a full year (see Figure 6.6 and 6.8). Initially, it was thought his collar had stopped transmitting after a last known point on 5 August 2012, and the monitoring programme was discontinued at the end of August when no further signals for any of the langurs were found. However, data for 1-20 was downloaded by chance on 4 November 2012 by Nguyen Hong Chung and biologist Sarah Elser whilst they were tracking a second newly released langur group. This download contained data from 5 August 2012 – 3 October 2012, although the collar appeared to be malfunctioning in the final few days, with GPS fixes being attempted at irregular intervals. Despite the fact that there was still sufficient memory capacity in the collar (it can hold up to 150 days of data before a download is required), and the download of data to the basestation was still possible on November 4th, GPS fixes had stopped occurring on October 3rd possibly indicating that the battery was nearing the end of its life. No further signals from, or sightings of, 1-20 were detected, so the animal’s survival past this point cannot be confirmed.

Initially tracking of individual 1-09 (adult female) went smoothly, but in February 2012, after my departure from Vietnam, I raised concerns with the EPRC over the lack of movement being shown in her GPS data that I was receiving. This situation continued to be monitored, and further investigation showed all data points were being recorded within a 100m² region, an unusually small area for an animal to remain in for an extended period of time. Possibilities of the animal having been injured (limiting movement) or having died were discussed, and Nguyen Hong Chung made unsuccessful attempts to access the area and sight the individual. The terrain surrounding the area was extremely mountainous with thick vegetation and no major trails nearby, making access difficult. Eventually, on 4 June 2012, 1-09’s GPS collar was recovered from the forest floor (GPS coordinates of collar’s location 20.402N, 105.82993E), with no sign of 1-09 in the area. The collar was mostly intact, with no break through the material or leather at any point, but there was
evidence of an animal having chewed on it extensively (see Figure 6.5). The most likely explanation is that the chew marks came from 1-09, who may have been irritated by her collar, and it had most likely slipped off over her head, possibly with her assistance. Alternatively it is possible the collar has been chewed on by a predator, or another animal after it became detached from 1-09. Although it is impossible to tell exactly when the collar parted from her, due to error in the GPS readings continuing to show small ‘movements’, examination of the data indicates that this is likely to have occurred sometime in mid-January 2012. Therefore all data for individual 1-09 after 15 January 2012 were discarded. For analysis purposes, 1-09 was tracked for 147 days collecting a total of 1559 GPS fixes with the last recorded point at 8.30pm on 15 January 2012 (see Figure 6.6 and 6.9).

Figure 6.5 Individual 1-09’s collar, recovered from the forest floor in June 2012, showing chew marks on the collar at the bottom of the photo - Photo by Nguyen Hong Chung.
Figure 6.6 The movements of the three released *T. delacouri* from release at the ‘Cage Site’ on 22 August 2011 to the end of each of their respective monitoring periods. Each successful GPS fix for individual 1-10 (Adult male) is shown in blue, 1-09 (Adult female) in pink, and 1-20 (Subadult male) in yellow. Note some points are obscured due to multiple points in the one location.
Figure 6.7 The movements of individual 1-10 from his release at the ‘Cage Site’ on 22 August 2011 to the 30 May 2012 (283 days). Data is given a temporal scale by points being broken into month long blocks, with light white/blue points being August 2011, through to dark blue in May 2012.
Figure 6.8 The movements of individual 1-20 from his release at the ‘Cage Site’ on 22 August 2011 to the 3 October 2012 (409 days). Data is given a temporal scale by points being broken into month long blocks, with light white/yellow points being August 2011, through to dark yellow/brown in October 2012.
Figure 6.9 The movements of individual 1-09 from her release at the ‘Cage Site’ on 22 August 2011 to the 15 January 2012 (147 days). Data is given a temporal scale by points being broken into month long blocks, with light white/pink points being August 2011, through to dark pink in January 2012.
6.4.3 Day journey and path length

There was a significant difference in the day journey length between the three released *T. delacouri* ($F_{(2, 852)} = 69.05, \ p < 0.001$); the difference holds across pairwise comparisons. Over the 283 days of monitoring, individual 1-10 travelled a minimum total distance of 207.9km and had an average day journey length of 735m ($\pm 18.4$m). The maximum distance travelled in one day was 1975m on 15 April 2012, and the minimum 145m on 10 September 2011 (see Figure 6.10). At his furthest point from the release site, 1-10 was 4287m away on a 263° bearing from the cage on the 29 April 2012 (refer back to Figure 6.7).

Individual 1-09 travelled a minimum total distance of 68.6km over 147 days, with an average day journey length of 467m ($\pm 16.2$m). She travelled a maximum distance in one day of 1472m on 27 December 2011 (see Figure 6.10), and a minimum of 30m on 4 January 2012 – which was about the time problems with her collar first started occurring. Around this same time, on 3 January 2012, 1-09 was at her furthest point from the release site at a distance of 3017m on a bearing of 252°.

Individual 1-20, over 409 days, travelled a minimum total distance of 238.8km with an average day journey length of 584m ($\pm 11.0$m). On the 18 November 2011, 1-20 covered the maximum distance travelled in one day at 1864m, with the minimum of 68m travelled on the 18 February 2012 (see Figure 6.10). Individual 1-20 travelled further from the release site than the other langurs, being 5308m away on 1 May 2012 at a bearing of 336° from the cage.

![Figure 6.10](image.png) The day journey length of each individual in a box and whisker plot, with the mean value shown by ‘X’.
When looking at travel distances across the day in 1.5 hour intervals between GPS fixes, there was a clear pattern (see Figure 6.11). All individuals covered the greatest average distance between 07:00 and 08:30; individual 1-10 averaged 108m in this time. A late afternoon peak of activity between 4:00pm and 5:30pm was also shown, and travel distances then dropped sharply as the animals settled for the night. On average sunrise occurs around 6:00am at Van Long, with sunset at approximately 6:00pm. Small distances were recorded between 7:00pm - 8:30pm and 4:00am – 5:30am, but some of these may simply be a result of errors in the GPS fixes and not actual movement. Individual 1-10 recorded a maximum leg distance of 620m in a 1.5 hour period, with 1-09 covering a maximum of 291m, and 1-20 715m.

![Figure 6.11](image-url) The average straight line distance an individual covered in each 1.5 hour leg between GPS fixes across the day, with standard error bars for each average given.

When looking at seasonal differences in day journey length between the summer (May – October) and winter months (November – April) at Van Long, individual 1-10 showed a significant difference between the seasons ($t = -2.70, p = 0.007 \ n_{\text{summer}} = 101, n_{\text{winter}} = 182$), with an average of 668m (± 29.3m) in summer and 771m (± 23.2m) in winter (see Figure 6.12). But 1-09 and 1-20 showed no significant difference between summer and winter journey lengths (1-09: $t = 0.37, p = 0.712 \ n_{\text{summer}} = 71, n_{\text{winter}} = 76; 1-20: t = 0.64, p = 0.521 \ n_{\text{summer}} = 227, n_{\text{winter}} = 182$).
Figure 6.12 The average day journey length of each individual, across the two seasons experienced at Van Long - the wet summer (May – October) compared with the dry winter (November – April). Standard error bars for each average are given.

Considering the average day journey length for each individual on a monthly basis (see Figure 6.13), there is no clear pattern of changes in journey length as the time from release increases. Individual 1-10 had the highest monthly average of 967m in April 2012, and although he showed a slight increasing trend, since the data do not cover the full year it is possible this was simply due to seasonal changes. For individual 1-09, the significantly decreased average in January 2012 of 282m was the most notable feature, and this was linked to her losing her collar some time in the first half of this month (data recorded after 15th January was discarded). Individual 1-20 had a noteworthy dip in journey length in February 2012 when the average dropped to just 357m. The reasons for this were unclear, although 1-10 also showed a slight dip in journey length in February. It may be a seasonal effect, with February at the tail end of the coldest period of the year (refer back to Figure 3.8), and this may also be linked to food availability and energy requirements at this time (Zhou et al., 2009; Workman, 2010b). Individual 1-20 also showed a dip in October 2012, but this is due to only four days of data being collected in this month, and is likely a function of the collar beginning to malfunction and record fewer GPS fixes towards the end of its life, a trait that may have occurred with all three collars.
Figure 6.13 Individuals average day journey length, broken down into months, showing changes in day journey length as time from release increases. Standard error bars for each average are given.

### 6.4.4 Ranging patterns

Early on in the monitoring period it became clear that the langurs were ranging much more widely than expected, given previous research (Nguyen Vinh Thanh & Le Vu Khoi, 2008a; Workman, 2010b) and my own observations of the Dong Quyen groups. Additionally they were not staying together as a cohesive family group, despite *T. delacouri* typically forming single-male-multifemale groups (Harding, 2011), and from as early as day five post release they were moving independently. This greatly increased the difficulty of tracking, as the radio pinger signal for each individual was only audible for one hour per day, and an individual could potentially move hundreds of metres in unpredicted directions in any day.

Individual 1-10 initially moved in a valley south of the release site before heading around Ba Chon in a clockwise motion and returning to the valley at the end of October 2011 (refer back to Figure 6.7, Figure 3.5 for area names and Appendix II of movement animation on disc). In November-December, 1-10 remained around Ba Chon, moving close to the reserve edge and within 100m of local villages, roads and the army camp at several stages, before heading north to a basin about 1km west of the cage site. In January-February 2012 he moved further north to the park’s northern boundary, and spent 19 days outside of the reserve’s northern-most boundary, before heading down the eastern border back to Ba Chon and at one stage
crossing the road to the Hang Tranh outcrop. In March, 1-10 continued to explore the Ba Chon area, again moving close to villages and agricultural lands, as well as visiting the basin west of the cage, before moving off to a range further west of Ba Chon, crossing a forest trail at the mountain’s base. In April-May 2012 he moved further west, now approximately 2km from Ba Chon’s slopes before heading north to the parks boundary and circling round the far west of the park in an anti-clockwise direction, reaching his furthest point from the release site of 4.3km at a bearing of 263°, before returning to his start point. He then explored a mountainous area parallel to the Ba Chon range, before crossing back to the basin west of the cage and was last recorded moving from here towards Ba Chon.

Individual 1-09 initially remained in the forested slopes just west of the cage, as well as exploring the basin 1.0km west of the cage during September 2011 (refer back to Figure 6.9, and Appendix II of movement animation on disc). In October she explored both further north and south of the basin before settling into a hilly 1.0km² area just to the west of the forest trail at the base of Ba Chon’s western slopes, and remained in this region during November. In December she began to venture further west, moving approximately 2.0km from the trail and crossing a second forest trail reaching her maximum distance from the release site of 3.0km at a bearing of 252° on 3rd January. Shortly after this it is believed she lost her collar in this area on the slopes of a steep valley, about 2.5km west of Ba Chon.

Individual 1-20 spent September 2011–February 2012 predominantly in the northern half of the Ba Chon area, and did not approach the reserve edge as closely as 1-10 had. In March 2012 he moved across the trail on the western side of Ba Chon before heading north to the basin west of the cage and onwards to the reserve’s northern boundary. In April – May he moved along a range extending out north of the reserve boundary for 35 days, at most reaching 3.4km past the northernmost point of the reserve and 5.3km from the release site, before returning to the reserve’s north-east corner in the Da Han area. In June–July 1-20 explored a ridge line just north of the cage site along the eastern border of the park, and in August he moved closely around the cage site area itself before returning to Ba Chon. He remained in the Ba Chon area throughout September, and this was his last known position at the beginning of October before his collar failed. In his time around Ba Chon, 1-20 recorded the maximum elevation recorded for any of the individuals, at 314m asl.
When considering the area that each individual covered, individual 1-10 had a Minimum Convex Polygon (MCP) of 1767ha, 1-09 521ha and 1-20 1111ha giving an estimate of home range size (see Figure 6.14).

![Minimum convex polygons for the ranging area each individual covered](image)

**Figure 6.14** Minimum convex polygons for the ranging area each individual covered

The quadrant system gives a more conservative figure of habitat use, only including cells animals were recorded to be in, although potentially missing other cells that had to be utilised to reach these points. This showed that individual 1-10 had a ranging area of 1020ha over 283 days, 1-09 284ha over 147 days and 1-20 720ha over 409 days (see Table 6.2 and Figures 6.15a, b, c).

**Table 6.2** A comparison of home range size estimates for the three released individuals done by the Minimum Convex Polygon (MCP) or Quadrant method.

<table>
<thead>
<tr>
<th>Individual</th>
<th>MCP (ha)</th>
<th>Quadrant (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-10</td>
<td>1767</td>
<td>1020</td>
</tr>
<tr>
<td>1-09</td>
<td>521</td>
<td>284</td>
</tr>
<tr>
<td>1-20</td>
<td>1111</td>
<td>720</td>
</tr>
</tbody>
</table>
Figure 6.15a Habitat ranging use by quadrant system for individual 1-10, showing all cells 1-10 was recorded to be in, with the frequency of points in each cell indicated by colour (light blue = few points, dark blue = many points).

Figure 6.15b Habitat ranging use by quadrant system for individual 1-09, showing all cells 1-09 was recorded to be in, with the frequency of points in each cell indicated by colour (light pink = few points, dark pink = many points).
When interpreting these ranging results, it should be noted that data for 1-09 were available for a much shorter period of time (refer back to Section 6.4.2), so her comparatively small ranging area may in part be a function of this. To assess all individuals equally, Figure 6.16 shows all three individuals’ ranging area up to the end of January 2012. In this time 1-10 had covered 412ha, 1-20 244ha exclusively in the Ba Chon area, compared with 1-09’s more sparsely spread 284ha. When looking at the ranging area each individual covered per month (see Table 6.3), individual 1-10 covered the largest areas with a maximum of 252ha in a month, and a mean of 176ha per month (range 92 – 252ha, with incomplete months excluded). Individual 1-09 averaged 74ha per month (range 28 – 104ha) and 1-20 110ha per month (range 48 – 216ha). Any seasonal pattern is hard to judge as the effect of time since release must also be considered, but both 1-10 and 1-20 recorded high ranging areas in March – May 2011, which is the transition from dry winter season to the wet summer. Individual 1-20 showed notably low values in September 2011, and February, June and July 2012 – but as this shows no clear seasonal pattern the reasons for this are hard to ascertain, with the exception of a possible dip in June-July in the height of summer. For the first 15 days of January 2012 individual 1-09 had an extremely small ranging area of just 28ha, and this is attributed to a possible fault in her collar or injury before it is thought her collar was lost. Individual 1-10
also showed a general trend of increasing values as time from release increased, although whether this would have dropped off if monitoring had continued past May is unknown.

**Figure 6.16** Habitat use by quadrant system from release in August 2011 up to January 2012 for all individuals, to give a fair comparison of area covered. Individual 1-10 is shown in the blue, 1-09 in pink and 1-20 in yellow. A light shaded cell indicates a low frequency of points in this cell, and a dark shade indicates a high frequency.
Table 6.3 Habitat use (calculated by the quadrant system) per month for each individual, for the duration of their tracking period. Any values marked with a * indicate that the data for this month are incomplete, so caution should be taken when comparing to other months.

<table>
<thead>
<tr>
<th>Month</th>
<th>Individual Monthly Ranging Area (Ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1-10</td>
</tr>
<tr>
<td>Aug-11</td>
<td>44 ha*</td>
</tr>
<tr>
<td>Sep-11</td>
<td>124 ha</td>
</tr>
<tr>
<td>Oct-11</td>
<td>96 ha</td>
</tr>
<tr>
<td>Nov-11</td>
<td>92 ha</td>
</tr>
<tr>
<td>Dec-11</td>
<td>136 ha</td>
</tr>
<tr>
<td>Jan-12</td>
<td>192 ha</td>
</tr>
<tr>
<td>Feb-12</td>
<td>192 ha</td>
</tr>
<tr>
<td>Mar-12</td>
<td>252 ha</td>
</tr>
<tr>
<td>Apr-12</td>
<td>252 ha</td>
</tr>
<tr>
<td>May-12</td>
<td>248 ha*</td>
</tr>
<tr>
<td>Jun-12</td>
<td>52 ha</td>
</tr>
<tr>
<td>Jul-12</td>
<td></td>
</tr>
<tr>
<td>Aug-12</td>
<td></td>
</tr>
<tr>
<td>Sep-12</td>
<td></td>
</tr>
<tr>
<td>Oct-12</td>
<td></td>
</tr>
</tbody>
</table>

The quadrant system was used to identify common areas that the individuals frequented (see Figure 6.17). This showed that the animals predominantly favoured areas around the release site, and stayed within the forested reserve rather than moving into the agricultural lands to the east of the release site. It also highlighted the use of the northern Ba Chon area by the male individuals, and exploration of the area west of Ba Chon mountain by 1-10 and 1-09.
Figure 6.17 Habitat use by quadrant system showing areas that were commonly frequented by the group. Any cell that had greater than 10 points each for two or more individuals was recorded, with the colour coding (see Legend) showing which individuals visited the area.

6.4.5 Proximity of individuals

The distance of individuals from one another as they dispersed post release showed that 1-10 was on average 1474m (± 18.4) away from individual 1-09, and there was a significant positive relationship between days since release and distance between them (F = 2143, df = 1326, p < 0.01; see Figure 6.18). Individuals 1-10 and 1-09 were only within 100m of each other during the first five days from release, and were only within 500m during the first 12 days with the exception of days 46 – 47. They were within 1km of each other for a total of 33 days across the study (or 22.6% of days), with the majority of these instances occurring early in the monitoring period. At the maximum, 1-10 was 3054m away from 1-09.
In the days since release, the distance of individual 1-10 to 1-09 (straight line distance in metres) generally increased, with a $R^2$ value (0.4823) for the linear trendline. Individual 1-10 was on average 1583m ($\pm$ 26.3) away from individual 1-20 during the study, and again there was a significant positive relationship between days since release and distance between the two ($F = 1410$, df = 2232, $p < 0.01$; see Figure 6.19). Despite an average proximity similar to the 1-10 – 1-09 relationship, the two males stayed notably closer, and were within 1km of each other across 118 days (41.7% of days) during the monitoring period. These instances occurred across the entire study, and were not exclusively clumped to the early days post release. This breaks down to 13 days on which they were within 100m of each other at instances, and 53 days within 500m (18.7%). At most, they were 6780m apart at the beginning of May 2012.

In the days since release, the distance of individual 1-10 to 1-20 (straight line distance in metres) generally increased, with a $R^2$ value (0.3873) for the linear trendline.
Individuals 1-09 and 1-20 kept an average proximity of 1388m (± 23.1) to each other, and showed a significant positive relationship between days since release and distance between the two of them, again showing a pattern of divergence over time (F = 4551, df = 1328, p < 0.01; see Figure 6.20). They were at their furthest apart in early January, at 3627m. They spent 41.8% of days within 1km of each other (61 days), similar to the relationship of 1-10 with 1-20. Of these days, 12 of them (8.2%) involved instances where the individuals were within 500m of each other, and they were within 100m of each other only during the first five days post release.

![Figure 6.20](image_url)

**Figure 6.20** In the days since release, the distance of individual 1-09 to 1-20 (straight line distance in metres) generally increased, with a $R^2$ value (0.7086) for the linear trendline.

### 6.4.6 Significant events and wild interactions

Throughout the post release monitoring period, there were a few events of significance that occurred which will be described here in more detail.

On the 29th September, just over five weeks past release, the adult female (individual 1-09) travelled over 1167m in a day, suddenly changing from the general SW direction in which she was moving, 500m from the cage, to head NNW to the most northerly part of the park that had not yet been explored by any of the release group at that time. This large distance travelled in one day was atypical for 1-09, and, coupled with the direction change, suggested that she may have been frightened by something, potentially an encounter with a wild langur group (see below Figure 6.21, outlining existing wild groups).
Despite difficulty in tracking the released langurs post Day 9, there were occasional visual sightings of different individuals. On 13th November a male langur, thought to be wearing a collar, was spotted by Nguyen Hong Chung and Nguyen Van Linh on the eastern slopes of Ba Chon, near the road that cuts through Van Long, and the GPS data confirmed that this was most likely individual 1-10. Two days later, I sighted both 1-10 and 1-20 in the same area, within 300m of each other. On the 26th November a wild group of 6+ individuals was sighted high on the eastern slopes of Ba Chon, with a male in the group conducting a bounding display accompanied by vocal hoots. This was then answered by another male north of the group, plausibly individual 1-10 judging from the GPS data confirming his location in this area. Ebenau et al. (2011) had previously sighted two wild individuals around the same area in May 2010 (see Figure 6.21). The sighting of a wild group in this area, frequented by both individuals 1-10 and 1-20, makes it highly likely that they have both encountered this group at some stage.

Previous research has indicated that T. delacouri had previously moved on occasion between western Van Long and the Hang Tranh outcrop, but this has not been noted since the road separating the areas was widened, with some suggestion that it may now be a dispersal barrier (Nadler et al., 2003). However on the 26th February 2012 individual 1-10 moved down the eastern slopes of Ba Chon and crossed the road on to the Hang Tranh outcrop. The most recent estimates of the population of wild T. delacouri on Hang Tranh were 10-15 individuals in one or two groups, and the population was known to be still present in 2012 (Ebenau et al., 2011; T. Nadler, pers comm. 2012; see Figure 6.21). Individual 1-10 spent a day and a half on the NW part of Hang Tranh, possibly encountering some wild groups whilst there, before returning to Ba Chon.

Additionally, it is possible that all three released individuals may have encountered a wild group at Ao Luon, consisting of four individuals, identified by Ebenau in March – April 2010, if they are still present (see Figure 6.21), as all released individuals moved within close proximity of this area. Similarly, individuals 1-10 and 1-20 potentially contacted wild T. delacouri in the Da Han and Dai Dong areas, as their presence was indicated by Ebenau et al. (2011; see Figure 6.21).
Figure 6.21 Probable locations of wild *T. delacouri* groups, outside of Dong Quyen, in Van Long Nature Reserve, mapped over the movements of the three released *T. delacouri*. Solid lines indicate confirmed visual sightings of groups, with Ebenau *et al.* (2011) sighting 10-15 individuals on Hang Tranh in March – June 2010, four at Ao Luon, two individuals on Ba Chon, along with the confirmed Dong Quyen population of 68-70 individuals. Additionally, I observed six individuals at this same location on Ba Chon in November 2011. Dotted lines indicate unconfirmed sightings – Ebenau heard a vocalisation at Da Han in March 2010, and estimated eight individuals at Dai Dong and six at Dong Tam based on local information and genetic sequencing of faecal samples. The main potential dispersal barriers identified by the EPRC have been highlighted – the road running through the reserve between the western black and Hang Tranh (marked in brown dotted line, with the significant barrier highlighted in white) and the dam separating Hang Tranh and Dong Quyen (marked in pink).

### 6.4.7 Accuracy of equipment

The signal range ability of the collars’ VHF radio pinger function had a significant impact on the ability to locate and track the langurs. The mountainous topography of the Van Long area, combined with steep karst cliff faces, makes the transmission of signals challenging. Additionally, signals would sometimes echo off surrounding hills and cliffs creating a strong signal in two directions which added confusion to the tracking process. With a very weak signal there was typically no directionality, with no approximate bearing of the animals’ location able to be obtained. A very weak radio signal could be obtained at a maximum of approximately 1230m through partially obstructed terrain. A strong signal, which
could clearly indicate the signal direction, could be obtained at up to approximately 620m in a clear path.

The base station’s ability to download GPS data from the collars was much more limited than the range abilities of the radio signal. Again, the surrounding terrain and the station’s position relative to that of the animal had a considerable impact on the likelihood of a successful download. The largest distance that a complete successful download was achieved at was approximately 900m across partially obstructed terrain, and 500m in an obstructed line.

The collars were set to attempt 12 GPS fixes per day, and an overall success rate of 81% successful fixes was achieved during this study. All successful fixes were three dimensional (containing latitude, longitude and height above ellipsoid) and within the accuracy limits set by the collar manufacturers. There was some location error, with some fixes found to be approximately ±20m from a known location, but this is within tolerable limits for a wildlife study of this nature (D'Eon & Delparte, 2005). Individual 1-10 had a success rate of 82%, 1-20 78%, and when looking at data up to 15 January 2012 (discarding data after the collar is thought to have fallen off), for individual 1-09, there was a success rate of 88%.

The collar batteries were estimated to last for 406 days on the settings used, based on lifetime calculator supplied by the collar manufacturer. Battery length is only an estimation, as several other factors, such as temperature, can impact on this (e-obs Digital Telemetry, 2010). The initial lifetime calculation was made using a default estimate of an average time of 60 seconds for each GPS fix, as there were no data available on the likely ‘time to fix’ figure in karst terrain within the Vietnam region. In this study the average time to fix was found to be 75.9 ± 0.03 seconds (with a 95% confidence level), meaning that the collars’ battery would be expected to last for a shorter time than estimated in the initial set up. In retrospect, the lifetime calculator estimates a battery life of 334 days for the conditions of this study, using the corrected average time to fix value. Individual 1-20’s collar exceeded this estimate and functioned for 411 days (collars were activated on 20 August 2011, two days before the release took place), but it continued to transmit a signal for download for at least 442 days when the last download was made on 4 November 2012. In contrast, individual 1-10’s collar functioned only for a minimum of 285 days,
although it is possible that it did function well past this point and the animal’s signal was simply out of range. Individual 1-09’s collar functioned for at least 289 days up to its discovery on the forest floor on 4 June 2012, and may have continued to function much longer if it had not been collected.

6.5 Discussion

Whilst this section will discuss the ranging patterns and behaviours of the released individuals, the EPRC’s release process will be evaluated and discussed in the following chapter (Chapter Seven).

6.5.1 Movements and day journey length

Daily ranging lengths can vary greatly in primates, from less than 100m to over 13km, for example *Papio hamadryas* (Kummer, 1968), depending on the species, with Colobines typically ranging 500 – 1000m in a day (Clutton-Brock & Harvey, 1977b; Mitani & Rodman, 1979; Isbell, 1991; Chapman & Chapman, 2000). Day range has been shown to be negatively correlated to the proportion of foliage in the diet, meaning that highly folivorous species such as the Colobines tend to have longer day ranges than their frugivorous conspecifics (Clutton-Brock & Harvey, 1977b; Mitani & Rodman, 1979; Davies & Oates, 1994). Day range length has also been linked to group composition (Symington, 1988; Isbell, 1991; Chapman & Chapman, 2000; Steenbeek & Van Schaik, 2001), habitat differences (Ostro et al., 1999; Merker, 2006; Zhou et al., 2011) and seasonality (Yiming, 2002; Zhou et al., 2007a; Sayers & Norconk, 2008; Ren et al., 2009).

The three released *T. delacouri* covered a large part of western Van Long Nature Reserve and beyond its boundaries during the tracking period, with individual’s 1-10 and 1-20 travelling over 200km. The average day journey length varied from 467m for 1-09 to 735m for 1-10, with some seasonal differences noted and a clear pattern of travel distances within the day found. The collar data collected in this study provide the most comprehensive data to date on the movements of *T. delacouri*, allowing calculated estimates of various ranging measurements, as well as giving insight into the behaviour of the first ever released *T. delacouri* individuals. Although behavioural focal observations were not possible, a lot of information was still able to be deduced from GPS data and associated field notes.
The limited amount of existing research on the ranging patterns of *T. delacouri* gives an average daily path length, estimated from tracking notes during full day observations, of 666m (range of 340m – 1458m) for one group on Dong Quyen and 792m (range of 420m – 1530m) for a second Dong Quyen focal group (Nguyen Vinh Thanh & Le Vu Khoi, 2006; Nguyen Vinh Thanh, 2008a; Nguyen Vinh Thanh & Le Vu Khoi, 2008a). Workman (2010b) calculated an average daily path length of 476m (range of 230m – 978m, n =16) for Dong Quyen groups, based on field notes and observed GPS points from full day follows. These findings are within approximately the same range as the results of this study which found average values for each individual between 467m and 735m a day, but with a larger range of day journey lengths, from 30m to 1975m. These instances of abnormally long day journey lengths highlight that the released langurs ranged widely at times, and did not stay in the original area of release. It should be noted that this current study uses a different methodology with straight line distances between a maximum of 12 GPS points a day, meaning that day journey lengths are likely to be an underestimation of actual travel distance (Isbell et al., 1999). The larger range of day journey lengths may be in part attributed to the slightly different topography of western Van Long, which is considerably larger with more rolling hills, unlike the exclusive karst environment of Dong Quyen, along with a significantly smaller population of existing *T. delacouri*. The released *T. delacouri* were also ranging as individuals, rather than as a group such as is typical for the species (Harding, 2011). This combination of factors potentially resulted in greater motivation and opportunities to travel and explore without entering other *T. delacouri* territories, which could in part explain the larger maximum ranging distances found in my study.

Looking at other limestone langurs, *T. francoisi* has been shown to have an average daily path length of 438m (range of 170m – 785m) (Zhou et al., 2007a), or a mean 881m (range of 350m – 2100m) for a group at Mayanghe Nature Reserve (Hu, 2007). Two groups of *T. leucocephalus* produced mean daily path lengths of 491m (range of 270m – 840m) and 512m (range of 215m – 970m) across the year (Zhou et al., 2011). Again these values are broadly comparable to the *T. delacouri* findings of this study, if not slightly shorter path lengths. But there is little ranging information available on the other four limestone langur species, and no closely related released animal examples available for comparison.
There is little research available on comparing the path lengths of released individuals with wild conspecifics. However, Ostro et al. (1999) found no significant difference in the day range length of translocated *Alouatta pigra*, compared with the group’s day length prior to translocation.

The released *T. delacouri* showed a notable pattern of changes in activity over the course of a day, travelling the greatest distances from sunrise to 8.30am and between 4:00pm to just before sunset. This travel pattern is typical of other primate species, and has been shown in both wild (Yiming, 2002; Huang et al., 2003; Ding & Zhao, 2004; Zhou et al., 2007a; Markham & Altmann, 2008; Schneider et al., 2010) and released (Keith-Lucas et al., 1999) individuals.

There was a slight seasonal difference in day journey length shown, with individual 1-10 having significantly longer day journey lengths in winter (771m compared with 668m in summer). *T. delacouri* on Dong Quyen were also noted to have path lengths that increased in winter months, which is when their preferred food, young leaves, was unavailable (Workman, 2010b), suggesting *T. delacouri* increased searching effort during times of food shortage. *T. francoisi* also increase travel in response to reduced food availability as they have been shown to have significantly longer path lengths in the dry season when fewer young leaves are available (Hu, 2007; Zhou et al., 2007a), forcing the animals to travel further to consume a wider diversity of plants. Conversely, Zhou et al. (2011) found a group of *T. leucocephalus* travelled significantly further during the hot rainy season compared with the cool dry season, but this was still linked to food availability with the preferred young leaves more available in the rainy season. Seasonal differences in this study were hard to interpret as it is likely that ‘time since release’ may also impact on day journey lengths, there being a slight increasing trend over time, and a full year of data was able to be collected for only one individual.

**6.5.2 Ranging patterns and dispersal**

An animal’s home range size reflects the area the animal predominantly occupies and feeds in (Milton & May, 1976; Mitani & Rodman, 1979; Harvey & Clutton-Brock, 1981), and for primate species can range from less than 1 ha (for example *Eulemur fulvus* (Sussman, 1975), *Galagoides demidovii* (Clutton-Brock, 1977a)) to over 2000 ha (e.g. *Papio anubis* (Rowell, 1966), *Papio cynocephalus* (Altmann &
Altmann, 1970), *Erythrocebus patas* (Hall, 1966)). Home range sizes can be related to a variety of factors, including body size and feeding habits (Milton & May, 1976; Harvey & Clutton-Brock, 1981). Folivores tend to have smaller home ranges than frugivores, relative to body weight, as specialist feeders often need to travel further to find food, whilst leaves are generally readily available (Milton & May, 1976; Harvey & Clutton-Brock, 1981).

Whilst Minimum Convex Polygons (MCP), as calculated in this study, can be used as home range estimates, the quadrant method provided a more conservative estimate. This difference is most likely due to the animal’s status as ‘released’ rather than ‘wild’ individuals, and the individuals widely exploring their new surroundings rather than settling into a defined home area leading to large MCP values. Even when considering quadrant method estimates, the released *T. delacouri* had much larger than expected home range sizes, varying from 284ha (individual 1-09) to 1020ha (1-10) during the monitoring period, and averaging 74ha – 252ha a month. Although their day journey length was within expected limits, they moved in unpredictable directions, rarely favouring any particular region, resulting in them covering a large area. All pairwise comparisons between released individuals showed a significant positive relationship between their distance from each other and days since release, indicating that they dispersed further and came to be further apart as time went on: 1-20 spent 41.7% of days within 1km from 1-10, and 41.8% from 1-09 whilst 1-10 and 1-09 spent only 22.6% of days within 1km of each other. Generally speaking all three animals appeared to operate as individuals, although 1-10 and 1-20 showed more periods of close contact spread throughout the monitoring period than the other pairs. Considering the terrain and environment, it could be questioned whether there is any feasible visual or audible contact possible between two individuals when they are 1km or more apart, with it likely that only hoot vocalisations would traverse this distance. Additionally, it should be noted that proximity distances may not necessarily indicate an animal’s ‘desire’ to stay closer to one individual than another, but may, in some instances, be a mere consequence of the three animals’ chosen individual ranging patterns throughout the habitat.

Previous research on wild *T. delacouri* groups on Dong Quyen estimated a home range size of 36 – 46 ha (Nguyen Vinh Thanh, 2008a; Nguyen Vinh Thanh & Le Vu Khoi, 2008a). *T. francoisi* in one study were found to have a home range size of
19ha, ranging 7 – 13.5ha per month (Zhou et al., 2007a), whilst the five groups in Hu’s (2007) study were found to have ranges varying from 46 to 111ha depending on habitat type. Comparatively, *T. leucocephalus* groups were found to have a home range of 23.8 – 33.8ha (Zhou et al., 2011). In comparison, the released *T. delacouri* in this study covered much larger ranges – with the smallest being 284ha for the adult female. Even when considering the ranges covered in a month, 1-09’s average of 74ha is still well above that reported by Nguyen Vinh Thanh (2008a). It is arguable that the term ‘home range’ does not really apply to this study’s animals, as their behaviour appears to reflect each individual exploring and dispersing within its environment, rather than establishing a discrete range within a short time period. This is likely due to the individuals’ status as ‘released’ animals in a novel and unfamiliar environment. If monitoring was able to be extended the individuals may have started to display more typical ranging behaviour in a more constricted area. This hypothesis is supported by the fact that individual 1-20, tracked for the longest period of 13.5 months, did return and remain in his initially inhabited Ba Chon area in August 2012 after exploring further afield, suggesting that he may finally have started to develop a home range. Additionally, the fact that they were moving as individuals, rather than in a group as is typical for *T. delacouri* (Harding, 2011), may have influenced their ranging behaviour. The scarcity of existing wild *T. delacouri* in western Van Long – approximately 10 individuals in two or three groups (Ebenau et al., 2011; and this study) - likely also contributed to the large ranging distances as there would have been little intraspecific competition for territories, compared with Dong Quyen.

A study of rehabilitated vervet monkeys (*Chlorocebus pygerythrus*) released in South Africa found that the group had a home range of 460ha in the first year post release (Guy et al., 2011), although the mean home range of a wild group of vervets was stated at 72.5ha, so, like the released *T. delacouri*, the released vervets ranged in a much greater area. Guy et al.’s (2011) possible explanations for this included exploration to locate food sources and reduced food availability or quality at the release site. Keith-Lucas et al. (1999) found the released captive-reared *Lemur catta* required in excess of 22 months before they had natural ranging behaviours, comparable to those of wild individuals. Ostro et al. (1999) also suggested that a longtime frame is required for groups to settle into a home range, with their
translocated *Aloutta pigra* groups taking six months to establish some sort of home range, but continuing to explore their new environment for over a year.

Primate group dynamics post-release are hard to predict, and for individuals in an established social relationship to separate, such as was the case in this study, is not unheard of. Most notably, two adult female *T. poliocephalus* translocated on Cat Ba Island, Vietnam, separated four months post translocation to travel in separate groups, despite having lived together as a unit for at least 10 years (R. Passaro, pers. comm. 2013). Cheyne *et al.* (2008) monitored a pair of gibbons (*Hylobates albibarbis*) in Kalimantan and, whilst the pair bond mimicked that of wild pairs pre-release, the animals separated immediately following release, the reasons for this being unclear. Wimberger *et al.* (2010) followed a released troop of rehabilitated vervet monkeys (*Chlorocebus aethiops*) in South Africa and found 26% of individuals left the troop on day one post release. They suggested this may have been due to lack of troop cohesiveness and absence of familial bonds. Goossens *et al.* (2005) monitored the success of 37 released chimpanzees (*Pan troglodytes*), and found that the group followed a typical fission-fusion pattern, with some intragroup aggression and the immigration of a few females to nearby wild groups. Comparatively, two established groups of Hatinh langurs, each containing one male and three females, transferred from the EPRC to a 18ha semi-wild enclosure at Phong Nha – Ke Bang National Park, soon merged into one single group post release (Vogt & Forster, 2008b; Vogt & Forster, 2008a; Vogt *et al.*, 2008; Vogt & Forster, 2010). In the first few weeks of monitoring, subgroups of individuals in a variety of combinations formed and dissolved, along with lone travellers, before all eight individuals formed one stable group at the nine week mark. The reason for the group of *T. delacouri* released in this study splitting into individual travellers within two weeks of release remains unclear – it might possibly be attributed to the ‘shock’ of release, the newfound ability to range across a large habitat, or in the case of the subadult male his want to disperse for future mating opportunities. It is also possible that individuals were influenced by existing wild *T. delacouri* although there is no evidence of this. Additionally it could be that habitat quality was low, causing a need to inhabit separate areas, but this seems unlikely given that a wild group of at least six individuals moving together has been sighted in western Van Long (personal observation).
6.5.3 Comparisons to wild and captive Delacour’s langurs

 Initially it had been intended to conduct behavioural focal samples on the released individuals to provide a clear overview of differences in captive, released and wild behaviour. Whilst this was not possible, comparisons of the released individuals’ ranging and dispersion behaviour along with behaviour from ad libitum notes can still be compared to the wild and captive findings to give a valuable insight into their adjustment to becoming free-ranging wild animals.

 One of the most distinct differences was the family group’s disintegration into individuals, rather than maintaining the single male-multi female format seen in both wild and captive animals (Harding, 2011). In captivity this social grouping is more a construct of how the animals are placed in cages, but it is the standard group make-up on Dong Quyen (personal observation), along with some instances of all male bands or groups with two adults (Workman, 2010b). Whilst the family was in captivity in Cage 2B at the EPRC, they had the lowest percentage of antagonistic interactions and a large number of affiliative interactions (refer back to Figure 4.6). Although 1-10 was dominant, 1-09 showed a strong reciprocal affiliative relationship with both 1-20 and 1-09 (Figure 4.7). Pair grooming was an important social interaction in both wild and captive groups (20% and 65% of social behaviours respectively), therefore the splitting of the group to travel as individuals when there was an established mating pair was extremely unexpected and shows that captive social groupings may have no bearing on social relationships post-release. Whilst lone adult males are not unheard of (one individual witnessed on Meo Cao, this study), there are no recorded observations of lone travelling subadults or females, suggesting female philopatry.

 On release the individuals maintained some of their ‘captive’ traits – such as chasing observers for food in the same manner in which they would approach keepers at the EPRC for their daily sweet potato feed, or by being drawn out of the forest by observers’ voices, showing their familiarity with humans. In addition, 1-10 frequently ranged near villages and around the army camp area again suggesting an affinity towards humans. Wild T. delacouri on Dong Quyen, whilst tolerating approach within about 20m by boat (as found in this study), were known to flee up the cliffs if humans tried to land on the karst (Workman, 2010b). On the other hand, the released individuals immediately displayed natural foraging behaviour.
comparable to what was seen on Dong Quyen, and continued to use grunt vocalisations towards each other as seen in both wild and captive groups.

6.6 Summary

Overall it was found that whilst the released individuals showed some behaviours that were comparable to their wild counterparts, such as day journey lengths and activity patterns within the day, the majority of their behaviours were less typical, dispersing across large home ranges and not moving as a group. An evaluation of the ‘success’ of this release, considering the EPRC’s aim of connecting the Van Long populations, along with recommendations for how things could be changed if further releases were to be conducted, is given in Chapter 7.

The released group quickly split-up to travel as individuals starting from day five post-release. As time since release increased, the individuals’ proximity to one another generally increased as well, reaffirming that they were no longer moving as a social unit. Although their average day journey lengths are comparable to wild T. delacouri, their upper range of day journey lengths were considerably higher. Overall they covered much larger areas of habitat than would be expected, ranging widely throughout Van Long and not settling into any defined home ranges. In their movements they showed a strong diurnal pattern of peaks in travel during the early morning and evening, but there was no strong seasonal link to their day journey lengths. Generally the radio GPS collars performed as expected, with one collar functioning for 409 days of tracking before it malfunctioned.

The conclusions able to be drawn from this chapter are limited by the monitoring period being less than one year for two out of three of the individuals. Ideally a full two year cycle of post-release monitoring of each individual would give a clearer overview of how they had settled into their new environment and any seasonal patterns that may be emerging. Technological limitations, such as the longevity of radio collars without malfunction and battery size, along with the cost and intensive personnel requirements, make long-term monitoring extremely difficult. Potential inaccuracies in the GPS readings must also be considered when interpreting results, given the difficult topography of the environment in relation to satellite access, but they are not thought to be significant. The behavioural conclusions that can be
drawn are greatly limited by the inability to make focal observations of the released individuals. Nonetheless, with so little information collected on *T. delacouri* and this being the first ever release of the species, the insights able to be elucidated from this study are extremely valuable to the future conservation strategies for the species. The use of GPS equipment gives a detailed view of the animals’ movements in a way never before captured for this species in any environment.

There are still several areas for further research when considering the behaviour of the released individuals. A habitat assessment of western Van Long is key, particularly focusing on areas the released individuals frequented, as it would help to identify preferred habitat types and sleeping sites used – in particular the frequency of cave sleeping versus tree sleeping and any climatic influences that may be linked to this. Any preferences for different habitat types across seasons and diurnal patterns should also be explored, and potentially linked to the feeding ecology work conducted by Workman (2010b) on Dong Quyen. Additional research into why the group split on release, and whether or not this may be harmful for their long term survival, would be helpful for any future releases. However, it appears this is a recurring theme in release and translocations, especially considering the Cat Ba translocation split, and is likely caused by the shock of release along with the opportunity to break anthropogenically formed captive social-groupings. A survey of villages to identify how frequently *T. delacouri* are sighted near settlements would help identify whether individual 1-10 was being overly curious of humans in his ranging behaviour (potentially increasing his risk of being hunted) or whether this is natural behaviour also seen in wild individuals. Detailed information on the existing wild populations in western Van Long and their ranging patterns would be extremely beneficial in assessing any potential interactions between released and wild individuals. Additionally it would give greater context to the dispersal patterns of released individuals if the home ranges and day journey lengths of current western Van Long groups were known. The potential and frequency of dispersal between outcrops (for example western Van Long to Hang Tranh, Hang Tranh to Dong Quyen) needs to be investigated so there is greater understanding on how a release may impact on the entire Van Long *T. delacouri* population.
Looking back along the farm road that leads to the release site in Vân Long Nature Reserve
**Chapter 7**

**Evaluation of the Release**

### 7.1 Introduction

The use of animal releases as a conservation tool, for rehabilitation purposes, or to restock game species, has become increasingly popular over the years and a distinct field of ‘reintroduction biology’ is now recognised (Kleiman, 1989; Seddon *et al.*, 2007). Strong success stories – such as the Arabian oryx, *Oryx leucoryx*, in Oman (Stanley Price, 1989) and the golden lion tamarin, *Leontopithecus rosalia*, in Brazil (Kleiman *et al.*, 1991) are extensively reported throughout the literature and increase people’s awareness of releases as a potential strategy. However, releases do require extensive planning, can encounter many logistical difficulties, and are an expensive option (Kleiman, 1989; Sarrazin & Barbault, 1996; Laidlaw, 2001; Baker, 2002; Seddon *et al.*, 2007).

Several authors have discussed the importance of extended monitoring of released animals to allow for analysis of the ‘success’ of the project and to identify common factors that are likely to lead to this (Griffith *et al.*, 1989; Kleiman *et al.*, 1991; Stanley Price, 1991; Sarrazin & Barbault, 1996; Keith-Lucas *et al.*, 1999; Fischer & Lindenmayer, 2000; Custance *et al.*, 2002; Reading *et al.*, 2002; Britt *et al.*, 2004; Wimberger *et al.*, 2010; Guy *et al.*, 2012; Trayford & Farmer, 2012). The concept of ‘success’ can be dependent on the particular project’s goals, and closely linked to the species released and the environment used. Noted prerequisites for success have included providing pre-release training (Aveling & Mitchell, 1982; Box, 1991; Custance *et al.*, 2002; McPhee, 2004), the choice of a suitable release site (Britt *et al.*, 2004; King *et al.*, 2012; Trayford & Farmer, 2012), and elimination of the factors that caused the initial population decline (Griffith *et al.*, 1989; Foose, 1991; Baker, 2002; Seddon *et al.*, 2007).

The IUCN has identified four different release types, each of which serves a unique purpose (IUCN, 1998). A ‘reintroduction’ is the attempt to establish a species in an area that was once part of its historic range, but from which it has been
extirpated or become extinct. A ‘reinforcement’ is the addition of individuals to an existing population of conspecifics. A ‘conservation introduction’ is introducing a species in an area outside its recorded distribution, but within an appropriate habitat and ecogeographical region, when there is no remaining area left within the species’ historic range. A ‘translocation’ is the deliberate and mediated movement of wild individuals or populations from one part of their range to another. In general usage, the term ‘reintroduction’ is often used to describe all release types, with the exception of ‘translocation’, which tends to be separately defined.

Given the EPRC’s stated goal of wanting to connect the successful Dong Quyen T. delacouri population with the relic population in western Van Long, promoting opportunities for interbreeding and supporting the genetic stability of the Van Long population as a whole (Nadler, 2012c), the T. delacouri release should be formally defined as a ‘reinforcement’ under the IUCN guidelines (IUCN, 1998; Baker, 2002). The stock type used was ‘captive born’ animals, and the release strategy was a cross between ‘hard’ and ‘soft’ releases – although the animals were held in a cage at the release site for 40 hours prior to release, there was no post-release support, meaning it was not a full soft release.

This chapter provides a detailed assessment of the EPRC’s release. It identifies problems encountered, considers whether or not the project was a ‘success’, and makes recommendations for how things could be altered for any potential future releases.

7.2 Review of steps taken compared to IUCN guidelines

The EPRC’s T. delacouri release programme has been reviewed in accordance with the IUCN/SSC Re-introduction Specialist Group’s Guidelines for Nonhuman Primate Re-introductions (Baker, 2002). These guidelines outline the ‘best practice’ scenario in a series of basic principles, but in reality not all elements of them may always be practical. All programmes should primarily focus on the species’ conservation welfare as a whole and mitigate risks wherever possible.

There is currently no formal written proposal from the T. delacouri release project available to be reviewed in this thesis, so all information is gathered from personal
observations and communications with T. Nadler and the EPRC team, along with Nadler’s preliminary report of the programme (see Nadler, 2012c).

7.2.1 Principle 1 – Identifying reintroduction need and overall assessment

There are many questions that need to be discussed when beginning a reintroduction programme, but the most crucial at the early stages is whether there is a need for a reintroduction. Managers must assess whether a reintroduction will enhance the long-term survival of the species as a whole, and consider any major risks to existing conspecifics (Cunningham, 1996; Sarrazin & Barbault, 1996; Baker, 2002). Released individuals can face a high risk of mortality, especially if a programme is not well managed. Additionally, due to their nature, reintroductions tend to be highly expensive and it should be questioned whether the funds could be better spent in other ways to aid the species’ conservation (Kleiman, 1989; MacKinnon & MacKinnon, 1991; Laidlaw, 2001).

As the EPRC’s captive–breeding programme for *T. delacouri* continued to grow, the idea of trialling a release back into the wild, in line with the Frankfurt Zoological Society’s ‘Vietnam Primate Conservation Programme’ goals, began to be discussed. At the beginning of 2011 the EPRC had a stock of 18 *T. delacouri*, including three breeding pairs (Nadler, 2012b). Additionally, subpopulations of *T. delacouri* around northern Vietnam were continuing to decline (Nadler, 1996b; Nadler, 2001; Conservation International, 2004; Fauna & Flora International - Vietnam Programme, 2004; Nadler, 2004a) and, backed by a recommendation in the 1994 Biodiversity Action Plan of Vietnam (Nadler, 2012c), plans to develop a release programme began. Although the project was expensive, with the GPS collars and tracking equipment making up a large proportion of the cost at around US$10,000 (T. Nadler, pers. comm. 2011), the funding received was particularly assigned to the project, and it is possible that other conservation projects for the species might not have brought in such generous grants. The release, being the first-ever for the species, was a major milestone and attracted a lot of attention. Additionally, the GPS collars did provide valuable information on the species’ ranging patterns, so regardless of the value of the release project as such, important information on *T. delacouri* was gained.
7.2.2 Principle 2 – Define aims, objectives, and time frame

The EPRC wished to conduct a release as they felt it was contributing to the overall conservation value of the species and there was the appropriate management structure to implement such a programme. With a relatively large and growing captive stock available, they could afford to release a small number of animals without inhibiting future captive breeding potential (Kleiman, 1989) and, given that such a small wild population existed, the addition of any extra animals would greatly contribute to the species genetic status. Definitive aims and objectives of the project were not made available for public release, but the project did appear to fit the overall IUCN guideline that the main principle should be for conservation.

The idea of translocating wild individuals from declining sub-populations in other areas to Van Long was not considered a viable option given the difficulties and the lack of existing protocol in how to catch wild individuals (T. Nadler, pers. comm. 2011). The EPRC was aware of the problems encountered in the Hatinh langur reintroduction project at Phong Nha – Ke Bang National Park, where managers were struggling to recapture individuals in a semi-wild enclosure for release (Nadler, 2012c). However, the Cat Ba Langur Conservation Project has now successfully captured and translocated two wild adult females within Cat Ba Island (Passaro, 2012b; Passaro, 2012a), suggesting that the idea of translocation needs to be further explored.

The project’s time frame was somewhat fluid, as it depended on many factors such as personnel availability, equipment deliveries, and paperwork approval, which were constantly changing. Although it is unclear when planning officially began to take place, discussions were well in place by the middle of 2009 with talks of the release occurring in 2010 or early 2011. It eventually occurred in August 2011.

7.2.3 Principle 3 – Establish a multi-disciplinary team

The IUCN recommends consulting widely in the proposal stages of a reintroduction project (Stanley Price, 1991; Baker, 2002), and contacting both the IUCN/SSC Re-introduction Specialist Group and Primate Specialist Group for advice. The EPRC was well placed to communicate with a variety of local and government boards throughout the programme’s time frame, given their long history of conservation work in the area. Backed by the Frankfurt Zoological Society,
Nadler and the EPRC team discussed the proposal with both the Cuc Phuong National Park and Van Long Nature Reserve management boards, along with the Ninh Binh Forest Protection Department. Local communes surrounding Van Long were also consulted (T. Nadler, pers. comm. 2011). Experienced wildlife veterinarian Dr Ulrike Streicher was also involved in some discussions, in particular in formatting the health screening protocol. However, if a proposal of the project with full transparency had been released to relevant conservation practitioners in the development stages, the input and advice of a wider range of personnel would have been able to be accessed.

7.2.4 Principle 4 – Assess proposed release site

The chosen release site is a crucial part in any reintroduction programme, and its suitability can have a great impact on the outcomes of a project. Assuming there is any habitat left within a species’ historic range, any release site should be within this range, and have long-term protection measures in place (Baker, 2002). Previous causes of the species’ decline should be identified and eliminated, and the impacts of reintroducing animals into the ecosystem investigated (Kleiman, 1989; May, 1991). A full assessment of all existing conspecifics and possible competitors/predators should be conducted, and the carrying capacity of the area determined. The seasonality of the region, and its effect on food availability, should be explored to help determine a suitable time of year for release (Konstant & Mittermeier, 1982; Chivers, 1991).

The EPRC chose Van Long Nature Reserve as the site for the release as it was considered the only area adequately protected from the risks of hunting and habitat degradation, which were the main factors in the species’ original decline (Nadler, 2004a; Nadler et al., 2007; Nadler, 2009a; Workman, 2010a). Subpopulations do exist in other protected areas, notably Cuc Phuong National Park (where the species was first re-discovered), in which 2008 figures estimated four groups with a total of 8–11 animals (Nadler, 2010b). But, previous surveys have estimated 4–5 groups with 20–25 individuals at Cuc Phuong (Nadler, 2001), which indicates that the population is in decline. In Pu Luong Nature Reserve, Thanh Hoa Province, numbers have decreased from 40–45 individuals in 8–9 groups in 1999 surveys (Nadler et al., 2003; Nadler, 2004a) to less than 30 individuals in 2010 estimates (T. Nadler pers. comm. 2011). These figures indicate that, despite being in protected
areas, threats to the populations are clearly still in existence and it would have been unwise to reintroduce new animals into such areas at this stage without further information on the causes of decline. This backs the EPRC’s assertion that Van Long was the only possible release site, as it met the conditions of having greatly reduced the causes of the original population decline and provided long-term protection. This was especially important when releasing naïve captive animals who appeared to lack a fear of humans. The EPRC has put over 10 years of work into Van Long and establishing a relationship with the surrounding communities, and this support is crucial in eliminating poaching and allowing the reserve to thrive.

On the other hand, given that the reserve contains the only increasing subpopulation of *T. delacouri* (Nadler, 2010b), it also held a great risk that disease transmission could potentially wipe out this crucial group, which could result in the eventual extinction of the species (McCallum & Dobson, 1995; Cunningham, 1996). It was also unclear what the area’s carrying capacity might be, which raises the question of whether reintroducing more animals into Van Long when the population was already naturally increasing was actually worthwhile. With continued protection, both the Dong Quyen and Hang Tranh populations may reach their own natural carrying capacity in time, leaving only the western portion of Van Long to be more sparsely populated by *T. delacouri*. Additionally, Van Long was not completely hunting free, with at least one metal snare trap discovered during fieldwork, and numerous instances of illegal wood chopping found, although undoubtedly it was much better protected than most other reserves, in part due to its smaller size (approximately 3000ha), making this a more manageable feat.

The choice of the exact release site within the reserve must also be carefully considered. The EPRC chose a site in the western portion of Van Long based on their extensive knowledge of the area and of what would be suitable habitat for *T. delacouri*, although a clear list of criteria required at a site would be advisable. The site was possibly a bit close to the forest edge, farm houses, and the army camp, at only 200m from agricultural pastures, increasing the risk of undesirable human-animal interactions. However, there was a trade-off in access to the site for cage construction and langur transport. This ruled out large parts of the inner reserve as being unfeasible given the terrain. Additionally, the local farmers were aware and supportive of the project (T. Nadler, pers. comm. 2011), which minimised the risk.
In the end, the released animals actually ended up covering much of the western Van Long area (and beyond) anyhow, ranging way outside their initial chosen release area.

In order to make a more informed decision about the chosen release site, a lot of additional information should have been gathered. There is still little information about the existing wild *T. delacouri* groups in western Van Long, with most of the knowledge drawn from occasional researcher or villager sightings. A comprehensive and up-to-date report of their numbers, home ranges, and breeding patterns should be established, including groups in the proposed reserve extension area (an additional 4000ha north of the current western Van Long boundary; Nadler, 2012c). This information would help predict how the reinforcement may impact on existing *T. delacouri* populations, and consideration of potential immigration corridors between western Van Long and Hang Tranh/Dong Quyen must be given. Individual 1-10 did cross the road over to the Hang Tranh outcrop, and whilst this does support Nadler’s aim of connecting the Van Long populations, it does also pose a disease transmission risk to the valuable Dong Quyen population. A survey of the food species present in any potential release area, comparing it to the feeding ecology work of Workman (2010b), which identified 16 key species, would be beneficial, along with an investigation of captive animals’ ability to cope with the potential predators they may encounter (such as leopards, dholes, and large snakes; Harding, 2011). A comprehensive overview of the environment, including a listing of all species present and how the release of further *T. delacouri* may impact on them, on the habitat, and the area’s carrying capacity, should be conducted.

7.2.5 Principle 5 – Review socioecological and behavioural data

A thorough understanding of the natural history of the species of interest, and that of closely related taxa, helps to aid in reintroduction programme decisions, and estimate the chance of survival (Kleiman, 1989; Baker, 2002). Any reintroduced animals should have a survival prospect equivalent to that of a wild individual of the same sex/age class in order for the release to be considered ‘humane’.

The EPRC has either written or been involved with the vast majority of the existing literature on *T. delacouri*, and so drew on this when planning the release. Nevertheless, as mentioned above, more consideration could have been given to the
timing of the release in relation to Workman’s feeding ecology work (2008; 2010a; 2010b). It would be best to release the animals at the height of preferred food availability, or consider a supplementary feeding programme although this does have the negative trade–off of continuing human involvement. *T. delacouri* preferentially feed on young leaves, and Workman found that this peaked in April, suggesting that the end of the dry season may be a good time for release, although drinking water availability may be an issue at this time and this would need to be investigated. A greater understanding of the social organisation of *T. delacouri* groups may also have been useful, as this might have helped prevent releasing a group that split into individuals, potentially decreasing their survival chances, although this may have been hard to predict. Literature on other wild limestone langurs could also be employed to supplement knowledge of *T. delacouri* where this is deficient.

7.2.6 Principle 6 – Determine if the socioeconomic, financial, and legal requirements can be met

Any reintroduction must have the permission of all relevant government agencies, and managers must be fully aware of all likely expenses involved with such a project (Baker, 2002; Reading et al., 2002). Reintroductions can often have a political side to them, and the potential impacts of this on a project should be considered (Stanley Price, 1991). Additionally, an assessment of the local communities and their views towards the project should be conducted, focusing on any possible human-wildlife conflicts (May, 1991; Marshall et al., 2007).

The EPRC’s release had the full support of both the Cuc Phuong National Park and Van Long Nature Reserve management boards, along with the Ninh Binh Forest Protection Department (Nadler, 2012c; T. Nadler, pers. comm. 2011). They in turn sought approval from the Provincial People’s Committee and the Ministry of Agriculture and Rural Development. The potential costs of the programme had been estimated based on equipment quotes and existing knowledge, and funding from external sources was obtained where necessary. As a result of the EPRC’s long–term involvement in the area, there was a good existing relationship with the local community, and public meetings discussing conservation at Van Long were often held. It is unclear whether any formal assessment of attitudes towards potential human-wildlife conflicts took place, but this is unlikely to be an issue unless
poaching occurs, and locals should be encouraged to keep away from the langurs and not offer them food.

### 7.2.7 Principle 7 – Assess suitability of release stock

Captive stock picked for release should be well managed, not inbred, and of known origin (Foose, 1991; Seal, 1991; Baker, 2002). Additionally, the release of captive stock should not endanger the existing breeding programme. Consideration should be given to training captive animals to ensure that they possess the required behaviours to survive in the wild and are not too acclimatised to humans (Kleiman, 1989; Laidlaw, 2001; Custance et al., 2002; McPhee, 2004). Animals should be released in an established grouping, which is of a similar composition to that which would be found in the wild. Consideration should also be given to the sex and age classes of the released animals, in relation to the aims of the project – if the aim is to increase breeding in an existing population, the release of mature females is likely to be most beneficial.

The EPRC chose to release a family group of an adult male, female, and their subadult son, who were previously housed together in a single cage. This left the EPRC with 15 *T. delacouri* individuals, but just two remaining breeding pairs. This could potentially put the continued viability of the captive breeding programme in danger, and a population viability analysis looking at the different scenarios when removing different individuals from the captive stock should be conducted to ensure that a release doesn’t compromise the future diversity of the captive population (Chivers, 1991; Foose, 1991; Kleiman et al., 1991; McPhee, 2004).

The EPRC is also equipped with two semi-wild enclosures, one of which currently houses *T. delacouri*. Animals in a semi-wild living situation are much better adapted to wild living as they are familiar with locomoting and feeding in such an environment (Custance et al., 2002). When selecting individuals for a release programme, using a semi-wild group would have better fit within this principle, and might have resulted in more natural behaviours in the release group. It is unclear exactly why these individuals were overlooked by the EPRC, although there were some concerns raised about how to capture the langurs in the semi-wild (T. Nadler, pers. comm. 2011). There was a system of alerting the individuals to feeding time by blowing a whistle and presenting food at the cage within the semi-wild, so a
continuation of this system (similar to the process described in Britt et al., 2004) may have led to the ability to capture the animals for release. It is also possible that the semi-wild group’s numbers, at five individuals, made them less suitable for release as it meant that the EPRC would lose a larger number of animals. The use of animals from a purely caged environment also raises the question of whether any pre-release training should have been conducted. Training is thought to be very beneficial to some species, whilst it might make little difference to the outcomes for others (Kleiman et al., 1991; Seddon et al., 2007). The captive animals had regular contact with keepers, and even post-release showed characteristics of being drawn to humans and expecting food. This did put them at increased risk of being hunted or of becoming a nuisance towards local farmers, but there were no reports of this happening and they appeared to quickly adapt to foraging in the wild.

7.2.8 Principle 8 – Evaluate the genetic status of release stock

Caution should be taken to ensure all released animals are of a homogeneous taxon and not inbred (May, 1991; Baker, 2002). A genetic assessment of the existing wild population is recommended.

Of the three individuals released by the EPRC, all were born in captivity so their parentage is known. Individual 1-10 was born to wild-born confiscated parents from Cuc Phuong and Chi Ne, and individual 1-09’s parents were both wild born in Cuc Phuong prior to confiscation. Genetic testing showed that neither sets of parents were related (T. Nadler, pers. comm. 2011). Samples of the genetic profiles of all released individuals were kept for records, and they could be utilised to determine any wild born offspring they may produce. Ebenau et al. (2011) have examined the genetic structure of T. delacouri in the Van Long area by testing faecal samples, and found some evidence of reduced genetic variation in the population. This suggests that reinforcement by a few new individuals would aid in increasing the genetic diversity and potentially increase immigration between Van Long subpopulations, but a release of primarily female individuals would be more beneficial in increasing breeding rates and spreading diversity faster (May, 1991; Sarrazin & Barbault, 1996).
7.2.9 Principle 9 – Ensure release stock has been cleared by a veterinary team

When a new animal is introduced to a group, there is always a risk of transmitting a novel disease (Baker, 2002). Primates, being closely related to humans, are very susceptible to human diseases (Wolfe et al., 1998; Homsy, 1999; Wallis & Lee, 1999). Captive primates are at an even greater risk, as a result of their close contact with the humans who care for them, with visitors, and with domestic animals, along with their small living quarters (Cunningham, 1996; Laidlaw, 2001). The impacts of new diseases to both conspecific and other wild populations are often unknown, and the effects can be devastating. To prevent this, careful consideration must be taken. Animals should be from well-managed facilities and in general good health, with up-to-date medical records. Animals should be screened for a variety of diseases, with vaccinations given when appropriate before initially being placed in quarantine. Extensive testing for ectoparasites and endoparasites should be conducted throughout the quarantine period, and samples of blood and serum should be banked (Woodford & Kock, 1991; Baker, 2002). Quarantine facilities should separate the animals from others by at least 20m, and personnel caring for them must be following procedures to prevent cross-contamination. Additionally, staff caring for the animals should be in good health and vaccinated against relevant diseases (Homsy, 1999; Wallis & Lee, 1999; Ancrenaz et al., 2003). An understanding of diseases and parasites that are naturally occurring in the wild population is helpful in assessing the risk that reintroduced individuals may pose.

All veterinary work on the release group was overseen by experienced wildlife veterinarian Dr Ulrike Streicher. A thorough clinical examination was conducted along with blood tests, tuberculosis tests, and parasite checks as outlined in Section 6.3.1. The majority of the IUCN recommended tests were covered, although the suggested tests for Foamy virus, Simian immunodeficiency virus (SIV)/HIV, and Simian T-Lymphotrope Virus (STLV) do not appear to have been conducted. Although there is currently no evidence of SIV occurring in any Asian primates in the wild, it has been found in captivity (Schrudde, 2009), suggesting that checking the status of the release group may have been advisable. Additionally, individual 1-09’s pregnancy was missed in both the April and May health checks, and, given that the gestation period of limestone langurs in general is estimated to be 170–200 days (Harding, 2011), she would have been at least three months pregnant at this time.
Had 1-09 given birth in the initial post-release period this may have jeopardised the well-being of both her and her infant. Specific testing of female candidates to rule-out pregnancy prior to release would be worthwhile.

Although the EPRC is equipped with a separate quarantine area, during 2011 this was being used to house surplus animals so the release group was quarantined in their standard cage, along with a lone male individual in the adjoining cage. A boot dip was placed at the cage entrance along with separate footwear and tools to be used within the quarantined cage, but this dip was infrequently changed and was not always used by the attending keepers. Additionally the situation of the cage within the main area of the Center meant that frequent tourist groups passed within 2m of the cage, and there were other non-quarantined primates within 10m. This allowed ample opportunity for disease transmission to be ongoing, and was a major risk considering the significant lag period between the second health check at the end of May and the release in August. Additionally, the IUCN recommends face masks and gloves to be used whenever handling quarantined animals, but this recommendation was not always followed.

A greater understanding of diseases currently present in the wild *T. delacouri* population and the natural parasitic load would not only be of general interest, but would assist in choosing appropriate stock for release (May, 1991; Cunningham, 1996; Miller, 2007). A released animal does not necessarily need to be completely disease and parasite free depending on the status of the wild population, and in some cases releasing a parasite–free individual may even decrease that animal’s chance for survival.

### 7.2.10 Principle 10 – Develop strategy for transport and final release

When arranging transport for a release, effort should be made to minimise the animals’ stress levels and have backup strategies in place should things not go to plan (Baker, 2002; Teixeira *et al.*, 2007). Ideally, diurnal primates should be transported at night when they are less active and temperatures are cooler. Individuals should be transported in separate crates, with a veterinarian monitoring them, and, in the case of a soft release, moved to a temporary enclosure at the release site. The release site should not be close to human settlements or to wild conspecific populations.
The three *T. delacouri* were transported approximately 50km by vehicle from the EPRC to Van Long Nature Reserve. Each individual was in a separate crate, and Dr Ulrike Streicher monitored them throughout the journey. The animals were transported in the mid-afternoon (crated about 12pm, released into forest cage about 4pm) during August, one of the hottest months in the region, so there was potential for the animals to overheat. It would be advisable to follow the IUCN’s recommendation of moving the animals overnight or at least during a cooler part of the day, although mid-afternoon is a typical rest time for *T. delacouri* so they were at least likely to be relatively inactive.

The animals initially spent approximately 40 hours in a 16m² cage in the forest before release into the wild. The possibility of extending the length of time the animals spent in the forest cage should be investigated, as it would give the animals more time for adjustment and also allow researchers a longer period to assess their behaviours and check for problems with the collars. Better yet, collars should be fitted whilst the animals are still in captivity, around two weeks before release, to allow time to identify an ill-fitting or malfunctioning collar and correct these issues prior to release. Individual 1-09, who possibly assisted in the removal of her collar due to continuing irritation (refer back to Section 6.4.2), was noted to be occasionally tugging at her collar whilst in the forest cage, although it was not enough to cause alarm and it was thought she would adjust. If we could have observed her over a longer period whilst she was still in captivity, her potential failure to adjust to the collar (presumably because it was too loose) may have been picked up and the issue could have been corrected prior to release. Additionally, the situation of the release site was arguably too close to existing human settlements (as discussed above in Section 7.2.4), and lack of knowledge about existing wild *T. delacouri* groups means its situation in relation to their home ranges is unknown.

The animals were released early in the day (at 8.15am), to give them maximum time to explore their surroundings and find a sleeping spot before dark. Efforts should be made to minimise stress at the time of release (Teixeira *et al.*, 2007), but in this case there were some 25–30 people present, most within 10m of the cage, which increased noise levels and undoubtedly distracted the animals. It would be advisable to have only the minimum required number of people present for the release and for observers to be well hidden at a distance from the cage. The animals should be left
to freely exit and re-enter the cage at will, and not be interfered with (Baker, 2002). Leftover food from the last feed was left in the forest cage, but it would be helpful to continue to provide supplementary food in the cage for 2–3 days following release, although it may not have been utilised as the langurs immediately began feeding in the forest post-release.

### 7.2.11 Principle 11 – Establish post-release monitoring and follow-up

Post-release monitoring is crucial in any re-introduction or translocation project, as it allows an understanding of the success of the programme (Kleiman, 1989; Chivers, 1991; Stanley Price, 1991; Fischer & Lindenmayer, 2000; Baker, 2002; Trayford & Farmer, 2012). Studies on the environmental and social impacts of the release should take place, along with continued conservation education in the community. The animals’ physical condition should be monitored through non-invasive techniques, and researchers should keep at least 10m from the animals at all times, and not consume any food within 200m (Wallis & Lee, 1999; Baker, 2002). A pre-approved plan should be developed to be put in action in case intervention is required, for example if an animal must be removed from the wild due to declining physical condition. Additionally, strategies should be developed to deal with any released animal that is approaching humans.

In the *T. delacouri* release there were initial issues with individual 1-10, in particular, approaching the researchers and seemingly being drawn to human voices. A specific action plan of how to deal with such events would have been beneficial. Additionally a system to monitor the animals’ physical condition post-release would have been very interesting, but given that they were rarely visually sighted the logistics of this may not have been practical. Likewise an intervention plan should one of the animals need to be removed from the wild was not developed, as the practicalities of this were viewed as unfeasible (T. Nadler, pers. comm. 2011), given the nature of the environment and the infrequency at which the individuals were even sighted. When concerns were raised about the welfare of individual 1-09, there was a relatively slow response in efforts to track and locate her. In future, such alerts should be acted upon more promptly – had she been found in an injured state, she might have been able to be rescued and treated back in captivity.
In order to monitor the released individuals, a combination of radio telemetry and GPS tracking was used. This combination approach allowed for effective post-release monitoring, even when the animals were rarely sighted (Honess & MacDonald, 2003; Hughes, 2003; Gau et al., 2004; Trayford & Farmer, 2012). The radio telemetry assisted in finding an animal’s rough location and allowing researchers to get close enough to download data from the collars. The GPS tracking recorded a more precise location throughout the day, and allowed us to see where a particular animal had been during periods when we had been unable to find it using telemetry. Telemetry in a karst environment, with its many rocky outcrops and cliff faces, is extremely challenging (Cooke, 2008), and training of researchers by an experienced user would have been helpful in improving telemetry techniques and possibly allowing us to sight the animals more frequently. GPS recording can also struggle to function in an environment like this, as the percentage of visible sky for possible satellite contact when an animal is beside a steep rock face or under a thick canopy can be very low (Sigrist et al., 1999; D’Eon et al., 2002; Dominy & Duncan, 2002; Sprague et al., 2004; D’Eon & Delparte, 2005; Markham & Altmann, 2008). Nonetheless, an overall successful fix rate of 81% was achieved for this study (refer back to Section 6.4.7), which was more than adequate to give a picture of the animals’ daily movements. In comparison, Sprague et al. (2004) found a fix rate of just 20% for a Japanese macaque in a semi-urban forested area, although Ren et al. (2008) found a similar rate to T. delacouri of 82.2% for Rhinopithecus bieti in high altitude temperate forest in China, whilst Markham and Altmann (2008) had a highly successful fix rate of 99.3% on baboons in an open savannah/woodland habitat in Kenya. The success of fixes is influenced not only by the prevailing habitat, but also the technology in use, the geographic location in relation to satellite movement, and the animals’ behaviour (Dominy & Duncan, 2002; Honess & MacDonald, 2003; Hughes, 2003; Sprague et al., 2004; Markham & Altmann, 2008; Trayford & Farmer, 2012). There is always error in GPS readings, and this was especially evident when, after 1-09 lost her collar, the GPS readings were still showing slight ‘movements’ of approximately 20m, and potential inaccuracies like this must be kept in mind when interpreting results. Additionally, there are potential biases such as ‘dead spots’ where the GPS does not work (see above), certain behaviours that cause the GPS to function poorly, such as cave sleeping, and the collar position slipping
and affecting the angle of the aerial (Honess & MacDonald, 2003; D'Eon & Delparte, 2005; Trayford & Farmer, 2012).

In this study, the longest monitoring period was 409 days, but ideally released animals would be tracked for two full years to give a clearer picture of their acclimatisation to life in the wild and seasonal trends. This could be achieved by having a larger battery pack, and, under animal wildlife recommendations that a collar should not be more than 5% of the animal’s body weight, it could weigh up to 265g depending on the individual (the collars used in this study were approximately 125g; American Society of Mammalogists, 1998; Gursky, 1998; Sikes & Gannon, 2011). Additionally, the collar’s settings could be altered to take less frequent GPS fixes, as this would save battery power. Whilst the settings used, 12 fixes a day, provided a detailed picture of where the animals moved and their activity patterns, a clear idea of the general areas occupied by the released individuals could still be gained with fewer fixes per day, whilst prioritising the more useful information that would be gained from a longer monitoring period. However, given that two out of three of the animals were tracked for less than a year due to technical problems with the collars (one possibly removed by its wearer, another with a suspected malfunction), it may not be realistic to try and track an animal for two years. It would also require intensive personnel input over a prolonged period, as tracking needs to be done regularly so as not to lose the animals, given the relatively short distance that the radio pinger signal transmits at in karst terrain. Additionally, it is unknown at what stage the leather attachment on the collars, designed to rot and allow the collar to fall off, would disintegrate.

7.2.12 Principle 12 – Document project outcomes

It is important that all results from release projects, regardless of the outcomes, should be reported so as to assist decision makers in any future projects (Chivers, 1991; Fischer & Lindenmayer, 2000). Valuable information can be gained even when a project is deemed unsuccessful, as it can help pinpoint where things went wrong and how they should be changed. Additionally, release projects often help to gather a lot of behavioural and ecological information about the species that may have been previously unknown.
This thesis, and any resulting publications, serves the role of reporting a detailed analysis of the first *T. delacouri* release project. Along with giving a factual description of how the release took place and the results of the tracking period, which shows the animals’ behaviour (Chapter 6), this current chapter provides a review of the processes and gives recommendations for changes that could be utilised in future projects.

### 7.3 Was the release ‘successful’?

#### 7.3.1 Definition of ‘success’

The definition of ‘success’ in reintroduction biology has been a much debated topic, with the long term timescales in conservation outcomes making it difficult to quantify (Griffith *et al.*, 1989; Kleiman *et al.*, 1991; King *et al.*, 2012; Trayford & Farmer, 2012). The conditions for success can differ greatly across the different release types (reintroduction, translocation, rehabilitation etc.), and are also dependent on the aims of the individual project (Fischer & Lindenmayer, 2000). Several researchers have highlighted the need for a clear set of universally applied criteria to judge whether or not a release was successful, and to assist in identifying factors that help and hinder the likely outcome of a project (Fischer & Lindenmayer, 2000; Britt *et al.*, 2004).

Griffith *et al.* (1989), when looking at translocations for conservation, defined success as the establishment of a self-sustaining population. Fischer and Lindenmayer (2000) applied this criterion when reviewing case studies, as did Custance *et al.* (2002), who argued that to be successful the animals must survive long enough to breed and found a self-sustaining population. However, as was noted by both sets of authors, these criteria can only be judged on a long–term timescale. Kleiman *et al.* (1991) further explored the idea of ‘success’, in relation to the Golden Lion Tamarin Conservation Project; whilst the Primate Society of Great Britain suggested that ‘success’ could be determined by the survival of released individuals for six months or more and their reproduction. Kleiman *et al.* pointed out that this fails to consider the different life history traits of primates – more specifically, that K-selected species are unlikely to reproduce in such a short time frame. Therefore, Kleiman *et al.* suggested that long-lived K-selected releases’ success could be judged...
by the animals’ post-release survival in the early years, whilst those of r-selected species could be assessed by their reproductive output and infant survival. Generally, several researchers use annual survival rates, often in comparison to that of wild conspecifics, as a preliminary measure of success (Kleiman et al., 1991; Britt et al., 2004; Wimberger et al., 2010; Guy et al., 2011; King et al., 2012). Evidence of reproduction can also be a good indicator of potential success in the first instance (Kleiman et al., 1991; Sarrazin & Barbault, 1996; Britt et al., 2004; King et al., 2012). Increasingly the use of population demographics and modelling is also being suggested as a method of measuring a release’s likely long-term success (Sarrazin & Barbault, 1996; King et al., 2012).

It is, consequently, important to note that the defining of ‘success’ at a generic level will always encounter difficulties, as it is greatly influenced by both the species and the release site, as well as the project’s goals (Trayford & Farmer, 2012). All release projects will require long-term population monitoring protocols in order to truly assess whether or not the project was successful (Fischer & Lindenmayer, 2000). Success can be marked by other less quantitative elements – such as the animals’ independence from humans for food and companionship (Wimberger et al., 2010), integration into wild groups (Britt et al., 2004), establishment in a defined area (Wimberger et al., 2010), and behaviour comparable to wild conspecifics (Guy et al., 2011). Additionally, Kleiman et al. (1991) highlighted the need to consider non-biological markers of ‘success’, such as achieving conservation educational goals with the local community.

7.3.2 Case studies of ‘success’ analysis

The Golden Lion Tamarin Conservation Project is arguably one of the most successful release projects in history (Kierulff et al., 2012). The project aimed to increase the species’ wild-living population numbers, and released individuals of the r-selected species were judged ‘successful’ if they produced offspring that would grow up in a wild environment, starting a new generation of wild animals (Kleiman et al., 1991). At the end of 1989, 71 animals had been introduced, with a survival rate of 38%. A total of 26 infants had been born to released tamarins, of which 80.8% were surviving at the end of 1989, giving an overall survival rate (existing plus offspring) of 68% for the original 71 released individuals. In total, 153 tamarins were released in the 1984–2000 period, with the addition of a group of five wild-born
animals released in 2005 (Kierulff et al., 2012). Population figures from 2005 show
that the total reintroduced population, including descendants, now numbers 598
individuals spread across 87 groups. Additionally, 42 tamarins from six groups were
also translocated from forest fragments. The project built on the knowledge gained
over the years to perfect their reintroduction strategies, monitoring protocols, and
population modelling schemes to produce a highly successful outcome.

Britt et al. (2004) analysed the success of a re-stocking project of captive-bred
black and white ruffed lemurs (*Varecia variegata*) into the wild in Madagascar,
based on Kleimen et al.’s r-selected criteria. Thirteen animals were introduced, with
five surviving (38.5%) at the one–year mark, which is comparable to the 1989
tamarin rates above. There was integration with wild troops, with a released male
siring a wild female’s infant, and a released female reproducing with a wild male.
When surviving infants born to released individuals are included, there was a
survival rate of 61.5% at the end of the first year, leading researchers to deem the
project a success.

Wimberger et al. (2010) evaluated the success of two rehabilitated vervet monkey
troops released in South Africa. They used post-release survival at the 10–month
mark as a basic indicator of success, with an average mortality of 20% across the two
groups, which was slightly higher than the wild average of 15%. However, if
animals that were missing, but not confirmed dead, were included mortality rose to
83% in one troop and 50% in the other, indicating that the release was in fact a
failure, despite other signs of apparent success, such as the animals exhibiting wild–
like behaviour, establishing a ranging area, and showing independence from humans.

King et al. (2012) reviewed the rehabilitation releases of western lowland gorillas
(*Gorilla gorilla gorilla*) in central Africa from 1996 to 2006. The first year post-
release survival rate was 98%, and during the monitoring period nine of the 20
reintroduced adult females gave birth, with an infant survival rate of 81.8% at one
year. These rates were comparable to those of wild gorillas, and indicate the initial
success of the project. However, the authors recommended a population model be
developed to help predict the likely long–term success.
7.3.3 Was the EPRC’s Delacour’s langur release successful?

*T. delacouri* is a long-lived and more K-selected species compared to the golden lion tamarin, with an estimated life-span of at least 20 years (Nadler, 2010a) and sexual maturation at 48 (females) or 60 (males) months (Workman, 2010b; Harding, 2011). Kleiman *et al.* (1991) suggested measuring success in such a species by the released individuals’ survival in the early years. At one year post-release, the survival of only one of the three *T. delacouri* individuals can be guaranteed, giving a survival rate of 33%. The outcome for the other two individuals is unknown, as their collars were no longer functioning by the 12–month mark. The small sample size makes this statistic unreliable, and with no data on the expected survival rate for wild *T. delacouri* it is hard to judge the project’s success from this.

The indirect monitoring style meant it was impossible to know whether any of the released langurs reproduced. Likewise, there is no evidence of any individuals integrating with wild groups, although there are likely to have been some encounters, based on the tracking data and occasional sightings of existing wild groups (refer back to Section 7.4.6).

The release could be deemed a success in that the individuals immediately began foraging in the wild, and showed independence in feeding, with no further interest in the food left in the cage. Individual 1-10 did, however, show an attachment to humans, approaching researchers for food and ranging close to settlements. He didn’t appear to show a fear towards humans, suggesting that he may have lacked natural predator awareness, which could increase his mortality risk. None of the three appeared to have established a defined ranging area as wild individuals do, although they may have done this in time. The immediate fission of the group post-release was unexpected, especially given that they were an established family group that had been housed together for an extended period with few signs of aggression.

Overall, there is not enough information to deem the release as a ‘success’, but the fact that the released individuals survived for at least the initial few months suggests that they were feeding sufficiently and must have been able to maintain some form of basic physical condition. However, elements of their behaviour, as outlined above, suggest they were not akin to wild conspecifics, and this may be an indicator of failure. The project’s goal was to connect *T. delacouri* populations across Van Long.
and allow genetic exchange, and at this stage there is no evidence of this having occurred, but it may in the future.

### 7.4 Future recommendations

In November 2012 the EPRC conducted a second release at the same site within Van Long Nature Reserve, of a captive *T. delacouri* adult male-female pair (S. Elser, pers. comm. 2012). The results and analysis of the first release were not yet complete at this stage, and ideally a second release would have waited for these before continuing. Nevertheless, there are several key changes that I would recommend if any further releases of *T. delacouri* or related species were to be considered. Additionally, my recommendations may be worth reviewing for other primate releases within Southeast Asia.

#### 7.4.1 Greater discussion on initial plans and release site

The controversy surrounding the initial release project might have been avoided if there was greater consultation and discussion with the wider Southeast Asian conservation community and other reintroduction biologists prior to its initiation. This would have provided a broader multi-disciplinary base on which to plan the release and identify potential challenges.

The choice of the release site within Van Long Nature Reserve, where there is already a healthy growing population, needs further discussion. The idea of establishing a whole new subpopulation in another protected area (such as Cuc Phuong National Park) should be further explored, as this might help ensure the survival of the species by broadening the geographic area in which stable populations occur. There would need to be an increased investment of personnel and funding to establish protection mechanisms for a new release site, which might be prohibitive but should still be investigated due to the huge conservation benefit it would add. Additionally the idea of translocating those wild subpopulations that are irreversibly declining into protected areas should be considered as a viable option, given the initial success of the Cat Ba Langur Conservation Project (Passaro, 2012b; Passaro, 2012a). By rescuing these subpopulations, the genetic diversity of the species could be maintained and additional stable subpopulations may be able to be formed.
Any future release site must be heavily protected, as hunting is still a risk to the species, and even within Van Long a metal snare trap was discovered during post-release monitoring. This is even more important if future releases continue to use animals from a caged environment, as their familiarity with humans puts them at increased risk of poaching. At Van Long it is likely that the EPRC’s good relationship with the local communes was of great help in protecting the released animals, considering that even with numerous guards and rangers the sheer size of the area means that a poacher could easily infiltrate the reserve.

There should be discussion over the idea of using animals that have been housed in one of the EPRC’s semi-wild areas for any future release project. Although there were no specific problems with the use of caged animals, it would seem unwise not to use semi-wild facilities when they are available, to increase the animals’ survival chances. Additionally, more consideration should be given to the impacts on the remaining captive population of removing certain individuals, and how this could potentially affect the ongoing viability of the captive breeding programme.

### 7.4.2 Further risk assessment and increase knowledge of existing situation

There was a lack of formal planning and risk assessment prior to the first release, which led to a lot of uncertainties when assessing the release process. A risk assessment would have identified several gaps in the knowledge about existing wild populations and the proposed release environment. A full assessment of the habitat surrounding any potential release site should be conducted, identifying the presence of food species and potential cave sleeping sites. Any existing uses of the site by humans or other animal species should be investigated, along with potential predatory risks. Additionally a comprehensive understanding of the ranging patterns of existing wild populations within the extended area, and their population structure, should be established. GIS modelling could be utilised to assist in analysing potential release sites (Seddon et al., 2007).

An investigation of the current routes used by *T. delacouri* in the Van Long area, in particular immigration across the road separating western Van Long from Hang Tranh and Dong Quyen, should be conducted. This would help give a greater understanding of how releases in the western portion might impact on the Dong Quyen population, and the likelihood for genetic transfer.
Contingency plans should be developed, outlining how to deal with a range of scenarios if unexpected difficulties are encountered, such as failure of a released individual to adapt or a serious injury. Although the terrain makes monitoring of the langurs very difficult, there still needs to be some pre-planning on how such issues would be dealt with in case the situation arises. With such a small number of *T. delacouri* remaining, every individual is precious and the loss of even one is a setback for the species.

A review of the health check and quarantine processes should be conducted in consultation with further veterinarian and reintroduction specialists to double check that all necessary steps are being taken. Disease transmission is arguably one of the biggest risk factors involved in release projects (Wolfe *et al.*, 1998; Homsy, 1999; Wallis & Lee, 1999; Baker, 2002), so continued investigations to look at how the processes could be further improved and refined, whilst considering IUCN guidelines, are crucial.

### 7.4.3 Changes to tracking equipment settings and processes

Whilst the GPS tracking system used for the release was largely successful, I would recommend some changes to the system for any future projects. An increase in the amount of time per day that the radio signal is active, say to two hours a day, would allow greater opportunities to track and sight the animals to check on their well-being. A decrease in the number of GPS fixes per day would help extend collar battery life so that the animals could be monitored for a longer period. Decreasing fixes to say seven a day between the hours of 4.30am and 7.30pm, with fixes every 2.5 hours would still give fairly detailed information about their daily movement, judging from the results of this study. These two changes would result in an estimated battery life of 504 days according to the manufacturer’s lifetime calculator, when using the settings described and an average first time to fix of 75.9s as found in this study. Whilst this is not the desired two full years of monitoring, the possibility of increasing the battery size to reach this bench mark should be explored (as discussed above in Section 7.2.11).

The option of using a tracking system that allows real–time satellite updates remotely (such as ARGOS) should be investigated, although the cost of these systems would require additional funding (Honess & MacDonald, 2003; Trayford &
Farmer, 2012). But they do offer the great advantages of being able to know an animal’s latest position, rather than discovering where they had been in hindsight, which was the system used in this study. This would allow more efficient monitoring and increase the potential for visual sightings, as well as decreasing personnel costs. Alternatively, investigations could be conducted into using a radio pinger signal that can be received at larger distances, to allow for more successful telemetry monitoring of the animals and assist in identifying their position for visual sightings.

In relation to the collar’s leather breakaway system, a small–scale study should be run to investigate how long the leather typically takes to disintegrate in the Van Long environment. Knowledge on when this process is likely to occur would be useful when considering collar battery life – there is no point extending battery life if the collar could fall off long before this.

In future releases it would be advantageous for the individuals to be marked in such a way that they could be identified from a distance. On the few occasions the individuals were spotted through the binoculars, it was often unclear which individual we were seeing. The idea of using coloured ear tags (Honess & MacDonald, 2003; Wimberger et al., 2010), marking each collar with a coloured tape (Cat Ba Langur Conservation Project, 2009), or fitting the animals with a second, permanent, collar as a marker (Schrudde, 2009) should be explored. By having a permanent identifier, the individual’s role in population demographics several years after the release could still be investigated.

A greater understanding of the accuracy of the GPS measurements in a karst terrain would be beneficial, as it would provide a clearer overview of the reliability of results.

7.4.4 Increased post-release monitoring

An extended post-release monitoring schedule, including population demographics across the area and ecological/population modelling, may be beneficial in truly evaluating the contribution of such release programmes on a long-term scale (Sarrazin & Barbault, 1996; King et al., 2012). Due to the species’ long-lived nature, the capacity of any GPS/radio tracking schedule is unlikely to last long enough to assess the contribution of the released animals to the population’s genetic
diversity, as was the aim in this project. Therefore a broader population monitoring protocol needs to be developed, ideally utilising modelling skills to assist in assessing the success of such releases.

7.5 Summary

The EPRC’s release of three captive-bred *T. delacouri* individuals into the wild achieved a major goal of the Frankfurt Zoological Society programme, and was a key milestone for the species. Although the release did not have a formalised plan that followed the IUCN recommended principles, some of the steps were covered. Many of the gaps resulted from a lack of knowledge about the existing wild populations, their behaviours, and the proposed release environment. Work from this thesis on the behaviours of wild and captive individuals may assist in increasing this knowledge, along with existing published literature. In the future, a thorough risk assessment along with increased consultation across the board would be recommended.

Overall, I believe there is still scope to question whether the release should have taken place in the format that it did. Whilst I agree with EPRC’s assertion that Van Long Nature Reserve was the only suitably secure site for a release at the time, it held major disease transmission risks and was not necessarily beneficial to the species as a population. The reinforcement of an area where at least parts of the population are already showing natural increase, after the removal of factors that caused the species to decline, is arguably not an effective use of resources. The concept of releasing captive-bred animals into a different area, once necessary protection measures have been achieved, or translocating existing isolated subpopulations, might better address the species’ future conservation potential. The release did serve the purpose of trialling the release procedures and tracking equipment in a relatively safe environment to identify problem areas and allow modification of protocol for any future releases. Additionally, valuable knowledge about the species’ ranging patterns was gathered from the GPS data.

At this stage, the EPRC’s *T. delacouri* release cannot yet be deemed a success or failure – there are indications in both directions, but monitoring over an extended period would be required to give a true assessment. The animals did, at the bare
minimum, show that they had the potential to survive in a wild environment. The project’s goal was to connect the Dong Quyen population with the relic populations in western Van Long, and to promote interbreeding and the genetic stability of the Van Long population as a whole. Whilst neither of these aims are yet to be achieved, this is not to say that they won’t be in the future. Overall, this project showed that there is definite potential for releases of *T. delacouri*, possibly in an alternative format, to be used as a conservation tool for the longevity and recovery of the species.
Rice paddies and lily pads in Gia Vân village, beside Vân Long Nature Reserve
Conclusions

This thesis has reviewed the first-ever release of captive Trachypithecus delacouri, Delacour’s langur, into the wild in Van Long Nature Reserve, Ninh Binh Province, Vietnam, along with investigating the behaviour of both wild and captive populations, by drawing comparisons and differences. The main findings and conclusions of this study are presented in this chapter, along with recommendations for future conservation strategies.

8.1 Activity budgets and behaviour

Activity budget data showed significant differences between wild and captive T. delacouri populations, although their budgets were broadly similar. Inactivity occupied the majority of the primates’ day (wild 75.0%, captive 61.9%), as is typical for colobines (Davies & Oates, 1994; Huang et al., 2003; Harding, 2011; Hadi et al., 2012), followed by feeding behaviours. Social, locomotion, and other behaviours filled in the remainder of their budget. A sub-category breakdown looked at the animals’ activity budget in more detail, highlighting the prominence of scanning behaviours in the wild population compared with captive. Quadrupedal locomotion was the main form of movement for the species, with occasional instances of jumping and climbing. Grooming was the most common social activity for the captive group, whilst play was the most observed in wild individuals, although, it should be noted that a potential sampling bias could be contributing to this difference, as wild animals may preferentially perform some behaviours in the valleys of the cliff faces out of view, and this needs further research. The only sex difference identified in activity budgets was captive males spending a significantly greater proportion of their budget involved in ‘other’ behaviours than females, which is due to their much higher frequency of vocalisations. There were more age class differences detected in activity budgets, with wild young spending a significantly greater amount of time in social behaviours than adults or subadults. Captive adults
spent significantly more time inactive and engaged in social behaviours than subadults, but less time feeding.

A variety of social interactions were witnessed between *T. delacouri* individuals, including embracing, play, aggressive contacts, and sexual behaviours, with cling and grooming being the most common. Each group showed a different dynamic, the eldest individuals tending to be the most dominant, and males showing some dominance over their female partners (although this was minimal). Antagonistic interactions occurred more frequently in the all-male group, and females were more likely to be involved in affiliative interactions. During antagonistic behaviours, 75.7% of interactions involved a vocalisation, usually by the non-dominant participant. When considering age, young are more likely to be involved in affiliative interactions, which is in part due to their large involvement in social play.

*T. delacouri* infants are born with a bright orange natal coat, which progressively blackens as they age before the white “shorts” are formed. The captive infant showed significant changes in his activity budget over the first three months of life, moving from predominant cling behaviours to becoming increasingly social and resting independently. Allomothering by the infant’s juvenile sister was seen from the age of four days, and the infant made his first independent movements at 15 days. He was first observed to feed on solid foods at four weeks of age, but continued to both nurse and eat a small amount of solid foods throughout the study.

### 8.2 Vocalisation behaviour

Seven different vocalisation types were identified in *T. delacouri*, of which Grunts were by far the most common (61.2% of all calls). Grunts were thought to be a type of contact call to maintain intragroup cohesion. Click and Hoot calls were performed exclusively by adult males, with Clicks seeming to function as an intergroup spacing call, whilst Hoots were part of the threatening bounding display and hence function as a loud/warning call. Meow calls were performed by subadult males, and were presumed to function as a contact call, although why they were used only by subadult males was unclear and needs further research. Juveniles and infants frequently used Squeal calls, which were typically utilised as a high-pitched distress call, but was context dependent and could also function to express excitement during play. There
were very few examples of Squawk and Screech calls available for analysis, and further sampling would be needed before they could be classified as distinct calls in their own right, but they were observed to function as alarm/distress calls during aggressive altercations.

A variety of factors impacted on when and how frequently an individual vocalised, and an individual’s sex/age class was significantly associated with the type of vocalisation it was likely to perform. Adult males performed the majority of calls (52.6%), with Grunts, Clicks, and Hoots being their most frequent vocalisations. Infants were also frequent callers, typically with Squeal calls. Adult females, on the other hand, vocalised extremely rarely. The animals typically vocalised more frequently around feeding times at the EPRC, but no trend was identified for the frequency of vocalisations across the day, possibly due to the captive setting. An analysis of vocalisation behaviour in a wild setting, although this would be extremely challenging, would provide an interesting comparison.

Detailed spectrogram analysis of the *T. delacouri* vocalisations helped to identify five distinct call types in the species (there was not enough data to differentiate Squawk and Screech calls), with the average peak frequency ranging from 325Hz to close to 4000Hz depending on the call type. Vocalisations typically used in distress/alarm function had high peak frequencies (Screech, Squawk, and Squeal), whilst those associated with intergroup spacing functions were performed at low frequency (Hoot and Clicks), which is known to transmit better over distance. The territorial Hoot call was the loudest, with the highest average and maximum power values; this call was often heard in the wild during interactions between two neighbouring groups.

During the vocalisation study, samples were also captured of other limestone langur species (*T. ebenus, T. francoisi, T. hatinhensis, T. laotum, and T. poliocephalus*) to allow comparison of interspecific differences. Generally the vocalisation behaviour was relatively similar between the different species, with all species found to have comparable vocalisation repertoires, although some differences in structures of the calls were found. Adult males of all species performed hoot vocalisations to accompany the characteristic bounding display, but there were
audible differences in the call between species, for example *T. francoisi* and *T. poliocephalus* included rapid inhalations and exhalations in their calls.

### 8.3 The Delacour’s langur release

A release of three captive-bred individuals (an adult male-female pair and their subadult son) into the western portion of Van Long Nature Reserve was conducted by the EPRC on 22nd August 2011. The group was tracked via GPS collars, for 283 days for individual 1-10, through to May 2012, and 409 days (October 2012) for individual 1-20. The adult female, individual 1-09, is thought to have lost her collar in mid-January 2012, so was able to be tracked for only 163 days. The group separated on Day 5 post-release, and continued to travel as individuals for the remainder of the study. After Day 9 post-release, sightings were very rare - the next sighting was not till mid-November. The released individuals ranged extensively, much more so than was expected given the known ranging habits of wild groups on Dong Quyen, and both 1-10 and 1-20 ranged outside the boundaries of the reserve. Estimated ranging areas for the individuals were from 284ha for individual 1-09, to 1020ha for 1-10, with individual 1-20 covering a total distance of 238.8km and area of 720ha in 13.5 months. Individual 1-20 ranged furthest from the release site, reaching a distance of 5.3km away from it at one stage. Whilst average day journey lengths were within expected limits (ranged from 453m for 1-09 to 735m for 1-10), their behaviour of moving throughout the reserve and not favouring particular locations led to their large estimated ranging areas. It may be that this behaviour is due to being in a novel and unfamiliar environment, and it is possible that with extended monitoring their home ranges would have become apparent.

The released *T. delacouri* showed a bimodal movement pattern with peak movements between 07:00 – 08:30, and 16:00 – 17:30. There was no obvious overall seasonal difference in day journey length, except that individual 1-10 did show significantly longer day journey lengths in winter. Generally the released individuals moved further away from one another over time, and there was a very slight trend of increasing day journey length as time post-release increased. It is probable that the released individuals came into contact with existing wild groups in western Van Long at some stage, and individual 1-10 crossed over the village road to
move onto the Hang Tranh outcrop in February 2012 for two days, where he is likely to have encountered wild groups. Generally speaking, although the released individuals did show some behaviours that mimicked what would be expected from the wild population, the majority of their behaviours, such as dispersing widely and moving as individuals, were atypical.

The EPRC stated that their aim in conducting the release was to connect the successful Dong Quyen *T. delacouri* population with the relict population in western Van Long, so promoting opportunities for interbreeding and supporting the genetic stability of the Van Long population as a whole. Success of a release can be judged by a variety of criteria (as discussed in Section 7.3). Thus Kleiman *et al.* (1991) suggested that in the case of long-lived K-selected species, post-release survival in the early years could indicate ‘success’, as well as considering the project’s goals. In the present case, there is not enough information so far to determine whether the *T. delacouri* release project could be considered a success or failure. The animals did survive at least the initial few months post-release, indicating the ability to maintain basic body condition, but the known survival rate at one year post-release was only 33%, and some of their behaviour suggested they were not properly adapted to the wild environment. Reproduction is not known to have occurred, and there is no evidence to suggest that genetic exchange between the existing wild populations in Van Long was promoted by the release. Therefore the question of whether the release was a ‘success’ remains open, and more extensive monitoring along with the passing of time would be needed in order to answer this question.

In reviewing the release in the light of the IUCN guidelines for nonhuman primate reintroductions, it is evident that, whilst the EPRC *T. delacouri* release did not really have a formalised plan, the IUCN principles were broadly followed, although some gaps were identified. The project would have benefited from more extensive formalised planning and risk assessments, including contingency plans and a review of the health check and quarantine processes to combat disease transmission risk. In addition, a broader consultation process of these plans with the conservation community as a whole could have helped prevent some of the controversy surrounding the release. The choice of the release site needs to be more thoroughly considered, to look at how the release could best benefit the species’ population as a whole. If Van Long continues to be the release site of choice, more information
needs to be gathered about the existing wild populations and their ranging behaviour in the western area, along with increased knowledge of the environment and its potential carrying capacity. In particular, in order to assess the legitimacy of the EPRC’s aim for increased genetic exchange with the Dong Quyen population, more information is needed about the frequency and paths of migration between the Van Long populations. Consideration needs to be given to the choice of the release group and to exploring the idea of translocating one of the diminishing wild subpopulations. If captive animals are to be used in the future, then they should come from a semi-wild environment as opposed to caged. Some changes to the GPS tracking system are advised, including adjusting settings to allow a longer post-release monitoring period, and exploring the possibility of using a real-time satellite system to allow more effective monitoring.

8.4 Conservation strategies for Delacour’s langur

8.4.1 Current conservation risk factors

Conservation strategies in modern Vietnam are taking place against a historical background of war and the associated political instability, along with its long lasting economic and environmental impacts, such as widespread chemical defoliation (Eames & Robson, 1993; Lang, 2001; Ang, 2005; Sterling et al., 2006; Hoang Van Chieu, 2012). Habitat degradation is widespread, with agricultural encroachment one of the main contributors, so the protection of key biodiversity hotspots, along with the endangered species within them, is essential (Eames & Robson, 1993). Black market trade of wildlife for pets, meat and traditional medicines remains an active business, and is fuelled by this being an economically profitable trade (Zimmerman, 2003; Workman, 2004; Alves et al., 2010; Nijman, 2010). Although extensive environmental laws and policies have been put in place, there is a lack of accountability and rules are often broken without consequences (Lang, 2001; Nadler et al., 2003; Sodhi et al., 2010; Bruun, 2012). There is a deep-seated culture of bribery, as well as the problematic situation of enforcers not wanting to penalise their friends and families, meaning few people are prosecuted. Community involvement is crucial in developing ways that people can coexist with biodiversity (Nguyen Ngia Bien, 2001; Workman, 2004; Hoang Van Chieu, 2012; Cano & Tellería, 2013).
Locals are usually the first to know about any illegal activities going on in the area and, by encouraging awareness and feelings of protectiveness towards their local biodiversity, conservation strategies are likely to be more effective.

Delacour’s langur remains at risk of extinction due to both environmental and anthropogenic pressures (Nadler et al., 2003; Nadler, 2010b; Workman, 2010b; Harding, 2011; Mittermeier et al., 2012). Hunting and wildlife trade remain one of the biggest threats, and the lack of effective law contributes to this. The few remaining areas of habitat continue to be threatened by agricultural encroachment, with Vietnam’s large human population an increasing pressure on land resources. There is also the newer threat of profitable mining operations setting up around limestone karst habitats to quarry for cement products, targeting what had previously been a safe zone for T. delacouri because of its unsuitability for farming. In addition, the structure of the remaining T. delacouri in isolated subpopulations makes the species much more vulnerable, as the loss of a key breeding adult in a group could spell the end of that entire subpopulation, with there being no opportunities for migration.

**8.4.2 T. delacouri population size estimate**

Of the 10 T. delacouri subpopulations thought to remain, comprising less than 200 individuals, only the Van Long population has begun to increase, and indeed is thought to have doubled in size from 2001 to 2010 (Nadler, 2010b; Workman, 2010b; Ebenau et al., 2011; Harding, 2011). Ebenau et al. (2011) estimated the Van Long population at 98-105 individuals; however the findings of this current study suggest that the population has continued to grow since then. In western Van Long, Ebenau et al. estimated 20 individuals, including a group of two T. delacouri in the Ba Chon area. However, I spotted a group of at least six individuals in this same area in 2011, indicating either that this group has expanded or that some individuals were missed in the initial survey. Adding on the three individuals released by the EPRC, assuming that they have all survived, I estimate that there are now at least 27 individuals in the western Van Long area (including the northern extension into Dai Dong and Dong Tam), and it is possible that more groups may have been missed in this large area.
The most recent population estimates of the Hang Tranh and Dong Quyen outcrops of Van Long come from the 2008 fieldwork of Workman (2010b), estimating 10-15 individuals on Hang Tranh and 68-70 on Dong Quyen. During my fieldwork at Dong Quyen I observed five T. delacouri groups and a total of 61 individuals, including 13 infants. As I surveyed only part of the Dong Quyen outcrop, there are undoubtedly additional groups outside of my research area, suggesting that the current population there is now likely to be much higher than the 68-70 individuals observed in 2008. This is also supported by the large number of infants I observed, indicating a healthy reproductive level in this subpopulation. Based on this information and building on Ebenau et al.’s figures, I would estimate that the combined Van Long subpopulation comprises at least 100 individuals as of 2011, but further population surveys, especially concentrating on the western area, are needed to confirm this.

8.4.3 Recommended conservation strategies

When considering future conservation strategies for T. delacouri and whether releases are a potential conservation tool, some key issues need to be addressed. The EPRC’s first T. delacouri release was a major milestone for the group, and filled an important role as a pilot project allowing researchers to learn a lot of information about how best to conduct a release and how released animals behave. Nonetheless, I do not think that continued releases in this current format are greatly beneficial for the species, or the best use of resources. A second release took place in November 2012, only 15 months after the first, not allowing enough time to identify potential problems from the first release, such as whether any disease transmission had occurred. In addition, there had been not enough time to make a full analysis of the first release, so there was no opportunity to review release protocol and make any recommended changes. It must also be questioned what further releases of captive T. delacouri into western Van Long are aiming to achieve, and whether their goals need to be modified. Whilst there is not yet enough information to say whether or not the first release was successful in achieving the EPRC’s goal of connecting the Van Long populations and promoting interbreeding, current evidence would suggest that immigration between the Van Long populations may be rare, and extensive research on this topic is needed. Therefore it is questionable whether the risks, such as
disease transmission and depletion of the captive breeding population, may outweigh the potential benefits of continued releases in this format.

However, animal releases may still hold importance as a conservation strategy for *T. delacouri* moving forward, and the idea of translocation of existing subpopulations needs urgent investigation. The majority of the current small subpopulations outside Van Long are slowly dying off as they cannot be adequately protected in their current environment without a large investment of resources (T. Nadler, pers. comm. 2011). Therefore, if it is not plausible to protect these individuals in-situ, the idea of moving them to an area where they have a greater chance of survival, and can contribute to the genetic exchange of existing populations, must be seriously considered. By leaving these small subpopulations untouched, we are potentially losing half the remaining *T. delacouri* population along with any unique genes. Whilst undoubtedly a translocation project would be expensive and challenging, the recent success of the Cat Ba Langur Conservation Project in translocating a group of two wild *T. poliocephalus* (Schruddle, 2009; Passaro, 2012a; R. Passaro, pers. comm. 2013) suggests that, with preparation and extensive research, it may be possible.

The continued protection of Van Long Nature Reserve remains a key conservation strategy, the reserve having played a major role in the species’ survival so far. The protection of the Dong Quyen population in particular from hunting threats is a huge success story for a critically endangered species, allowing numbers to rebound from approximately 35-40 individuals in 2000 to at least 70 as of 2011 (Workman, 2010b). Along with the work of rangers and guards, backed by the EPRC and the Ninh Binh Forest Protection Department, the support of the local communities surrounding the reserve is crucial in enforcing wildlife laws and allowing *T. delacouri* to thrive. The proposed expansion of the reserve north of the existing western portion (Nadler et al., 2012), to cover a 4000ha block, would greatly expand the available protected habitat for the species, and is to be strongly recommended. Not only would this area cover the existing Dai Dong and Dong Tam *T. delacouri* populations, but it is also an area that was utilised by two of the released individuals in this study. By including this area in Van Long Nature Reserve, the risk of mining companies moving into this limestone block is eliminated, and additional valuable protected habitat to translocate groups into, or allow expansion of existing *T. delacouri* groups, is provided.
Whilst the outlook for the critically endangered Delacour’s langur remains uncertain, concentrated conservation efforts have already made a big difference to the populations’ situation. Continued efforts, focusing research on improved conservation management strategies for the species, are crucial in attempting to secure *T. delacouri’s* survival as a species of the future.
A local fisherman at Văn Long Nature Reserve
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239


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## Complete Ethogram

<table>
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<tr>
<th>Main Category</th>
<th>Sub Category</th>
<th>Code</th>
<th>E/S?</th>
<th>Definition</th>
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<tbody>
<tr>
<td>Out of View</td>
<td>Out of view</td>
<td>OV</td>
<td>State</td>
<td>Individual cannot be seen clearly by observers</td>
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<tr>
<td>Vocalisation</td>
<td>Click</td>
<td>VC</td>
<td>Event</td>
<td>Sequence of very soft ‘clicking’ noises, with gap between clicks decreasing as the call tails off; often several calls given in a row, typically by an adult male</td>
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<td>Grunt</td>
<td>VG</td>
<td>Event</td>
<td>Short, deep ‘grunt’ noise, typically by an adult male</td>
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<td>Hoot</td>
<td>VH</td>
<td>Event</td>
<td>Loud and deep ‘hooting’ noise performed by adult males during a bounding display</td>
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<td>Squawk</td>
<td>VK</td>
<td>Event</td>
<td>Short throaty ‘squawk’ of mid pitch, typically given during an aggressive altercation</td>
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<td>Meow</td>
<td>VM</td>
<td>Event</td>
<td>Similar in sound to a domestic cat’s meow, a drawling sound typically given by sub-adults and juveniles</td>
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<td>Screech</td>
<td>VR</td>
<td>Event</td>
<td>High pitched ‘screeching’ call, typically given during an aggressive altercation</td>
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<td></td>
<td>Squeal</td>
<td>VS</td>
<td>Event</td>
<td>Used by infants and juveniles; a long and high pitched ‘squealing’</td>
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<td>Excretion</td>
<td>Urinate/Defecate</td>
<td>EE</td>
<td>Event</td>
<td>Individual releases urine or faeces</td>
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<td>Sexual</td>
<td>Present to another</td>
<td>SA</td>
<td>Event</td>
<td>An individual approaches another and turns so their anogential area is facing them</td>
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<td></td>
<td>Inspection</td>
<td>SI</td>
<td>Event</td>
<td>Individual looks at, smells and/or touches the anogential area of another</td>
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<td>------</td>
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<td>--------------------------------------------------------------------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Copulation</td>
<td>SC</td>
<td>State</td>
<td>Animals are seen to mount and thrusting is observed.</td>
<td></td>
</tr>
<tr>
<td>Rump Holding</td>
<td>SH</td>
<td>State</td>
<td>An individual grasps the rump of another from behind, but without mounting.</td>
<td></td>
</tr>
<tr>
<td>Threat/Submission</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aggression non-contact</td>
<td>TN</td>
<td>Event</td>
<td>An animal chases/displays to another or threatens another animal with a head bob, yawn, stare, or grin without physically contacting them.</td>
<td></td>
</tr>
<tr>
<td>Aggression contact</td>
<td>TC</td>
<td>Event</td>
<td>Hit, bite, grab or wrestle. Hit = animal swings limb and impacts another individual; Bite = animal contacts another individual using the force of their teeth; Grab/Wrestle = animal reaches out and clutches another animal with their limbs</td>
<td></td>
</tr>
<tr>
<td>Submissive</td>
<td>TS</td>
<td>Event</td>
<td>An individual avoids or flees from another aggressive animal or lip-smacks in response to a threat.</td>
<td></td>
</tr>
<tr>
<td>Threat Display</td>
<td>TD</td>
<td>State</td>
<td>Individual displays, typically in an aggressive fashion - may be accompanied by vocalisations, bounding, thumping, movement etc. Display is more than just a one-off event movement, and takes place over a few seconds</td>
<td></td>
</tr>
<tr>
<td>Cling behaviours</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solicit climb</td>
<td>NS</td>
<td>Event</td>
<td>Partner-initiated attempt to get infant to climb/pull onto body – may or may not be successful. Scored for individual performing behaviour or infant being solicited to.</td>
<td></td>
</tr>
<tr>
<td>Climb on</td>
<td>NC</td>
<td>Event</td>
<td>Infant climbs on to any part of a partner’s body. Scored for infant performing behaviour or partner being climbed onto.</td>
<td></td>
</tr>
<tr>
<td>Pushed off/Rejected</td>
<td>NP</td>
<td>Event</td>
<td>Individual prevents infant from climbing onto body or forces an infant off their body. Scored for partner or infant involved.</td>
<td></td>
</tr>
<tr>
<td>Event</td>
<td>State</td>
<td>Description</td>
<td></td>
<td></td>
</tr>
<tr>
<td>----------------------</td>
<td>-------</td>
<td>-----------------------------------------------------------------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Climb off NO</td>
<td>Event</td>
<td>Infant climbs off a partner’s body, returning to a natural substrate. Scored for partner or infant involved.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transfer/taken NT</td>
<td>Event</td>
<td>Infant is voluntarily or forcefully moved from being carried/held by one individual to being carried/held by another. Scored for individual or infant involved.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Attempts taking NA</td>
<td>Event</td>
<td>Attempt by an individual to take an infant being held by another is rejected. Scored for individual attempting take or infant involved.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prevents taking NE</td>
<td>Event</td>
<td>Attempt by another to take infant being carried is prevented by the current carrier. Scored for individual carrying infant or infant involved.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Attempted Climb-off NL</td>
<td>Event</td>
<td>Infant attempts to climb off carer but is prevented</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ventrally Held NV</td>
<td>State</td>
<td>Infant held on carers chest</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dorsally Held ND</td>
<td>State</td>
<td>Infant being supported off ground on carers back</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hanging Hold NH</td>
<td>State</td>
<td>Infant hanging from carer’s chest as the latter stands/moves</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Grooming**

<table>
<thead>
<tr>
<th>State</th>
<th>State</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Autogroom GS</td>
<td>State</td>
<td>Individual picks through their own hair, including picking at fingers, toes or other body parts</td>
</tr>
<tr>
<td>Be groomed GB</td>
<td>State</td>
<td>The individual is groomed by another, who picks through its hair; includes picking at fingers, toes, or other body parts.</td>
</tr>
<tr>
<td>Groom another GA</td>
<td>State</td>
<td>The individual grooms another, by picking through the other’s hair, including fingers, toes, or other body parts</td>
</tr>
<tr>
<td>Reciprocally groom GR</td>
<td>State</td>
<td>Two individuals groom one another at the same time</td>
</tr>
<tr>
<td>Groom request GQ</td>
<td>Event</td>
<td>Individual uses body position, possibly accompanied by vocalisation, to solicit grooming</td>
</tr>
<tr>
<td><strong>Play</strong></td>
<td><strong>Manipulates object</strong></td>
<td><strong>PO</strong></td>
</tr>
<tr>
<td>----------</td>
<td>------------------------</td>
<td>--------</td>
</tr>
<tr>
<td><strong>Play by locomotion</strong></td>
<td><strong>PL</strong></td>
<td><strong>State</strong></td>
</tr>
<tr>
<td><strong>Playing with another</strong></td>
<td><strong>PA</strong></td>
<td><strong>State</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Contact</strong></th>
<th><strong>Muzzle</strong></th>
<th><strong>CM</strong></th>
<th><strong>Event</strong></th>
<th>Face to face contact between two individuals</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hold/Carry</strong></td>
<td><strong>CH</strong></td>
<td><strong>State</strong></td>
<td>Individual carries or holds another (excluding infant), with the latter being completely supported off the ground</td>
<td></td>
</tr>
<tr>
<td><strong>Be held/carried</strong></td>
<td><strong>CL</strong></td>
<td><strong>State</strong></td>
<td>Individual is carried or held by another (excluding infant), being completely supported off the ground</td>
<td></td>
</tr>
<tr>
<td><strong>Contact</strong></td>
<td><strong>CA</strong></td>
<td><strong>Event</strong></td>
<td>Individual approaches and touches another individual (in a non-aggressive manner), no grooming involved</td>
<td></td>
</tr>
<tr>
<td><strong>Be contacted</strong></td>
<td><strong>CB</strong></td>
<td><strong>Event</strong></td>
<td>Individual is approached and touched by another individual (in a non-aggressive manner), no grooming involved</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Locomotion</strong></th>
<th><strong>Quadrupedal</strong></th>
<th><strong>LQ</strong></th>
<th><strong>State</strong></th>
<th>Travels on all four limbs with at least two limbs in motion; moving from one location to another</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Jump</strong></td>
<td><strong>LJ</strong></td>
<td><strong>Event</strong></td>
<td>A ‘springing motion’ clear off the ground/surface by a sudden muscular effort of the limbs</td>
<td></td>
</tr>
<tr>
<td>Activity</td>
<td>Code</td>
<td>Category</td>
<td>Description</td>
<td></td>
</tr>
<tr>
<td>-------------------</td>
<td>------</td>
<td>----------</td>
<td>------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Climb</td>
<td>LC</td>
<td>State</td>
<td>Purposeful ascending or descending a near vertical surface in a quadrupedal locomotion mode</td>
<td></td>
</tr>
<tr>
<td>Branchiate</td>
<td>LB</td>
<td>State</td>
<td>An individual is suspended/hanging/swinging from a substrate by its front limbs; stationary or locomoting</td>
<td></td>
</tr>
<tr>
<td>Bipedal Walk</td>
<td>LW</td>
<td>State</td>
<td>Individual walks/runs on two legs, placing one foot in front of another</td>
<td></td>
</tr>
<tr>
<td><strong>Feed</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Concentrated</td>
<td>FC</td>
<td>State</td>
<td>Actively preparing or eating/masticating food</td>
<td></td>
</tr>
<tr>
<td>Feeding</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Foraging</td>
<td>FF</td>
<td>Event</td>
<td>Individual searching for food, occasionally putting food into mouth</td>
<td></td>
</tr>
<tr>
<td>Drinking</td>
<td>FD</td>
<td>State</td>
<td>Lapping or licking water from a source e.g. stream, rock pool</td>
<td></td>
</tr>
<tr>
<td>Nursing</td>
<td>FN</td>
<td>State</td>
<td>Infant feeding from the mother’s nipples, or mother feeding infant by suckling</td>
<td></td>
</tr>
<tr>
<td>Denied nursing</td>
<td>FE</td>
<td>Event</td>
<td>Infant’s attempt at suckling is refused; or adult refuses suckling to infant</td>
<td></td>
</tr>
<tr>
<td>Receives/ Steal</td>
<td>FR</td>
<td>Event</td>
<td>Individual takes food from another individual, either through an aggressive manner or it being presented</td>
<td></td>
</tr>
<tr>
<td>Gives/Stolen from</td>
<td>FG</td>
<td>Event</td>
<td>Individual loses food to another individual, either through an aggressive manner or by offering it</td>
<td></td>
</tr>
<tr>
<td><strong>Inactive</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resting</td>
<td>IR</td>
<td>State</td>
<td>Stationary with no active head movement and no other activity being conducted, eyes may be closed or open</td>
<td></td>
</tr>
<tr>
<td>Embrace resting</td>
<td>IE</td>
<td>State</td>
<td>Resting whilst in full body contact with one or more other individuals</td>
<td></td>
</tr>
<tr>
<td>Scanning</td>
<td>IS</td>
<td>State</td>
<td>Sitting in a stationary position, with head and eyes moving around i.e. acting as sentry</td>
<td></td>
</tr>
<tr>
<td>Standing Scan</td>
<td>IA</td>
<td>State</td>
<td>Standing stationary on all fours with head and eyes moving around i.e. acting as sentry</td>
<td></td>
</tr>
<tr>
<td><strong>Other</strong></td>
<td>Other activities</td>
<td>OA</td>
<td>Any other activity that cannot be fitted in to the other categories, <em>ad libitum</em> notes taken</td>
<td></td>
</tr>
<tr>
<td>-----------</td>
<td>-----------------</td>
<td>----</td>
<td>----------------------------------------------------------------------------------</td>
<td></td>
</tr>
</tbody>
</table>

**DVD Index**

An electronic copy of this thesis is included on the DVD.

**Chapter 3**

*Study Population - Wild Delacour’s langurs on Dong Quyen*

Footage of a group of wild *T. delacouri* on Dong Quyen outcrop is included on the DVD.

**Chapter 5**

*Vocalisation Clips*

Audio examples of each *T. delacouri* vocalisation, along with available vocalisation examples for the other limestone langurs are presented on the DVD. Some clips have been amplified or had high frequencies filtered out to enable the listener to easily pick out the vocalisation.
<table>
<thead>
<tr>
<th>Clip #</th>
<th>Species</th>
<th>Vocal</th>
<th>Performer</th>
<th>Modifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><em>T. delacouri</em></td>
<td>Click</td>
<td>Adult male</td>
<td>Amplified, Filtered</td>
</tr>
<tr>
<td>2</td>
<td><em>T. delacouri</em></td>
<td>Grunt</td>
<td>Adult male</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td><em>T. delacouri</em></td>
<td>Hoot</td>
<td>Adult male</td>
<td>Amplified, Filtered</td>
</tr>
<tr>
<td>4</td>
<td><em>T. delacouri</em></td>
<td>Meow</td>
<td>Subadult male</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td><em>T. delacouri</em></td>
<td>Screech</td>
<td>Juvenile</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td><em>T. delacouri</em></td>
<td>Squawk</td>
<td>Juvenile</td>
<td>Amplified</td>
</tr>
<tr>
<td>7</td>
<td><em>T. delacouri</em></td>
<td>Squeal</td>
<td>Infant orange</td>
<td>Amplified</td>
</tr>
<tr>
<td>8</td>
<td><em>T. ebenus</em></td>
<td>Click</td>
<td>Adult male</td>
<td>Amplified, Filtered</td>
</tr>
<tr>
<td>9</td>
<td><em>T. ebenus</em></td>
<td>Grunt</td>
<td>Adult male</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td><em>T. francoisi</em></td>
<td>Grunt</td>
<td>Adult male</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td><em>T. francoisi</em></td>
<td>Hoot</td>
<td>Adult male</td>
<td>Amplified, Filtered</td>
</tr>
<tr>
<td>12</td>
<td><em>T. francoisi</em></td>
<td>Squeal</td>
<td>Infant orange</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td><em>T. hatinhensis</em></td>
<td>Grunt</td>
<td>Adult male</td>
<td>Amplified</td>
</tr>
<tr>
<td>14</td>
<td><em>T. hatinhensis</em></td>
<td>Squeal</td>
<td>Infant black</td>
<td>Amplified</td>
</tr>
<tr>
<td>15</td>
<td><em>T. laotum</em></td>
<td>Grunt</td>
<td>Adult male</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td><em>T. poliocephalus</em></td>
<td>Click</td>
<td>Adult male</td>
<td>Amplified, Filtered</td>
</tr>
<tr>
<td>17</td>
<td><em>T. poliocephalus</em></td>
<td>Grunt</td>
<td>Adult male</td>
<td>Amplified</td>
</tr>
<tr>
<td>18</td>
<td><em>T. poliocephalus</em></td>
<td>Hoot</td>
<td>Adult male</td>
<td>Amplified, Filtered</td>
</tr>
<tr>
<td>19</td>
<td><em>T. poliocephalus</em></td>
<td>Squeal</td>
<td>Infant black</td>
<td></td>
</tr>
</tbody>
</table>

**Chapter 6**

*Footage of the release*

A video showing the moment of release into the wild when the Van Long forest cage was opened by Tilo Nadler, on 22nd August 2011.

*Released individuals’ movement animation*

An animation of the movement of the three released individuals from day one through to the end of monitoring on day 409 is presented on the DVD. Individual 1-10 (adult male) is shown in blue, 1-09 (adult female) in pink and 1-20 (subadult male) in yellow with the green square showing the release site and red line the reserve boundary. In regards to time scale, each second in the animation represents approximately three days.