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SPECIES DISTRIBUTION, ABUNDANCE AND CONSERVATION IN NAKAI-NAM THEUN NATIONAL PROTECTED AREA, CENTRAL-EASTERN LAOS: IMPLICATIONS FOR FUTURE LOCAL WILDLIFE CONSERVATION PROJECT

Camille N. Z. COUDRAT

May 2013

SPECIES DISTRIBUTION, ABUNDANCE AND CONSERVATION IN NAKAI-NAM THEUN NATIONAL PROTECTED AREA, CENTRAL-EASTERN LAOS: IMPLICATIONS FOR FUTURE LOCAL WILDLIFE CONSERVATION PROJECT

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OXFORD BROOKES UNIVERSITY

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ABSTRACT

Southeast Asia is experiencing unprecedented biodiversity declines brought about by human population growth and economic development leading to unsustainable use of natural resources and loss of natural habitat. The scientific community has emphasized this biodiversity crisis in the past decade, calling for immediate action. In this context, I set my research as a case study in Nakai-Nam Theun National Protected Area (NNT NPA), central eastern Laos where wildlife hunting has been rampant and management strategy failing to prevent wildlife declines. This research aimed **(1)** to re-assess and bring forward the importance of NNT NPA for wildlife conservation, **(2)** to identify the key species for which NNT NPA is a priority for their conservation, **(3)** to use the data collected to develop a long-term project in the area for research and conservation. In addition to this local-level case study, I aimed **(4)** to identify the National near-future priorities for research and conservation of Lao non-human primates (*primates*). For the latter, I reviewed the literature for the most reliable occurrence localities of Lao primate species across the country to model their potential distribution. I used the models to re-assess their current status and identify the remaining gaps in our knowledge that need to be addressed. For the research in NNT NPA, I collected baseline data on key species occurrence and threats within the area. From January 2011 to March 2012, I conducted transect surveys in 10 different sites in the area. At each site, I set four to 20 transects, each replicated up to three times. During the transect walks I recorded all diurnal primate species sighted. In addition, I used the camera-trap database of 2006-2011 collected by NNT NPA's management staff. Using modelling softwares (MAXENT, ENFA, DISTANCE) to provide baseline predictions, I analysed both my transect survey and the camera-trap survey data to assess the current status and distribution of red-shanked doucs (*Pygathrix nemaeus*), four macaque species (*Macaca arctoides, M. assamensis, M. leonina, M. mulatta*), small-carnivores (i.e. Viveridae, Prionodontidae, Herpestidae and Mustelidae), small medium-sized cat species and muntjacs species (*Muntiacus* spp.) occurring in the area.

My analysis of Lao primates distribution models at the National level reveals that **(1)** so-far unvisited regions of northestern Laos may hold populations of highly-threatened colobines. Future research should focus on the taxonomy and distribution range limit between taxa of *Nomascus*, *Pygathrix*, *T. francoisi s.l.* and *T. germaini s.l.* The modelling results emphasise the need for more research on primate species in Laos, a country of high priority for primate conservation. My case-study research in NNT NPA reveals that **(2)** based on a MAXENT analysis, I predicted a conservative suitable habitat of *ca.* 1600 km^2 in NNT NPA and through a distance analysis, I estimated an average group density of 2.8 groups/km^2, yielding a potential for ca. 4900 groups in the area. The population of red-shanked doucs in NNT NPA likely represents the world's largest and the best hope for their long-term global survival. **(3)** Based on a MAXENT analysis using records from both transects and camera-traps, the four resident macaque species were predicted to occupy a different geographical range and niche within NNT NPA. *Macaca arctoides*, *M. assemensis*, *M. leonina* and *M. mulatta*, respectively were predicted along a general environmental gradient: from low to high temperature and precipitation, and high to low elevation and slopes. The potential distribution of these four co-existing, and morphologically similar species will have important implication for their management and future research. **(4)** Of 20259 camera trap-days, from March 2006 to January 2011 only 21 images taken were of these four cat species. All these species were found with much lower survey efforts in NNT NPA in the 1990s. These species are readily camera-trapped in other evergreen forest sites in South-east Asia. In combination, these factors indicate that the present low encounter rate is likely to represent their induced low density in NNT NPA due to high hunting pressure. This indicates that protected large forest blocks or mainly primary forests do not ensure the long-term survival of hunting-sensitive species. **(5)** Of the at least 21 small-carnivore species (Viverridae, Prionodontidae, Mustelidae, and Herpestidae) confirmed in Laos, 15 occur in Nakai-Nam Theun NPA of which ten were photographed during this survey: common palm civet *Paradoxurus hermaphroditus*, masked palm civet *Paguma larvata*, large Indian civet *Viverra zibetha*, Owston's civet *Chrotogale owstoni*, spotted linsang *Prionodon pardicolor*, binturong *Arctictis binturong*, yellow-throated marten, ferret badger sp(p). *Melogale* sp(p)., hog badger *Arctonyx collaris* and crab-eating mongoose *Herpestes urva*. The high rate of hunting with ground snares in the

area put some of these species at high risk of local extinction; however, NNT NPA remains one of the most important areas in Laos for small-carnivore species, in particular for the Owston's civet and otter species. **(6)** Based on an ENFA and MAXENT analysis, Critically Endangered large-antlered muntjac *M. vuquangensis* and other resident muntjac species differ in their predicted potential distribution. The former is predicted at lower elevation range, in the western part of the NPA. NNT NPA represents the core habitat of *M. vuquangensis* and its conservation should be a priority in the area **(7)** Over my field work in NNT NPA I counted over 3000 ground snares (active or about to be set). Despite a management strategy in place and funding available, wildlife conservation in NNT NPA has not been successful. The major threat to wildlife is unsustainable hunting, using ground snares, by both Lao and Vietnamese hunters driven by a lucrative wildlife trade between the two countries. This indicates the urgent need for wildlife management improvement in the area, to be targeted on illegal hunting activities and the need for a long-term research and conservation project to improve our knowledge of this rich wildlife, ensure its long-term conservation and empower and educate local communities towards an integrated conservation strategy.

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ABREVIATIONS

AUC – Area Under the Curve
CBD – Convention on Biological Diversity
CITES – Convention on the International Trade of Endangered Species
CR – Critically Endangered
CTD – Camera-trap-day
DD – Data Deficient
DPA – District Protected Area
EN – Endangered
ENFA – Environmental Niche Factor Analysis
FA – Forested Area
GIS – Geographic Information System
GoL – Government of Laos
GPS – Geographic Position System
ICEM – International Centre for Environmental Management
IUCN – International Union for the Conservation of Nature
Lao PDR – Lao People's Democratic Republic
LC – Least Concern
m a.s.l. – metre above sea level
MAF – Ministry of Agriculture and Forestry
MAXENT – Maximum Entropy
NA – National Assembly
NBCA – National Biodiversity Conservation Area
NGO – Non Governmental Organisation
NNT NPA – Nakai-Nam Theun National Protected Area
NPA – National Protected Area
NT – Near Threatened
NT2 WMPA – Nam Theun 2 Watershed Management and Protection Authority
NTFP – Non-Timber Forest Products
NTPC – Nam Theun Power Company
PM –Prime Minister
PPA – Provincial Protected Area
RERI – Relative Encounter Rate Index
ROC – Receiver Operative Curve
SEMFOP – Social and Environmental Management Framework and Operational Plan
UNDP – United Nations Development Programme
UTM – Universal Transverse Mercator
VU – Vulnerable
WCS – Wildlife Conservation Society
WGS – World Geographic System
WMPA – Watershed Management Protection Authority
WWF – World Wide Fund for Nature

CHAPTER 1

GENERAL INTRODUCTION

1. Brief overview of the project, objectives and aims

From January 2011 to March 2012, I conducted several field surveys in different sites of Nakai-Nam Theun National Protected Area, in the central-eastern part of Laos. The surveys consisted of transect walks and focussed primarily on diurnal primates (I also collected data on hornbills and black-giant squirrels at the same time). I was in addition given permission to analyse the long-term camera-trap database that management staff collected from 2006 to 2011 (and still on-going). I use the data collected and the camera-trap database to assess the conservation status, abundance and distribution of small-medium sized cats, small carnivore species, muntjac species, and some diurnal primate species.

The objectives of the project were:

- To collect baseline data on key study-species occurrence throughout NNT NPA
- To assess the intensity of threats in the area
- To analyse the camera-trap data base for some key species
- To assess distribution and status of key study-species by using modelling methodologies

The ultimate aims of this project are:

- To re-assess and bring forward the importance of NNT NPA for wildlife conservation
- To identify the key species for which NNT NPA is a priority for their conservation
- To develop a long-term project in the area for research and conservation

2. Thesis structure

The thesis is presented in 10 chapters. The first chapter is the general introduction (CHAPTER 1) in which I give a background about Laos, its natural history and regulations regarding wildlife conservation as well as an introduction to Nakai-Nam Theun National Protected Area. The general method (CHAPTER 2) describes all aspects of the fieldwork and other activities that were conducted during my time

spent in Laos, and includes the data that were not necessarily analysed in this thesis. This gives an idea of the experience I gained in addition to what is presented in the chapters that follow. Because of the diverse methodologies used and the various taxa covered, all chapters are stand-alone and presented in a typical scientific paper format (i.e. introduction, methods, results, discussion) allowing the reader to gain a better understanding of my research. In CHAPTER 3, I reviewed the literature and consulted experts to obtain the most reliable and up-to-date occurrence localities of primate species in Laos to model their National potential distribution with MAXENT Software. This gives an introduction to the importance of the country for primate conservation. In CHAPTER 4 I present the first baseline data of red-shanked douc density in NNT NPA using the data I collected and suggest it is the largest population in the world. In CHAPTER 5 I combine both the camera-trap data and my transect data to model the niche of the four macaque species occurring in NNT NPA. In CHAPTER 6, I present the results of the 2006-2011 camera-trap data to show the low abundance of non-*Panthera* cat species in NNT NPA likely due to over-hunting. Likewise, in CHAPTER 7 I present small-carnivore (i.e. Viverridae, Prionodontidae, Mustelidae, Herpestidae) camera-trap data and hypothesize that the lower encounter rate in some areas is due to higher accessibility to humans; overall, NNT NPA encompasses (at least) 15 species of small carnivores and set its importance for the conservation of these species, in particular for Owston's civet and otter species. In the CHAPTER 8, I used two modelling methods (MAXENT and ENFA) to model and compare the niche of Endangered large-antlered muntjac and other muntjac species of NNT NPA and discuss the implications for species management. In CHAPTER 9 I present the records of threats collected during my surveys in NNT NPA to highlight the dramatic hunting pressure occurring there. Finally, despite wildlife conservation issues in the area, in CHAPTER 10 I provide an optimistic opening on the future of wildlife research and conservation in the Indo-Burma region and list the next steps planned towards a long-term conservation and research project in NNT NPA. All maps, figures and illustrations in this thesis were self-made and photos taken by myself or my assistant (unless otherwise mentioned).

3. Laos

3.1. Background

Lao People's Democratic Republic (Lao PDR or Laos, hereafter – note: the use of the word 'Laos' designates the country, while 'Lao' is always used as an adjective to indicate the associated noun are from Laos e.g. Lao people; Lao primates) is a landlocked country of 236,800 km^2 located in the Indochinese peninsula, surrounded by Myanmar and China to the North, Thailand to the west, Vietnam to the east and Cambodia to the south (Figure 1.1). Laos has a population of 6,256,197 and population density of 26 inhabitants per km^2, the lowest of neighboring countries, though Laos' population growth rate of 2.2 % is one of the highest in Southeast Asia (Lao Statistic Bureau, 2010).

Figure 1.1: Location of the 236800 km^2 land-locked country of Laos in Southeast Asia.

Laos is one of the most culturally diversified countries in the world. According to official sources (the Lao Front for National Construction) Lao ethnics have been

divided into 49 different groups and some 200 subgroups (Chamberlain and Phomsombath, 2002; Word Bank, 2006) with over 230 different languages spoken (Manivong and Sophathilath, 2007). The different ethnic groups can be classified into four general ethno-linguistic families: the Lao-Tai (67% of the population), the Mon-Khmer (21%), Hmong-Lu Mien (8%), and the Sino-Tibetan (3%) (King and van de Walle, 2010).

The country is divided in 17 provinces each of them comprising several districts. Most of the Lao population (73 %) lives in rural areas (Lao Statistic Bureau, 2011) and rely on agriculture and forest harvest practices. Although poverty has been largely reduced in the past two decades with development projects, this mainly benefited urban population located along the Mekong River and its major tributaries. Indeed, rural areas encompass 82 % of the countries' 'poor' (according the National poverty line) (Lao Statistic Bureau, 2008). In the most remote villages – mostly in the northern and eastern parts of the country, bordering Vietnam – lacking access to markets and infrastructures, poverty remains at 43 % (Lao Statistic Bureau, 2008). With about 10% of the country's villages inside National Protected Areas (Southammakot, 1999, cited in Chape, 2001) and 70 % of the National population relying on natural resources (UNDP, 2009), forest management is crucial in Laos for people livelihoods and flora and fauna conservation. Up until the early 2000s, few Lao specialists had been trained, due to limited access to education, which remained problematic for many in the country (Chape, 2001). This paucity has however improved in the past decade with the establishment of new legislations and policies that aimed at expending education access, quality and equality (UNESCO, 2008). These reforms have led to an increase of overall literacy rate and school enrolment, though there remain substantial inequalities in education level between rural vs. urban populations, ethnic minorities and genders (Benveniste et al., 2010). Curriculum for undergraduates has been developed notably in the sector of natural conservation (see *3.3*).

Laos land can be divided in three major biogeographic regions: the Northern Highlands, the Annamite Range and the Mekong Plain (Duckworth et al., 1999; Berkmuller et al., 1995). The Northern Highlands are characterized by the highest

mountains of Laos, including the highest peak of the country Phou Bia, 2820 m (Duckworth et al., 1999). This region has the most suffered from deforestation mostly from shifting cultivation (Berkmuller et al., 1995). The Mekong Plain, to the west bordering Thailand, is essentially flat terrain of low altitude mostly below 200 m (Duckworth et al., 1999) and is largely covered with agriculture lands (Berkmuller et al., 1995); it is also where urban centers are mostly concentrated. To the east, bordering Vietnam, the Annamite Range is unique for its patches of wet evergreen forest, which are inhabited by endemic species. This region ranges generally from 500 to 2500 m.

Laos has a tropical monsoon climate characterized by a wet season typically from May to October and a dry season from November to April. Mean annual rainfall is about 1720 mm ranging from 1500 mm to 2500 mm (Lao Statistic Bureau, 2009). Mean temperature varies between min 22°C to max 32°C (Lao Statistic Bureau, 2009) with April the hottest month of the year.

3.2. Natural history

The first explorations of Laos' forests date back from the French colonization (1887-1953; Stuart-Fox, 1995) (e.g. Thomas, 1927; 1929; Osgood, 1932; Delacour, 1940; Bourret, 1942; 1944; Sayer, 1983). Some other anecdotal remarks on flora and fauna of Laos can be found in narratives of hunters or explorers travelling through the regions (e.g. Garnier, 1869-1885; Bassenne, 1912; Legendre, 1936; Cheminaud, 1939; 1942; Fraisse, 1955). Some other studies following this period are Deuve (1972) and Chazée (1990). Some of these accounts however encompass various errors regarding distribution and identification of species (Duckworth, 2008).

General wildlife surveys resumed throughout the country in the 1990s (reviewed in Duckworth et al., 1999) when the protected area system establishment process started. These surveys allowed setting base for major conservation programs that are nowadays implemented. The few and incomplete historical surveys led to discovery and rediscovery in the 1990s of – along with the description of new species of

reptiles, amphibians and fish – several small and large mammals in Laos. These include Endangered kha-nyou (*Laonastes aenigmamus*), a rodent identified as a surviving member of the family Diatomyidae previously thought to have gone extinct about 11 million years ago (Dawson et al., 2006; Jenkins et al., 2005); Critically Endangered saola (*Pseudoryx nghetinhensis*), an antelope-like bovid discovered in 1993 in Laos (Schaller and Rabinowitz 1995) following its description in Vietnam in 1992 (Stone, 1992; Dung et al., 1993), endemic to the Annamite mountain range; Endangered large-antlered muntjac (*Muntiacus vuquangensis*) discovered in Laos in 1994 following its description in Vietnam (Duckworth et al., 1994; Evans and Timmins, 1995; Tuoc et al., 1994); Data Deficient Annamite muntjac (*M. truongsonensis*), endemic to Laos and Vietnam, first discovered in Vietnam (Giao et al., 1998) and later discovered in Laos with camera-trap images (Timmins et al. 2008); Data Deficient Annamite striped-rabbit (*Nesolagus timminsi*) discovered in Vietnam and Laos in the 1990s (Surridge et al. 1999, Averianov et al. 2000), which remains little known. In 2009, a rare new bird species was described, Least Concern bare-faced Bulbul (*Pycnonotus hualon*) inhabiting limestone habitats of Laos (Woxvold et al., 2009).

Numerous species of global, regional or national significance occur in Laos. Over 60 Globally Threatened animal species occur in Laos (Duckworth et al., 1999) including, to name a few, several wild cat species (Vulnerable marbled cat [*Pardofelis marmorata*], Vulnerable clouded leopard [*Pardofelis nebulosa*], Near Threatened Asiatic golden cat [*Catopuma temmincki*], Near Threatened leopard [*Panthera pardus*], Endangered fishing cat [*Prionailurus viverrinus*] and Endangered tiger [*Panthera tigris*] – most likely the last viable (if small) population of tigers in Laos, and one of the most important of Indochina may only be found in Nam Et-Phou Louey NPA, northern Laos; Johnson et al., 2006); Endangered Asia Elephant (*Elephas maximus*); Critically Endangered Siamese crocodile (*Crocodylus siamensis*); several primate species including six gibbon species (notably Critically Endangered black crested gibbon [*Nomascus concolor*] and Critically Endangered Northern white-cheeked gibbon [*N. leucogenys*]), Endangered red-shanked douc (*Pygathrix nemaeus*), 3-5 langur, macaque and loris species; Vulnerable Asiatic black bear (*Ursus thibetanus*) and Vulnerable sun bear (*Helarctos malayanus*). Laos is also renowned

for its bird species diversity with approximately 800 different species, notably the country holds populations of Endangered white-winged duck (*Cairina scutulata*), Near Threatened crested argus (*Rheinardia ocellata*), Vulnerable rufous-necked hornbill (*Aceros nipalensis*), Endangered green peafowl (*Pavo muticus*).

Of the 1140 species (excluding fish and plants) included in the last national wildlife review (Duckworth et al., 1999), 319 were of national or global conservation significance. Very few studies have specifically focused on a species; most studies have been general surveys. Taxonomy remains problematic for some groups including primates.

Laos is considered one of the most forested countries in the region compared to its neighbours Thailand, China and Vietnam. The country's forest cover (with canopy density of 20% or more) was estimated at 41.5 % (9.8 million ha) in 2002 compared to 47.2% (11.2 million ha) in 1992 (Fidloczky, 2003; GoL, 2005), attributed mainly to uncontrolled pioneering shifting cultivation and logging. Forest cover since then has not been revised but it is given as 31% by the Population Reference Bureau (2011) and was predicted to be reduced to 30% by 2020 by Fidliczky (2003). Laos encompasses some ecosystems of high regional and global value including the evergreen forests of the Annamite mountain range, the central Indochina limestone karst habitat, the dry dipterocarp forests of the Mekong Plain, the Bolaven Plateau, the Northern Highlands and the Mekong River (Robichaud et al., 2001).

Flora in Laos is one of the least studied compared to its neighbouring countries. Historical studies took place in the 1800s, but virtually no further research was carried out between the 1940s and late 1980s (Inthakoun and Delang, 2008). More research started in the 1990s (reviewed in Inthakoun and Delang, 2008) many of which focussed on medicinal plants and non-timber forest products. The two major and most recent checklists of the flora of Laos were published by Newman et al., (2007) and Inthakoun and Delang (2008).

3.3. Flora and fauna conservation

Actions taken by the government devoted to conservation started in the early 1990s – later than most of Southeast Asian countries – with the establishment of a protected area system (Robichaud et al., 2001; Chape, 2001) considered one of the best in the world. It was designed according to the description of the country's biogeographic regions by MacKinnon and MacKinnon (1986) and is therefore representative of the three main biogeographic regions of Laos (Robichaud et al., 2001). In 1993, the Prime Minister of Laos designated by decree (Prime Minister's Decree 164) 18 'National Biodiversity Conservation Areas', NBCAs (now called 'National Protected Areas', NPAs) and three more were added to the system by 2008; the 21 NPAs covering over 14% of the total country's area (Figure 1.2) (Robichaud et al., 2001). Additional protected areas under the Provincial' or District' authorities makes the total cover of designated areas for protection of about 23 % of Laos (ICEM, 2003). Government of Laos took the decision not to exclude communities from protected areas, and base its strategy on a combination of conservation and livelihood development (Clendon, 2001). Indeed biological diversity and natural resources are the main socio-economic resources for Laos (ICEM, 2003) and non-timber forest products (NTFPs) are the principal, if not the only, sources of income for some rural villages; worth an estimated US $183.7 million a year at the national level (excluding firewood and aquatic animals) (GoL, 2005). As a result, under the Forestry Law, the forest areas designated for the protection and conservation of wildlife and habitats are subject to zonation, with different level of management and use (see *3.4.2. Forestry Law*, below) therefore National Protected Areas and other conservation forests have actually multiple use zones and are not strictly protected in totality.

Figure 1.2: The 21 National Protected Areas in Laos, together covering some 14% of the total land area.

Laos acceded to the Convention on Biological Diversity (CBD) in 1996, which resulted in the development of the National Biodiversity Strategy to 2020, and Action Plan to 2010. This strategy and action plan aims to "maintain the country's diverse biodiversity as one key to poverty alleviation and protect the current asset base of

the poor as support to the implementation of the government's priority programmes" (GoL, 2004: 5) and was based on seven programmes (scientific data and biodiversity knowledge development; biodiversity management; human resource development; public awareness and involvement; institutional and legal frameworks; implementation; international cooperation) (GoL, 2004).

In 2000, the Government of Laos initiated a Forestry Strategy to 2020 and was adopted in 2005 (GoL, 2005). This strategy set base (1) to improve richness of existing forest through natural regeneration of up to 6 million ha and tree planting of up to 500,000 ha; (2) to conserve environment, habitats and wildlife species; (3) to supply forest products from natural forests in a sustainable way (GoL, 2005). Several National laws exist to address targets of the strategy (e.g. Forestry Law, Wildlife and Aquatic, Land Law, Agriculture Law, Environmental Protection Law), some of which were promulgated or updated in response to the Forestry Strategy to 2020.

Despite these efforts, implementation on site of these different strategies and plans has proved to be a real challenge. Lack of cooperation between authorities has created gaps from governmental policies to implementation at the district or village levels (e.g. Hodgdon, 2006; Fujita and Phengsopha, 2008) and lack of human resource, staff motivation and training worsens the situation.

Therefore, threats to wildlife and its habitats remain problematic in the country. The main causes of threats are direct: (1) wildlife hunting for local consumption, (2) wildlife trade (local or international involving National and International hunters, mainly from Vietnam, Thailand or China), and indirect: (3) deforestation due to agriculture practices, commercial logging (legal and illegal), and other natural resource projects (e.g. hydropower dams, mining, commercial tree plantations) also leading to infrastructure development increasing access to forests; (4) population growth, (5) socio-economic development; (6) weak management plans and implementation.

To tackle the wildlife trade issue, one of the most severe causes of wildlife depletion, Laos acceded to the Convention on International Trade of Endangered Species (CITES)

in 2004 and the Lao Wildlife Trade Working Group was established in 2009 within the Ministry of Agriculture and Forestry including members of several conservation organisations (IUCN, WWF, WCS, Green Discovery, ElephantAsia, Free the Bear Fund, The World Bank). The group launched in November 2009 the first Campaign for Wildlife Conservation, which was very well received by the government, the private sector and civil society. Twenty-one different agencies have been involved including the Lao government. Wildlife and aquatic species are protected under the Wildlife and Aquatic Law and classified under three categories: 'prohibition', 'management' or 'common or general' according to their global and national level of conservation status (see *3.4.1. Wildlife and Aquatic Law* below).

Several International donors and NGOs have been actively involved in wildlife conservation activities in Laos (c.f. Phongoudome and Sirivong, 2007). International conservation organisation programmes mostly include area- or species- specific projects. Some National species conservation plans exist for a few key species including tiger (MAF, 2010), saola (Robichaud, 1999) and gibbon species (MAF, 2011) other specific programmes focus on Eld's deer *Rucervus eldii*, Irrawaddy dolphin *Orcaella brevirostris*, giant cat fish *Pangasianodon gigas* and Siamese crocodile *Crocodylus siamensis* (WWF, 2010; WCS, 2012). Several NPAs have not had effective management implementation, which has resulted in encroachment of their habitats and wildlife at a point that is now not reversible (e.g. Dong Phou Vieng NPA), and for many of them current status is unknown. The fewer National Protected Areas that get more active conservation management are those that have received external-initiated (i.e. non-governmental) funding and/or management planning: Nam Et-Phou Louey NPA and Nam Kading NPA have had a continuous management scheme through a partnership of the WCS-Lao Programme and the Lao government, involving strategically implemented law enforcement patrols and long-term wildlife monitoring (Johnson, 2013; Hallam and Hedemark, 2013); Xe Sap NPA, through the Carbon and Biodiversity Project (CarBi), implemented by WWF-Lao Programme and Ministry of Natural Resources and Environment, has recently received resources for capacity building, management planning and wildlife monitoring (Bekker, 2012); a management plan was formulated in 2009 for Him Namno NPA in collaboration with the IUCN-Lao Programme (MoAF, 2010); and Nakai-Nam Theun NPA is receiving

funding from the Nam-Theun 2 Power Company to implement wildlife conservation and livelihood development projects (see section 4).

Postgraduate programmes in the sector of environment, conservation biology, or forestry have been limited in Laos due to a lack of curriculum development and funding for students. Though there has been some improvement through the National Biodiversity Strategy and Action Plan (GoL, 2004). The WCS-Lao programme in collaboration with the Lao Government have developed programmes for primary school level, as well as the first 5-year Bachelor degree programme in Environmental Science and Management, launched in 2004 at the National University of Laos (World Bank, 2005). Another conservation education project was initiated by WCS-Lao Programme with the Faculty of Forestry of the National University of Laos, targeting rural primary school children in Bolikhamxay Province. The project consisted in a Mobile Conservation Education Unit that aimed at raising awareness of the importance of wildlife at the National level as well as locally for villagers' livelihood (Hansel et al., 2010). The NGO GreenCare Fund regularly brings urban secondary school children in field trips during which they learn about and participate in activities related to the environment and wildlife conservation (GreenCare Fund, 2013). The NGO The Global Association for the People and Environment provides teachers training and improve school facilities in Southern Laos; it also initiated the non-profit organization Sustainable Laos Education Initiative, with the creation in 2009 of the Sai Nyai Eco-School in Southern Laos, which provides regular workshops and yearly education on sustainable agricultural practices to boarding students coming from all around the district (GAPE, 2013; SLEI, 2013).

3.4. Legal framework regarding wildlife

The two main laws regarding protection of wildlife are the Wildlife and Aquatic Law No. 07/NA and the Forestry Law No. 6/NA. The main information to understand how wildlife is legally managed and protected in Laos is summarized below.

3.4.1. Wildlife and Aquatic Law

The Wildlife and Aquatic Law was promulgated in 2007 (National Assembly Lao PDR, 2007a). It has for objective to protect, ensure the sustainable use of and raise awareness of all animal species on the Lao territory.

Section II divides wildlife and aquatic species in three categories:

1- The Prohibition Category (I)

   Defines "rare, near extinct, high value and are of special importance in the development of social-economic, environmental, educational, scientific research," which shall be "managed, inspected and preserved." "The utilization of these animals shall be permitted by the government" (Art. 11: 4)

2- The Management Category (II)

   Defines species "considered as beneficial in terms of national economic, social, environmental interests, and in addition are important for livelihoods of multi-ethnic people and educational scientific research" which shall be "managed, inspected, preserved, protected and use will be controlled." (Art. 12: 4-5)

3- The Common or General Category (III)

   Defines "wildlife and aquatic that are able to reproduce widely in nature, and are very important for social-economic development, and educational scientific research," which can be "used in accordance with the law and shall guarantee the use [does] not threaten species numbers or adversely impact the ecological environment system." (Art. 13: 5).

Management plan for wildlife and aquatic life is designed through a collaboration between the Ministry of Forestry and Agriculture, relevant organisation and local authorities and villagers (Art. 16-17).

Art. 24 on Hunting of wildlife and Aquatic stipulates that (1) animals within the Prohibition Category are totally protected and it is strictly forbidden to hunt them for any reason and in any area in Laos. Capture of the animals in this category must receive previous authorisation from the Ministry of Agriculture and Forestry; in case of human-wildlife conflicts, incidents should be reported to authorities for resolution. (2) Animals in the Management Category may be hunted only in the areas authorized (see *3.4.2. Forestry Law*) and during specified season; only with appropriate equipment which does not deplete the whole population; and only for within village use. (3) The animals in the Common or General Category may be hunted only during specified season and with appropriate equipment, which does not deplete the whole population.

Art. 52 on general prohibitions related to wildlife and aquatic lists the following actions as strictly prohibited to any individual, local or international organisation in Laos: (1) catching any of the animals listed in the Prohibition Category, (2) tormenting any wildlife, (3) Illegal catching, hunting, trading or possession of wildlife without required permissions, (4) catching any animals within the 'Conservation Forests' (see *3.4.2. Forestry Law*) and during the breeding season; pregnant females or with infants shall not be caught, (5) produce, import, sell or use weapons that lead to unsustainable hunting practices, (6) destruction of wildlife habitats, (7) modify boundary signs of wildlife zones, (8) practise wildlife husbandry businesses damaging the environment, (9) import, export of wildlife without prior specific authorisations, (10) corrupt any authority staff, (11) carry out tasks of the wildlife management staff, (12) other action in violation of laws and regulations on wildlife and aquatic.

Art. 69-72: Penalty against violators of the laws and regulations can face fines (minimum 200,000 kip/US$ 25), imprisonment from three months to five years, depending on degree of violation, or other appropriate sanctions. Education about the law is also given to the offenders.

3.4.2. Forestry Law

The Forestry Law was first promulgated in 1996 and last revised in 2007 (National Assembly Lao PDR, 2007b). It has for objective to describe the regulations regarding protection, management and sustainable use of forest areas in Laos.

There are three categories of forest areas that can be designated and have different management and protection levels:

1- Conservation Forest:

"Conservation forests are forests classified for the purposes of conserving nature, preserving plant and animal species, forest ecosystems and other valuable sites of natural, historical, cultural, tourism, environmental, educational and scientific research experiments." (Art. 11: 6)

Conservation Forests can be designated at the National, Provincial, District levels. These areas correspond to the (National/Provincial/District) Protected Areas that give emphasis on biodiversity conservation.

The Conservation Forests are divided into 'Total Protection Zones' in which any activities are prohibited, 'Controlled Used Zones" in which people are allowed to use wood and NTFPs according to the management plan and wildlife regulations, 'Corridor Zones' between two designated forest areas, in which any activity is prohibited, and 'Buffer Zones' which are managed to prevent negative impacts on the Conservation Forests (Art. 23).

2- Protection Forest:

"Protection Forests are forests classified for the function of protecting water resources, river banks, road sides, preventing soil erosion, protecting soil quality, strategic areas for national defence, protection from natural disasters, environmental protection and so on." (Art. 10: 6). Protection forests put emphasis on watershed in opposition to biodiversity in the Conservation Forests.

Protection Forests are divided into 'Total Protection Zones' in which any activities are prohibited or 'Controlled Used Zones" in which people are

allowed to use wood and NTFPs according to the management plan and wildlife regulations (c.f. Art. 23)

3- Production Forest:

"Production Forests are natural forests and planted forests classified for the utilization purposes of areas for production, and wood and forest product businesses to satisfy the requirements of national socio-economic development and people's living." (Art. 13: 6)

Production Forests are divided into 'Preservation Zones' for protection or regeneration of habitat of special historical, research or socio-economic value, and 'Development Zones' for logging and NTFPs harvesting (c.f. Art. 25).

3.4.3 Conceptual model of forest and wildlife management in Laos

Figure 1.3 shows a conceptual representation of wildlife and habitats management in Laos according to the Wildlife and Aquatic Law and the Forestry Law.

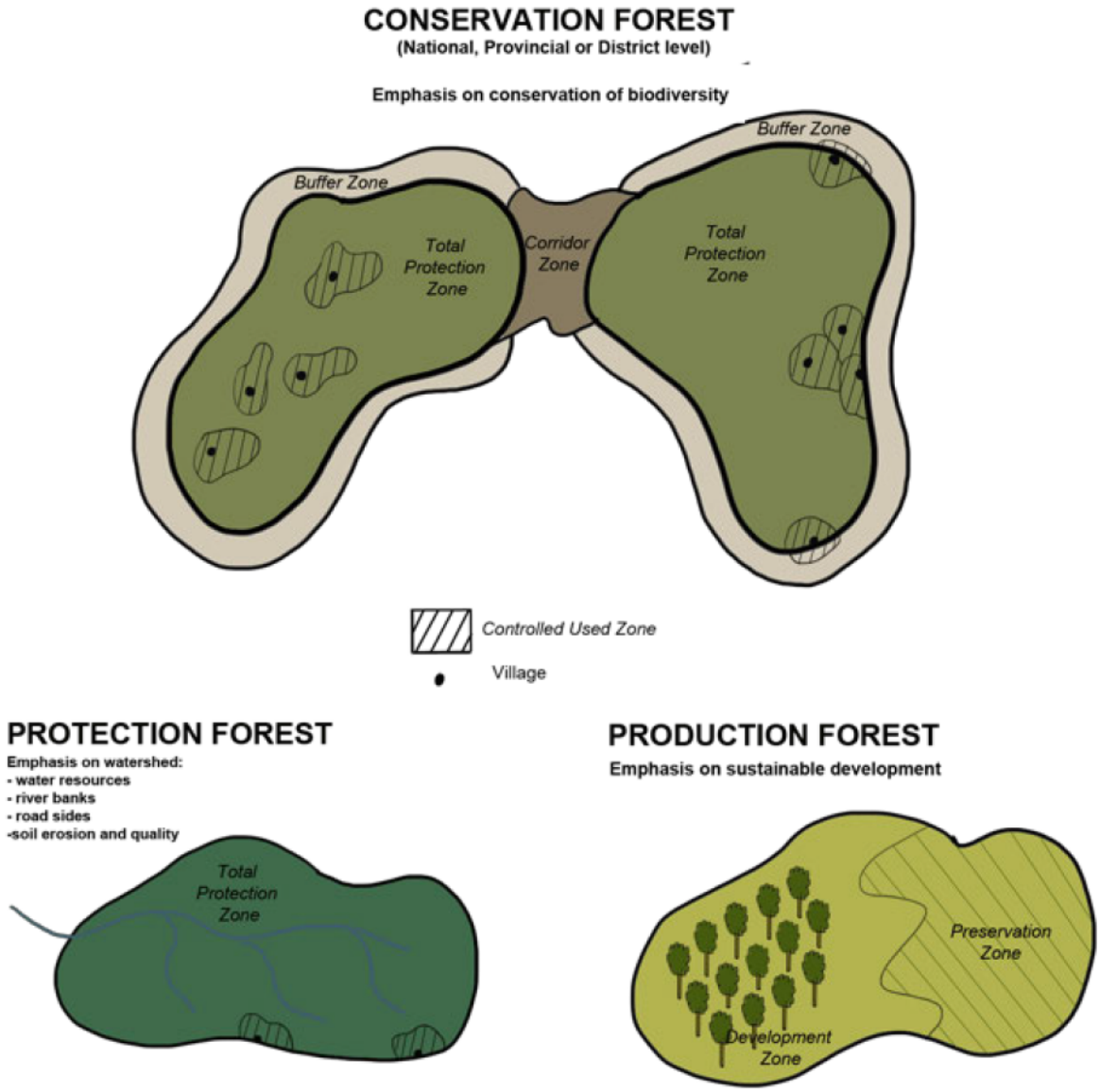


Figure 1.3: conceptual representation of wildlife and forest management in Laos according to the Wildlife and Aquatic Law and the Forestry Law

Forest products can therefore only be collected within 'Controlled Use Zones' of Conservation Forests and Protection Forests and in 'Preservation Zones' of Production Forests, with strict restriction on the species (only animals into the 'Management' or 'Common or General' Categories can be harvested and only tree species that are authorized), season (no hunting during breeding season allowed) and technique used (no technique which may disseminate a population such as guns and rifles, explosives, chemicals and poisons, electrification and sound waves).

4. Nakai-Nam Theun National Protected Area

Nakai-Nam Theun National Protected Area (NNT NPA; 17°34' – 18°23' N 105°02' – 105°46' E) was established by Prime Minister Decree 164 in 1993. It is located in the central eastern Laos and shares a ~155 km border with Vietnam (#12 on Figure 1.2) and covers an area of ~3550 km^2. It is named after the Nam (=river) Theun that traverses the NPA in its centre in addition to four other major rivers: from north to south, the Nam Xot, the Nam Mon, the Nam Theun, The Nam Noy and the Nam On. Thirty-one villages are found within the area (Figure 1.4).

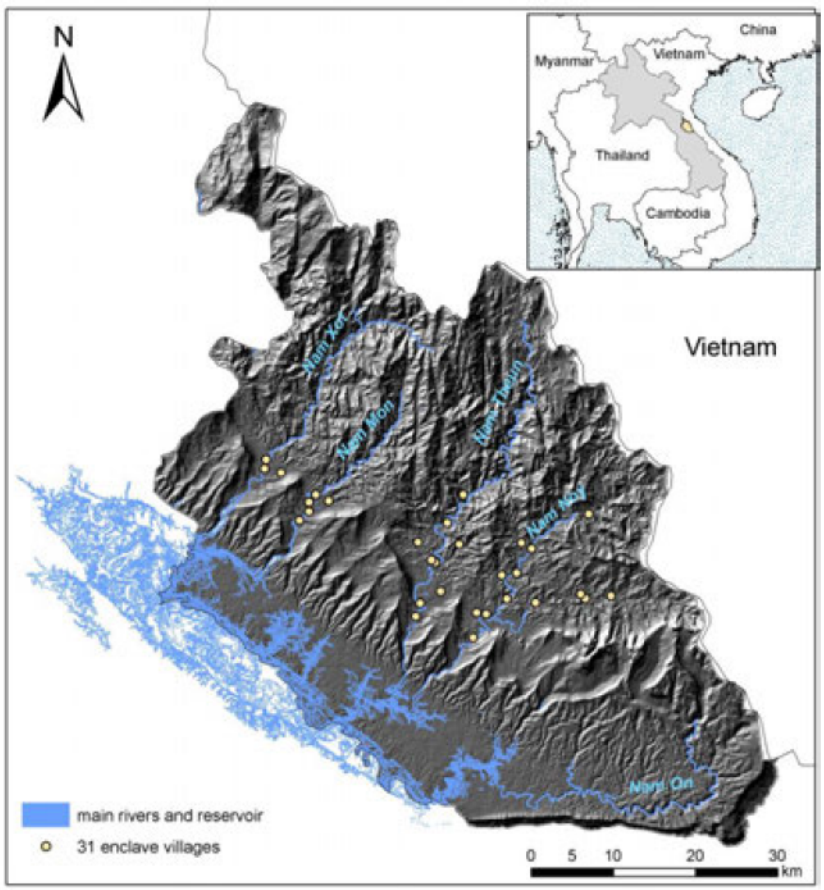


Figure 1.4: Topography (with elevation range of ~400 to 2300 m a.s.l. and five major rivers across the area: the Nam Xot, Nam Mon, Nam Theun, Nam Noy and Nam On) and the 31 enclave villages of Nakai-Nam Theun National Protected Area.

4.1. Habitat

NNT NPA still remains largely forested with around 80% of forest cover (Robichaud et al., 2009). The area encompasses a variety of different habitats. The most common forest type encountered is dry evergreen forest found between 500 to 1800 m a.s.l. Other more localised forest types include the semi-evergreen/pine forest, wet-evergreen forest close to the Vietnam border over 600 m a.s.l., and upper mountain forest at the highest elevations from 1800 m a.s.l. (Timmins and Evans, 1996). The different forest types categories have been studied in more detailed and mapped over the NPA (Jarvie, 1997; NTPC, 2005). Elevation throughout the NPA ranges from ~400 m to c. 2300 m a.s.l.

The area is of particular importance notably for its geographical location within the Annamite mountain range which is characterized by a unique climatic pattern and species diversity and endemism. This mountain range is solely found in Laos, Vietnam and Cambodia; with Laos probably retaining the most undisturbed part of it.

4.2. Wildlife

Initial surveys for fish (Kottelat, 1998), reptiles and amphibians (Robichaud and Stuart, 1999), birds and mammals (Timmins and Evans, 1996) in the mid-1990s, have ranked NNT NPA among the highest priority of the county's NPAs for National as well as Global biodiversity importance based on species richness, distinctiveness, endemism as well as value for communities, potential for ecotourism and threats faced (Robichaud et al., 2001). Several of the species inhabiting the NPA are classified in the IUCN Red List of Threatened Species (c.f. Box 1.1; IUCN, 2012b) Fish remain little-known in the area; reptiles and amphibians have been little studied (c.f. WCS, 1997; Robichaud and Stuart, 1999); of particular importance, confirmed to occur in mountainous areas are CR Indochinese box turtle (*Cuora galbinifrons*), EN keeled box turtle (*Cuora mouhotii*), EN yellow tortoise (*Indotestudo elongat*) and VU impressed tortoise (*Manouria impressa*). The area holds over 430 bird species (Timmins and Evans, 1996; WCS, 1997), which is the highest number found in a single protected area in all of Southeast Asia (Robichaud et al., 2001); notably, NT crested argus

(*Rheinardia ocellata*), and five species of hornbills including VU rufous-necked hornbill (*Aceros nipalensis*), NT brown hornbill (*Anorrhinus tickelli*) and NT great hornbill (*Buceros bicornis*).

A large number of mammal species are found in the area, including several globally threatened. Some of the last discovered large mammal species in the world occur in the area. These include CR saola (*Pseudoryx nghetinhensis*), EN large-antlered muntjac (*Muntiacus vuquangensis*), DD Annamite muntjac (*M. truongsonensis*), and DD Annamite striped rabbit (*Nesolagus timminsi*) (see section 3.2. above). Six species of wild cats have been confirmed in the area: LC leopard cat *Prionailurus bengalensis*, NT Asian golden cat *Catopuma temminckii*, VU marbled cat *Pardofelis marmorata*, VU clouded leopard *P. nebulosa*, EN tiger *Panthera tigris* and NT leopard *Panthera pardus*. That tigers still remain in NNT NPA remain uncertain; they were confirmed in the 1990s from camera traps (Robichaud and Stuart, 1999), sightings (Duckworth, 1998) and hunted remains (Duckworth et al., 1999), but no clear evidence of tigers have been found ever since – tracks, possibly belonging to the species were last seen in 2007 (WMPA, pers. comm.). The population has likely been extirpated by the unsustainable hunting of the species. Large cable snares (targeted at tigers) were regularly encountered in the NPA in the 1990s but only small wire snares are nowadays used by poachers. Similarly, tigers have never been recorded from camera-traps since the technique has been used (2006) in several survey blocks (c.f. CHAPTER 6). This may therefore indicate the possible local extinction of tigers in NNT NPA.

With nine species of primates, the area is one of the most important for primate conservation in the country: VU pygmy slow loris (*Nycticebus pymeaus*), VU Bengal slow loris (*N. bengalensis*), LC rhesus macaque (*Macaca mulatta*), NT Assamese macaque (*M. assamensis*), VU pig-tailed macaque (*M. leonina*), VU stump-tailed macaque (or bear macaque) (*M. arctoides*), EN red-shanked douc (*Pygathrix nemaeus*), EN southern white cheeked gibbon (*Nomascus siki*), and EN Hatinh langur (*Trachypithecus [francoisi] hantinhensis*). Probably the country's largest population of Asian elephants (*Elephas maximus*) remains in the NPA's plateau (eastern part of the NPA) with an estimated ~150 individuals from the last survey in 2006 (Hedges et al., 2013; Ahlering et al., 2011).

Box 1.1 – International Union for Conservation of Nature (IUCN) Red List of Threatened Species Categories and Criteria (IUCN, 2012b)

There are nine Categories in the IUCN Red List of Threatened Species, independant of the level of conservation action in place for the taxon assessed:

Evaluated	Data	Category	Detail (IUCN, 2012b)	
YES	YES	EXTINCT (EX)	No reasonable doubt that the last individual has died	
		EXTINCT in the Wild (EW)	Known only to survive in cultivation, in captivity or as a naturalized population (or populations) well outside the past range	
		CRITICALLY ENDANGERED (CR)	Facing extremely high risk of extinction in the wild	Threatened categories assessed with CRITERIA A to E c.f. below
		ENDANGERED (EN)	Facing a very high risk of extinction in the wild	
		VULNERABLE (VU)	Facing a high risk of extinction in the wild	
		NEAR THREATENED (NT)	Close to qualifying for or is likely to qualify for a threatened category in the near future	
		LEAST CONCERN (LC)	Widespread and abundant taxa are included in this category	
	NO	DATA DEFICIENT	Indirect, assessment of its risk of extinction based on its distribution and/or population status	
NO	-	NOT EVALUATED	Not yet been evaluated against the criteria	

The three threatened categories (CR, EN, VU) are assessed based on a list of Criteria. There are four levels of criteria ([A, B, C, D, E]; [1, 2, 3, etc]; [a, b, c, etc]; [i, ii, iii, etc]). The five major criteria (A, B, C, D, E) are as follow:

CRITERIA A. Reduction in population size (past and/or future)
CRITERIA B. Geographic range (Extant of Occurrence and Area of Occupancy)
CRITERIA C. Current population range and decline
CRITERIA D. Very small or restricted population size
CRITERIA E. Probability of extinction in the wild (based on Quantitative Analysis of data)

4.3. Local Communities and Livelihoods

There are 31 villages within the NPA and several surrounding the NPA's boundaries. A variety of ethnic groups inhabit these villages and are distinguished according to their linguistics. Four ethno-linguistic groups can be distinguished: **(1)** the Vietic, which are further divided into four subgroups according to their livelihood system (Vietic I-IV); **(2)** the Brou, which are the most common and widespread within the NPA and share the same language (brou/bru); **(3)** The Tai–Kadai and Sek which are found mostly on the plateau, western edge of the NPA; **(4)** the Hmong, found in the northern part outside the boundary of the NPA, in Khamkeut district (IUCN, 1998; NT2-WMPA, 2005). The total population of the 31 enclave villages is estimated at ~6000 persons (NT2-WMPA, 2005).

Most groups have their own distinctive ethnic language; although some groups speak a language very similar to the common Lao language. However, most people from an ethno-linguistic group will be at least bilingual and speak the common national Lao language in addition to the ethnic language since school is taught in Lao language.

These ethnic groups practice a combination of different livelihood systems. There are four livelihood systems practiced in the NPA: **(1)** Swidden agriculture combined with important reliance on non-timber forest products (NTFPs) for food and cash income (5% of NPA population); **(2)** mainly swidden agriculture combined with livestock and NTFPs for food and cash income (50%); **(3)** swidden agriculture combined with paddy cultivation and with reliance on livestock and NTFPs (35%); **(4)** mainly paddy cultivation with crops, livestock and trade for cash income (10%).

4.4. Nam Theun 2 hydropower electric dam

In 1993, planning for the country's largest hydropower electric dam – the Nam Theun 2 – along the Nam Theun started with extensive field work on site conducted by a team from the International Union for Conservation of Nature (IUCN) Lao program and the Wildlife Conservation Society (WCS) Lao program to develop an environmental and social action plan for the watershed and corridor areas (IUCN, 1998). The project received funding from several institutions with the major investors including the World Bank and the Asian Development Bank. The shareholders comprising the developers (75% share) and the government of Laos (25% share), form the Nam Theun Power Company (NTPC). In 2005, construction of the dam started and after completion in 2010, began export of electric power. The dam resulted in a flooded area of 450 km^2 (the reservoir) along the eastern border of the NPA (Figure 1.4). The project's social and environmental impacts have, since 1997, been assessed by the International Panel of Experts, which has for responsibility 'to provide independent review of and guidance on the treatment of environmental and social issues associated with a project under preparation' (POE, 1997: 4). The Panel has been visiting the site every year and producing reports submitted to the Lao Government and The World Bank. The Panel has so far produced 20 reports (available online <http://www.namtheun2.com/reports/panel-of-expert-report.html>), where they highlight the major social and environmental issues encountered over their visit and provide recommendations.

4.5. Protection and management

The project planning and implementation includes the "[m]anagement of the project's environmental and social impacts on the Nakai plateau, in the NT2 watershed, and in the downstream areas of the Nam Theun and Xe Bang Fai rivers" (Porter et al., 2011; p. 5).

In 2000, zonation of the NPA was declared through the Prime Minister Decree No. 193/PM (PM, 2000) and described boundaries for (1) the NNT NPA, (2) the Nakai Plateau and (3) two corridor areas: Phou Hinpoun-NNT and Him Namno-

NNT corridor. These three areas together form the Nam Theun 2 Watershed and are included in the management planning (PM, 2000).

In 2001, the Nam Theun 2 Watershed Management and Protection Authority (NT2 WMPA), a management authority specifically dedicated to meet the project's environmental and social requirements, was established under Prime Minister's Decree No. 25/PM (PM, 2001) and subsequently amended by the Prime Minister's Decree No. 39/PM in 2005 (PM, 2005) and the Prime Minister's Decree No. 471/PM in 2010 (PM, 2010). The role of this agency is to "manage, develop and protect Nakai-Nam Theun National Protected Area and Nam Theun 2 Watershed Area in cooperation and coordination with local administrations and divisions or department." (PM, 2010; p. 4-5). To meet its responsibilities, the authority prepares management plans and develops regulations that are communicated to the inhabitants of the watershed and enforced. It is receiving funding (US$ 1 million/year) directly from the NTPC for a period of 25 years from the beginning of commercial exportation of electric power (2010).

Large scale *Environmental and Social Impact Assessments* as well as *Management Plans* were prepared in accordance with the World Bank's Environmental and Social Safeguard Policies that aim at mitigating negative impacts of large infrastructures to people and the environment (Serra et al., 2011). These included the Environmental Assessment and Management Plan (EAMP) (NTPC, 2005) and the Social and Environment Management Framework and First Operational Plan (SEMFOP) (NT2 WMPA, 2005) for the Nam Theun watershed. The latter document, developed by NT2 WMPA, has for objective to 'effectively protect the watershed, and its forests, habitats, wildlife and biodiversity values, and at the same time, safeguard the well-being, traditional livelihoods and culture of its human inhabitants' (NT2 WMPA, 2005: xi). Using adaptive management, an updated version (SEMFOP II) was prepared in late 2012.

NT2 WMPA is composed of two main divisions actively involved in the implementation of the management plan activities: the law enforcement division and the rural development division. The law enforcement division implements direct conservation activities and is divided into 3 sections:

- The conservation outreach and community awareness (COCA) responsible of educating villagers in and around the NPA about regulations, laws and NPA's zonation (NPA's boundary demarcation, village's 'Controlled Used Zone' and 'Total Protection Zone'; see section 3.4.2.).
- The patrolling and enforcement section responsible for training and managing village patrolling teams. In addition, road and reservoir checkpoints around the NPA are regularly or permanently monitored for in- and out- movement of people.
- The biodiversity research section, responsible for wildlife monitoring. Activities include camera-trapping and transect walks within different sampling blocks of the NPA.

The NT2-WMPA is audited independently every year by the Independent Monitoring Agency, which oversees and report on its budget expenditure and management activities to advise on areas in need of improvement (PM, 2010).

A current complete re-organisation of WMPA is being planned to re-direct funds and improve management (NT2-WMPA, 2012; Saola Working Group, 2013) and should be implemented in 2013.

The two major issues currently faced by NPA are the combination of:

- Unsustainable use of forest products through illegal hunting mainly driven by trade and practised by Lao and primarily by Vietnamese crossing the international border.
- Inadequate management strategy due to lack of human resources.

Fauna & Flora International has been conducting a 2011-2013 project in collaboration with the Vietnamese Government and the Lao Government that aim to improve management efforts and law enforcement at the International border along Nakai-Nam Theun NPA to mitigate wildlife trade (FFI, 2010).

CHAPTER 2

GENERAL METHODS

1. Field work

From January 2011 to April 2012, ten different sites within NNT NPA were visited (Figure 2.1; Table 2.1). The ten areas were semi-randomly selected on the basis of (1) wide cover of the NPA including different habitat types and (2) accessibility. From April to May 2011, due to difficult access and data collection during rainy season in the area, I was involved in another project in Dong Phou Vieng NPA, central Laos through Veterinarians Without Borders-Canada; details of this project are not presented here as I did not use these data for this thesis. The two reports that resulted from the project are however presented in APPENDIX I.

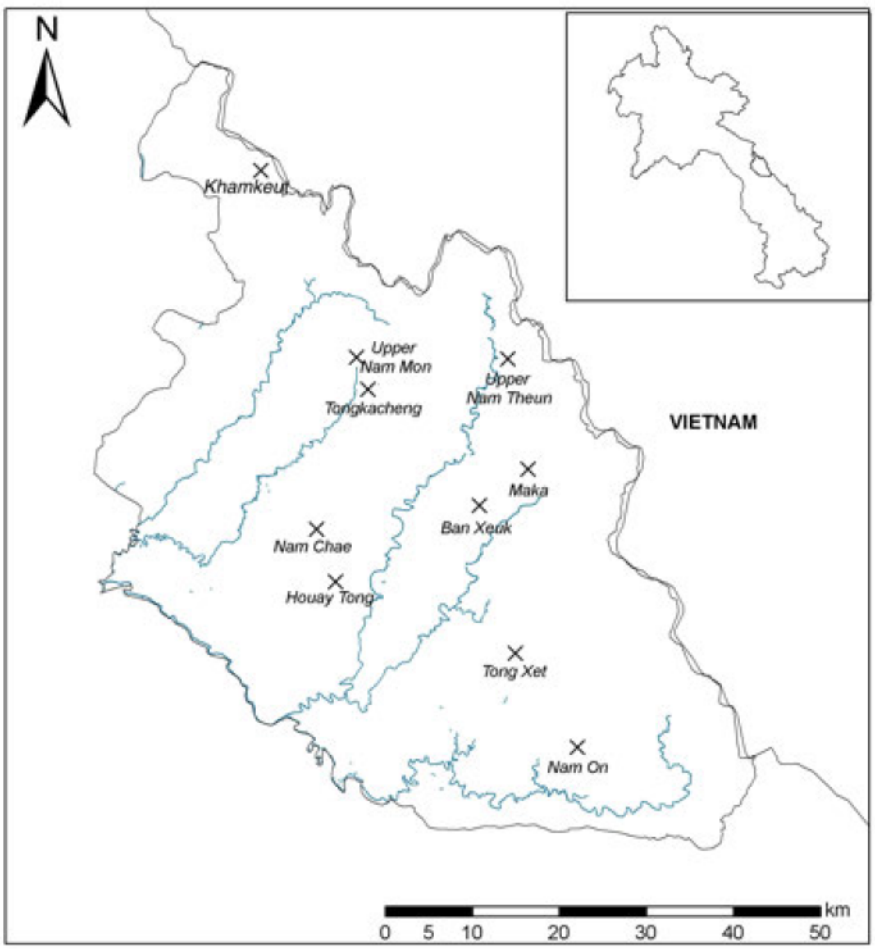


Figure 2.1: Research sites visited over the 10-month study period in Nakai-Nam Theun National Protected Area, Laos

Table 2.1: Date of field work (including travel time to and from field site) for each of the 10 areas visited within NNT NPA in 2011-2012

study sites	dates
Nam Chae	29 Jan – 2 Feb 2011
Ban Xeuk	17 Feb – 6 Mar 2011
Maka	13 Mar – 31 Mar 2011
Thong Xet	18 Jul – 3 Aug 2011
Khamkeut	16 Sept – 28 Sept 2011
Nam One	19 Oct – 4 Nov 2011
Nam Theun	11 Jan – 23 Jan 2012
Houay Tong	10 Feb – 27 Feb 2012
Tongkacheng	12 Mar – 24 Mar 2012
Nam Mon	25 Mar – 5 Apr 2012

For each field trip, travel to first campsite was between 2-4 days, involving boat, motorbike, foot walk and/or tractor rides. A night was always spent at the closest village of the field site in order to meet with the village chief, and inform him about the activities planned. He was in charge of selecting three villagers who would join the fieldwork, and other porters if necessary to get to the first camp (Figure 2.2). (Three villagers was the minimum number of people to be hired, as villagers rarely agree to stay at camp on their own; therefore, usually one villager joined the activities while the two others stayed and maintained the camp during the day).

Figure 2.2: Typical arrangement of my hammock and tarp at a campsite

1.1. Transect surveys

In each area, four to 20 transects were randomly pre- selected on a 1:50,000 topographic map and generally placed along and perpendicular on both sides of a main watercourse (Figure 2.3). All transects were 500 m apart and measured from 0.84 to 2.36 km (true length measured in GIS ArcView 9.3 from actual start- to end- GPS transect points). Some transects were walked up to 3 times; including all repeats, a total of 310 km of transect were walked over the study period (Table 2.2). The dissimilarity in number of transects, transect length and repeats is due to time constraints, logistics, and unpredictable circumstances that forced early interruption of the survey. Two transects were walked per day as illustrated in Figure 2.3. For each pair, the same one was always walked first and the other, second. No significant difference was found in number of primate sightings between transects walked in the morning vs. transects walked in the afternoon (Mann-Whitney U test U=3537.0, p=0.420), suggesting

that the team did not influence primate groups by displacement during the first transect walk. Time start of the first transect occurred from 6h35 to 9h38 am, with an average start at 7h43 am. Time start of the second transects occurred from 9h30 to 14h15, with an average start at 11h29 am.

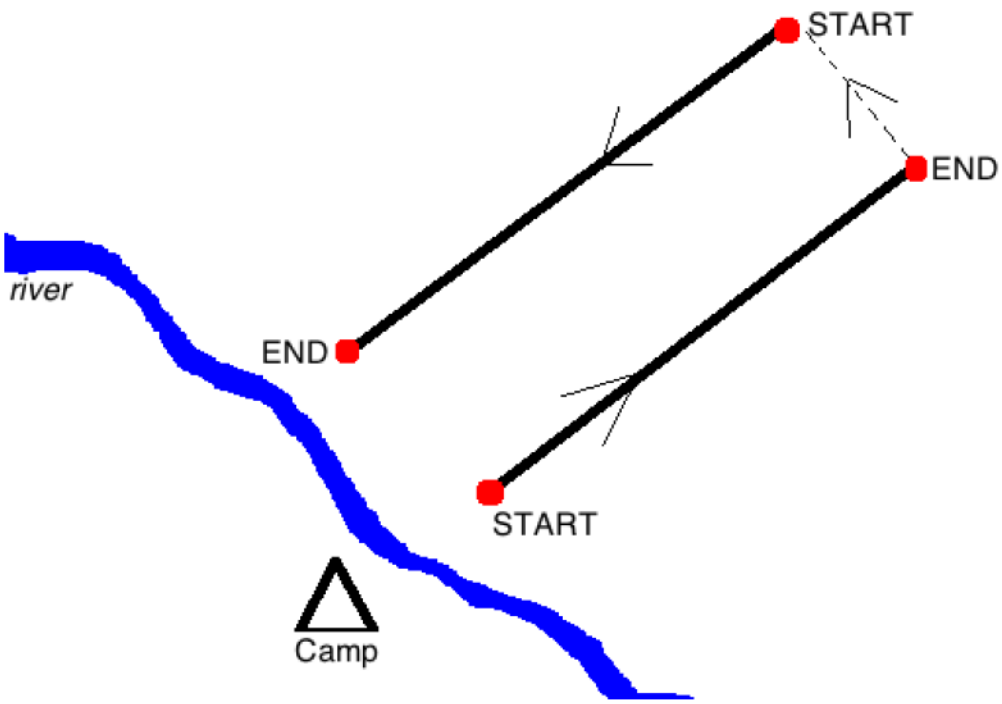


Figure 2.3: representation of daily 2-transect walk. No significant difference was found in number of primate sightings between transects walked in the morning vs. transects walked in the afternoon (Mann-Whitney U test U=3537.0, p=0.420),

Table 2.2: The ten sites surveyed from Jan 2011 to April 2012 in Nakai-Nam Theun NPA with detailed survey effort (number of transects and kms walked) (c.f. Figure 4.1).

Sites Date of field work		**estimated site size (km^2)***	**transects**	**number of repeats**	**transect length (km)**	**sub-total (km)**	**total survey effort (km)**
1	**Nam Chae**	19.82	1	1	1.07	1.07	**21.47**
	29 Jan – 2 Feb 2011		2	1	1.05	1.05	
			3	1	0.87	0.87	
			4	1	0.84	0.84	
			5	1	0.95	0.95	
			6	1	0.96	0.96	
			7	1	0.98	0.98	
			8	1	0.88	0.88	
			9	1	0.89	0.89	
			10	1	0.83	0.83	
			11	1	0.96	0.96	
			12	1	0.96	0.96	
			13	1	1.47	1.47	
			14	1	1.76	1.76	
			15	1	1.18	1.18	
			16	1	1.17	1.17	
			17	1	1.44	1.44	
			18	1	1.05	1.05	
			19	1	1.16	1.16	
			20	1	1	1	
2	**Ban Xeuk**	4.21	1	3	2.36	7.08	**36.16**
	17 Feb – 6 Mar 2011		2	3	1.8	5.4	
			3	1	1.78	1.78	
			4	3	1.55	4.65	
			5	3	1.96	5.88	
			6	3	1.91	5.73	
			7	3	1.88	5.64	
3	**Maka**	6.05	1	3	1.67	5.01	**40.29**
	13 Mar – 31 Mar 2011		2	3	2.04	6.12	
			3	3	1.39	4.17	
			4	3	1.96	5.88	
			5	3	1.67	5.01	
			6	3	2.02	6.06	
			7	3	1.68	5.04	
			8	2	1.5	3	
4	**Tong Xet**	4.97	1	1	1.72	1.72	**10.55**
	18 Jul – 3 Aug 2011		2	1	1.22	1.22	
			3	1	1.95	1.95	
			4	1	1.7	1.7	
			5	1	1.99	1.99	
			6	1	1.97	1.97	

5	**Khamkeut**	4.69	1	1	1.78	1.78	**9.8**
	16 Sept – 28 Sept 2011		2	1	1.79	1.79	
			3	1	1.89	1.89	
			4	1	1.65	1.65	
			5	1	1.24	1.24	
			6	1	1.45	1.45	
6	**Nam On**	6.57	1	3	1.75	5.25	**42.45**
	19 Oct – 4 Nov 2011		2	3	1.73	5.19	
			3	3	1.77	5.31	
			4	3	1.87	5.61	
			5	3	1.77	5.31	
			6	3	1.76	5.28	
			7	3	1.72	5.16	
			8	3	1.78	5.34	
7	**Nam Theun**	1.96	1	3	1.89	5.67	**22.08**
	11 Jan – 23 Jan 2012		2	3	1.86	5.58	
			3	3	1.76	5.28	
			4	3	1.85	5.55	
8	**Houay Tong**	9.71	1	3	1.95	5.85	**58.02**
	10 Feb – 27 Feb 2012		2	3	1.95	5.85	
			3	3	1.92	5.76	
			4	3	1.78	5.34	
			5	3	1.89	5.67	
			6	3	2.04	6.12	
			7	3	1.96	5.88	
			8	3	1.89	5.67	
			9	3	2	6	
			10	3	1.96	5.88	
9	**Tongkacheng**	4.54	1	3	1.93	5.79	**34.38**
	12 Mar – 24 Mar 2012		2	3	1.95	5.85	
			3	3	1.78	5.34	
			4	3	1.79	5.37	
			5	3	2.02	6.06	
			6	3	1.99	5.97	
10	**Nam Mon**	4.99	1	3	1.85	5.55	**35.01**
	25 Mar – 5 Apr 2012		2	3	1.98	5.94	
			3	3	1.84	5.52	
			4	3	1.92	5.76	
			5	3	2.06	6.18	
			6	3	2.02	6.06	
TOTAL		67.51	81	176			**310.21**

* estimated size of study site is obtained via drawing a Maximum Convex Polygon around all transects at each site (in ArcGIS 9.3)

** total survey effort includes replications

The variability of survey effort between sites and transects was due to several unexpected circumstances during field work or methods adjustment. My original survey method for each site was to walk 20 transects one-km of length (c.f. Nam Chae site); this was later adjusted given the disturbance engendered by the transect-cut when walked for the first time. The method was then adjusted as to include ten transects, each walked three times. When two research sites were visited over a single field trip (due to its remoteness and long-travel distance, e.g. Tongkhacheng and Nam Mon sites; Ban Xeuk and Maka sites), the number of transects at each site was reduced to six (given that food for the entire field trip needed to be carried). In some instances, the food brought ran out which forced the team to stop field-work before the totality of the planned transects could be walked (e.g. Nam On site). Poor weather conditions involving strong daily rain also forced us to end field-work earlier (e.g. Khamkeut site; Tong Xet site). In upper Nam Theun site, a team from WMPA was sent to find us to tell my assistant he had to immediately go back to Nakai in order to pass an exam to become a government staff.

Each transect had to be cut using machete. Only minimal cutting was carried out and only bush marking was used in order to repeat the transect on the exact same path. The disturbance from transect cutting likely resulted in a decrease of primate sightings. There was a significant difference in the number of primate sightings between the three repeats (Friedman test χ^2=95.73, $p<0.01$) (Figure 2.4).

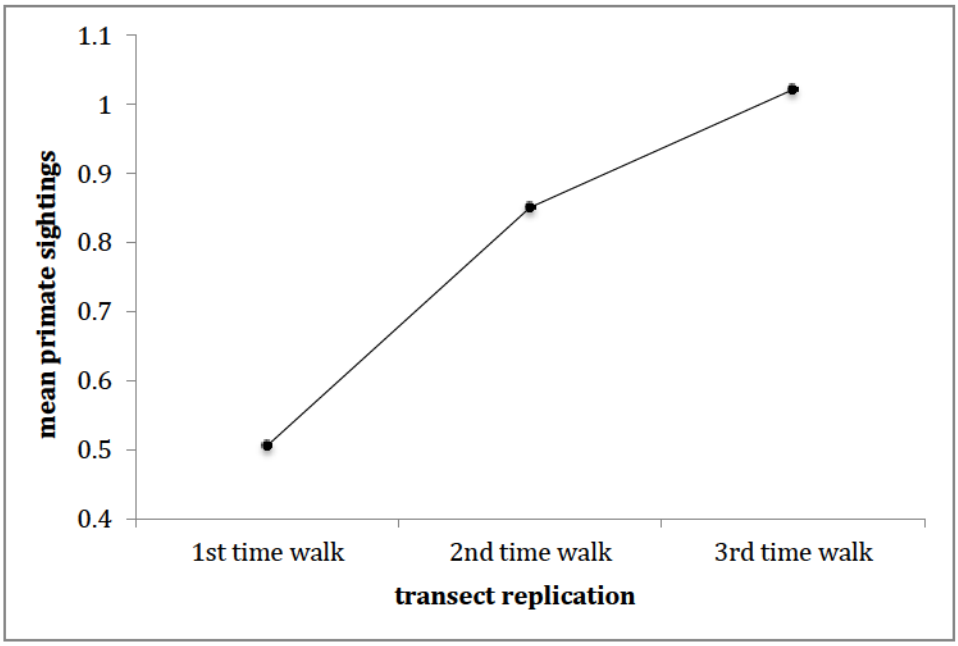


Figure 2.4: Mean primate sightings for each of the three transect replications

Transect surveys were conducted with a team of two to four people. Each transect was always walked by myself and my assistant, Mr. Chanthalaphone Nanthavong, WMPA-staff. One guide (villager from closest village) usually joined the walk. The team of four (with two guides) only occurred (but not in all survey sites) for the first walk when transects were repeated, to allow the two guides to swap cutting labour when forest was dense. Walking speed was kept as much as possible at ~1km/hour; difficulty of the terrain meant that speed was slower for some transects The first time a transect was walked also reduced speed due to time spent cutting the transect: indeed, there was an overall significant difference in walking time (controlled for transect length using the ratio walking-time/transect-length) between the three transect replications (ANOVA for repeated measures F=39.87, $p<0.01$), with the first time-walk significantly longer than the second (F=47.81, $p<0.01$). Walking time between the second and third replications was not significant (F=1.91, $p=0.173$) (Figure 2.5).

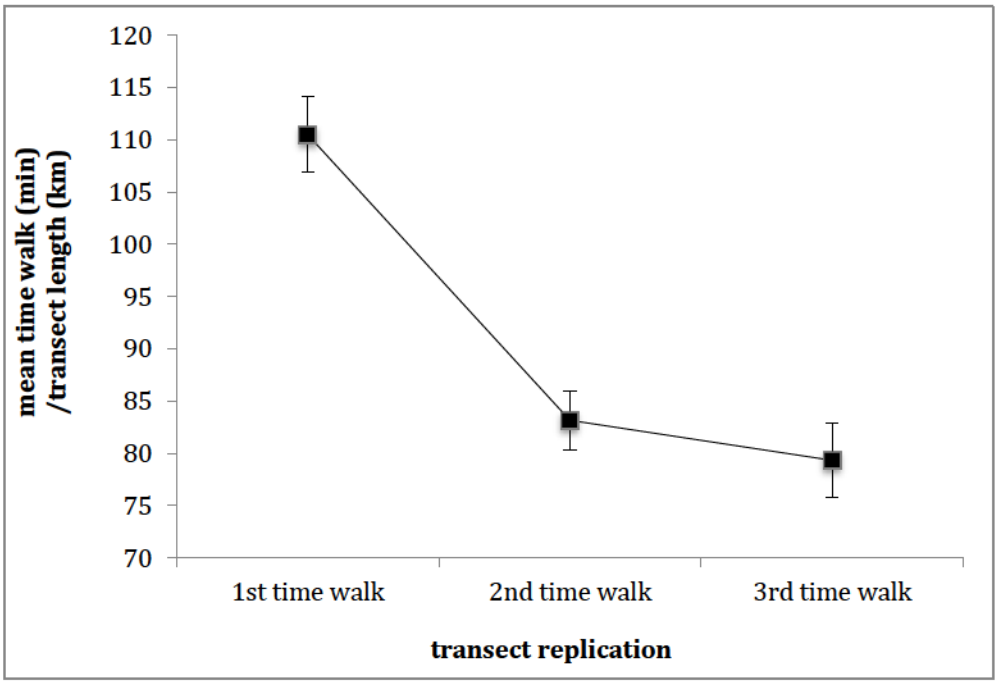


Figure 2.5: Mean and standard error of the ratio transect-walking-time (min)/transect-length (km) between the three repeated walks of all transects (N=81).

Diurnal primates, hornbills and black giant squirrels were the focus species of the study. Data collected at each detection included: date; species ID (at species, genus or group [e.g. large vs. small hornbill] level); time; transect number; repeat number; GPS point; cue (e.g. heard or sighted); animal-to-observer distance; animal-to-transect angle; group size estimate; weather; habitat; elevation; activity/remarks (systematic activity of primate included their response to humans; e.g. flee; hide; alarm call; move in canopy). Only data collected on primates is analysed in this thesis.

Animal-to-observer distance and animal-to-transect angle were later used to calculate the perpendicular distance from the animal to the transect using the formula **c = a * sin(b)** where c is the perpendicular distance Animal-to-Transect; a is the Animal-to-Observer distance and b is the Animal-to-Transect angle (Figure 2.6). When Animals were in groups (e.g. primates), distance was measured to the approximate centre of the group. Distances were measured using a range finder, and angle was measured with a compass-clinometer. When animals where heard, perpendicular distance to transect was estimated.

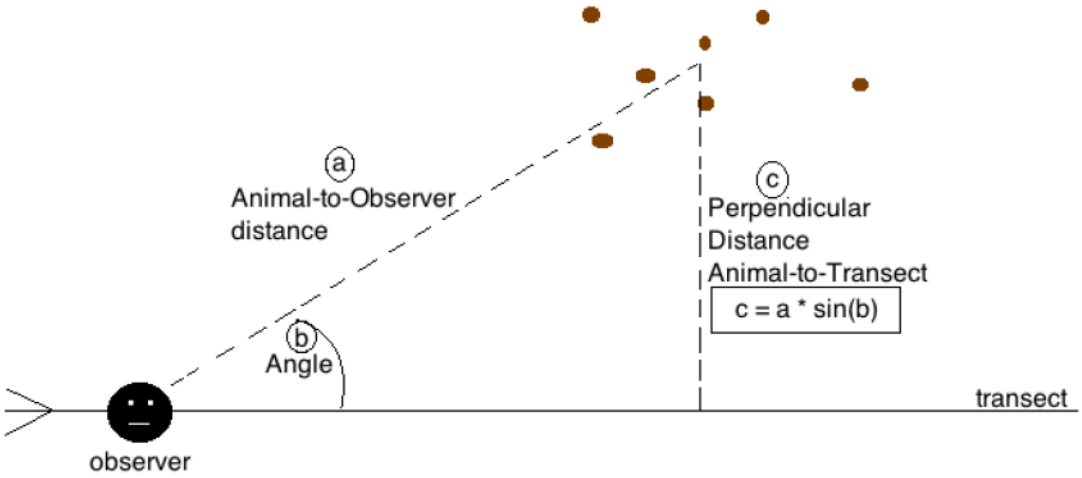


Figure 2.6: representation of transect walk methodology to record distance and angle data

I had an overall total of 128 primate sightings (of groups or solitary individuals): 64 doucs, 52 macaques and 12 gibbons along the transects. The total number of sightings and total transect length walked (survey effort) significantly differed between the ten research sites (Kruskal Wallis test H=27.47, p<0.01 for sightings; H=92.17, p<0.01 for survey effort) (Figure 2.7). There was however no significant difference in number of primate sightings between low (0.0 – 1.5 km), medium (>1.5 – 1.8 km) and high (>1.8 km) transect lengths (using the median primate sights of transects replications; Kruskal Wallis test H=3.37, p=0.186).

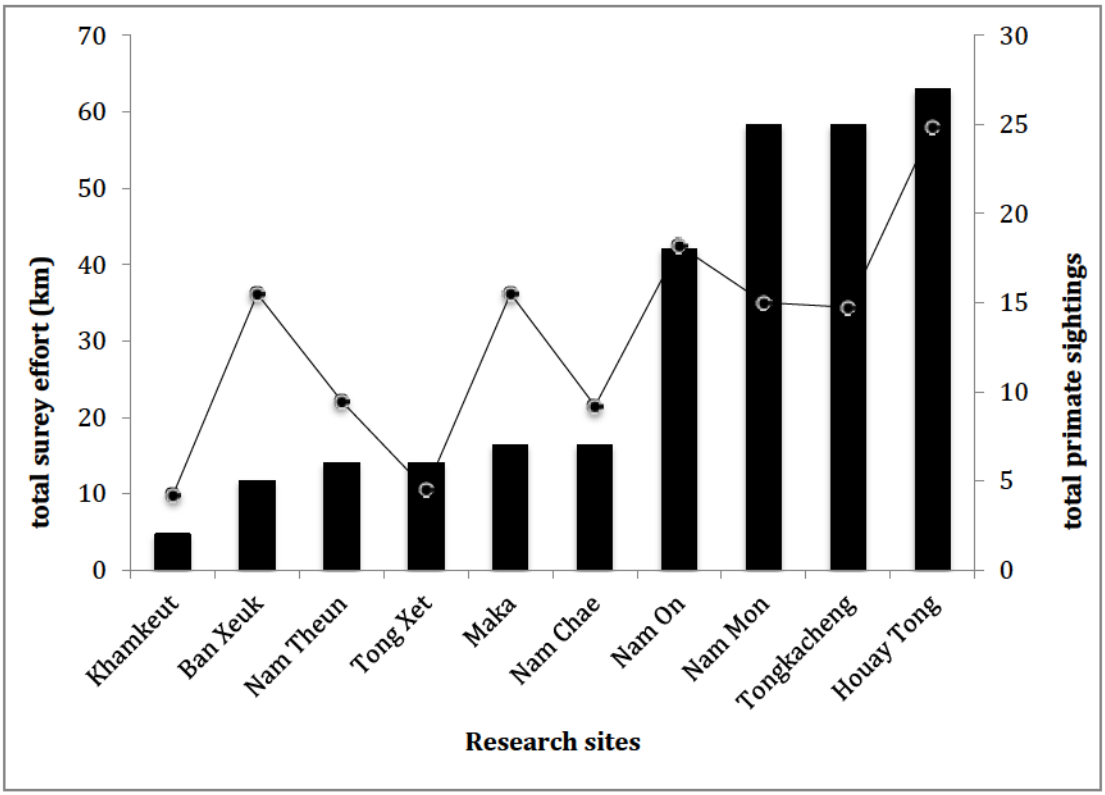


Figure 2.7: Total survey effort (⊙) and total primate sightings (bars) for each of the ten study sites visited (ordered by ascending primate sightings) which show sightings increased with survey effort.

There was a significant difference in number of primate sightings (median of transect replications) between a low (74 – 83 %) medium (>83 – 91 %) and high (>91 %) values of the maximum daily humidity (recorded everyday with a thermohygrometer) (Kruskal Wallis test H=11.07, p<0.01). *Post Hoc* tests showed the difference was significant between the low and medium classes (Mann-Whitney U test U=101.5, p<0.01) but not between medium and high classes (U=222.5, p=0.568).

1.2. Threats record

Given that all transects were included within total protection zones of the NPA (where any human activity is prohibited c.f. *3.4.2.* and *3.4.3.*), any anthropogenic activities was considered as illegal and as threat to wildlife. I recorded any instance of threat at anytime during the field period. These were categorised as (1) logging, (2) gunshots, (3) snares, (4) poacher camps, (5)

poachers (number and nationality), (6) other (e.g. animal remain not in snare, fishing poison). For snares and camps, I recorded their status (active or inactive). Wire snares encountered (at hunter camps or already set) were collected or otherwise destroyed and counted (collection of snares was sometimes not possible for logistic reasons). All animal species (remains or live) encountered at hunter camps and/or in snares were recorded.

1.3. Vegetation sampling

Vegetation data were collected using the plot-less sampling method (Ganzhorn, 2003) (Figure 2.8). Along each transect, up to four points (200 to 400 metres apart) were randomly selected (due to difficult terrain and time constraint, fewer points were sometimes sampled on some transects). At each point, four quadrants were created following the North-East East-West orientation. Within each quadrant, I collected the following data: (1) distance to the closest tree with a circumference at breast height (CBH) > 30 cm, using a tape measure; (2) CBH of the tree; (3) bole height of the tree (ground to first branch); (4) crown of the tree; (5) phenology status of the tree (see below); (6) local common name of the tree; (7) a photograph of the canopy to later estimate canopy cover.

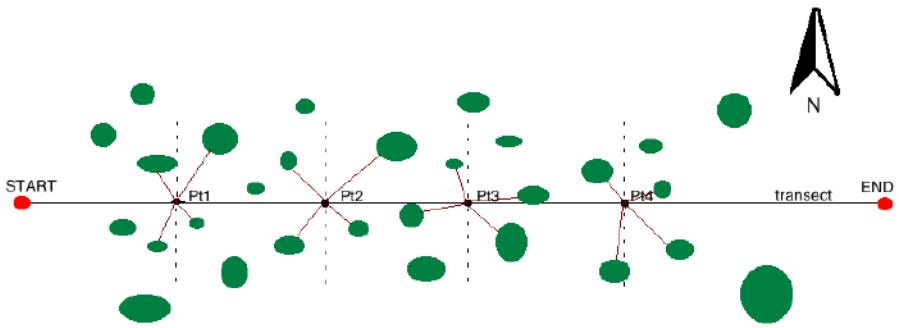


Figure 2.8: representation of plot-less vegetation sampling methodology along a transect, with distance to closest tree in each of the four quadrant at each point sampling.

The phenology status was scored for: mature leaves, young leaves, flowers, and fruits in the tree. I used a three-point-scale (Table 2.3; White and Edwards, 2000).

Table 2.3: scoring scale used to record phenology status of trees (modified after White and Edwards, 2000)

Score	0	1	2
Mature leaves	none to very few	up to 75%	>75%
Young leaves	none	few or limited to 1-2 branches	numerous over most canopy
Flowers	none	few or limited to 1-2 branches	abundant over most canopy
Fruits in tree	none	few	abundant over most canopy

The canopy cover was estimated using the photographs taken in each of the quadrants. Each photograph was scored for the amount of light within them using a four-point-scale: 0 = no light; 1= up to 25%; 2= 25% to 50%; 3= 50% to 75%; 4= 75% to 100%. Descriptive vegetation characteristics of each of the 10 visited sites are presented in APPENDIX II. Additional information on vegetation characteristics of NNT NPA can be found in the Environmental and Social Impact Assessment (Jarvie, 1997; NTPC, 2005).

1.4. Villagers interviews

Full approval was granted from Oxford Brookes University's Ethics Committee to conduct interviews (APPENDIX III). A set of questions was prepared for semi-structured interview with the villagers participating in the fieldwork. The interview generally took place in the evening at the campsite. Mr. Chanthalaphone Nanthavong translated the interview. When respondents seemed reluctant to answer some questions, the question was either reformulated or passed. Further questions were sometimes added depending on the answers received to each question.

The pre set questions used to lead the interviews were as follow:

- What primate species occur in the area? (without showing any pictures to avoid leading)

- How often/for how long/how far do you go into the forest?
- What age do you start going in the forest?
- What do you collect from the forest?
- Do you feel that animal populations have decreased?
    - Why?
- What does 'National Protected Area' means to you?
- How has it changed the way you live life here?
- What does WMPA do in the area?
- In your life, have you seen any changes in the rules?
    - For example?
- Do you feel animals and trees are threatened in the area?
- What do you feel should be done to protect animals and trees?
- How do you think villagers can be more involved in conservation?
- What is stopping people from doing it?
- Do you often see outsiders in forest and/or village?
    - How often?
    - What are they doing?
- Do you buy goods from them?

1.5. Education project

I received funding from *Care for the Wild International* for publication of a children's storybook *'Save Douky, the red-shanked douc'* (APPENDIX IV) that I created in 2009. The story pictures a baby red-shanked douc being captured for pet trade with his mother. Text was translated to Lao by Santi Saypanya from the Wildlife Conservation Society-Lao Program (WCS-Lao Program). Nine hundred copies were printed for distribution in Laos.

The main objective of this children's story book were (1) to raise awareness of primate conservation issues, in particular primate pet trade, among children living in Laos, (2) to introduce children to the primate species of Laos, (3) to reach a large audience of children throughout the country.

The book was disseminated in Laos via on-going projects of non-governmental and governmental organisations, schools and through my own project in NNT NPA, where 20 copies were given to local schools in each village visited. A final report that presents the use and dissemination of the book was prepared for *Care for the Wild International* (APPENDIX V).

1.6. National dissemination of preliminary results

Following each field trip, a report was written and sent to WMPA. At the completion of the field work, all the reports written were combined and edited into one single document which was distributed to WMPA, International wildlife conservation NGOs working in Laos, as well as to the Biology Department of the National University of Laos. A final presentation was given at WMPA, and my recommendations (c.f. CHAPTER 10) were taken into account for the current development of a new law enforcement strategy planning (NT2-WMPA, 2012; Saola Working Group, 2013).

CHAPTER 3

ENVIRONMENTAL NICHE MODELLING OF NON-HUMAN PRIMATE SPECIES IN LAO, PDR: TOWARDS AN ASSESSMENT OF THEIR NATIONAL STATUS AND DISTRIBUTION

Introduction

Even today due to complex socio-political reasons, the diversity and distribution of mammals within many countries along the equatorial belt remain almost unknown. In the past five decades, political unrest has primarily taken place in countries of biodiversity hotspots (Hanson et al., 2008; McNeely, 2003). Armed conflicts, although not systematically (Gorsevski et al., 2012; McNeely, 2002), may often result in biodiversity loss (Stevens et al., 2011; McNeely, 2002), as well as constrain the existence of a natural resource management governance (e.g. Prasad Oli, 2006). Vast areas have remained unexplored and species inhabiting these areas are still poorly known and often classified as Data Deficient (IUCN, 2012). In countries such as Myanmar, Democratic Republic of Congo or Tanzania, where recent faunistic surveys have been few and patchy, new primate species have been discovered and described even in the past few years (Geissman et al., 2010; Hart et al., 2012; Jones et al., 2005). Lao People's Democratic Republic (Laos hereafter) is another such country that hitherto has remained little studied for decades of political instability (Stuart-Fox, 1997). Intensive wildlife surveys only started in the 1990s (Duckworth et al., 1999), resulting in the discovery of many mammal species not previously found in the country, including some new to science (Duckworth et al., 1994; Evans and Timmins, 1995; Schaller and Rabinowitz, 1995; Surridge et al., 1999; Timmins et al., 1998; Jenkins et al. 2005). Even today, some regions remain unvisited. Ecological modelling for such countries provides a basis around which vital biodiversity surveys can be structured and populations' status assessed.

Laos is currently undergoing rapid economic development notably through large mining, hydropower and commercial agriculture projects (Singh, 2008). Coupled with one of the highest human population growth rates in Southeast Asia (2.1%; Lao Statistics Bureau, 2011) and a strong reliance on natural resources for local consumption (Krahn and Johnson, 2007) and illegal trade (Nooren and Claridge, 2001), the country is facing a biodiversity crisis, mirroring loss across Southeast Asia (Sodhi et al., 2004). Despite an existing network of forest areas under legal protection status (*conservation* or *protection* forests) at

the national, provincial or district level (Robichaud et al., 2001), covering some 43% of the total land (calculated using ArcGIS), biodiversity conservation has been challenging and/or failing in many of these, despite decades of experimentation with different approaches. Conservation prioritization is therefore the best approach in the country for the many species in need of intervention (Coudrat et al., 2012).

Laos may hold 20 non-human primate species (*primates*, hereafter), depending on the taxonomy used (c.f. Table 3.7). The majority (15) of them are listed as globally threatened in the IUCN Red List (IUCN, 2012) and one is, in a narrow taxonomic definition, endemic to the country (Lao langur *Trachypithecus laotum* sensu stricto; Steinmetz et al., 2011). Primate species-specific research has been limited in Laos (e.g. Phiapalath, 2009; Phiapalath et al., 2011) with no current studies. It is not until the 1990s that country-wide wildlife surveys were conducted, from which most knowledge of Lao primates results (e.g. Duckworth et al., 1999). In comprehensive reviews of national distribution and status for several primate species (Boonratana et al., 2011; Coudrat et al., 2012; Duckworth et al., 2010; Duckworth, 2008; Steinmeitz et al. 2011; Timmins et al., 2013a; Timmins et al., 2013b; Timmins and Duckworth, 1999, 2013), large gaps in understanding primate distribution, status, ecology and taxonomy are repeatedly depicted. Villager interviews have often been used in Laos to collect information on species occurrence in un-surveyed areas yet are frequently unreliable (e.g. Coudrat et al., 2012; Duckworth, 2008; Timmins and Duckworth, 2013).

General understanding of primate distribution in Laos is the first step for planning future conservation and research projects in priority areas. Given the scarcity of data available for each species, habitat suitability models are valuable tools to gain information on these little known taxa. The method has been increasingly used in the past two decades to study little known species for which field data are limited and challenging to collect (e.g. Wisz et al., 2008). These models have been applied to wildlife conservation management in many ways and for various species across different continents (e.g. Anderson and

Martinez-Meyer, 2004; Clements et al., 2012; Gray et al., 2007; Ortega-Huerta and Peterson, 2004; Rood et al., 2010; Wilting et al., 2010; Thorn et al., 2009; Vina et al., 2010; Zhang et al., 2012).

I present the first primate distribution models for Laos based on the most recent (1990s to present) and accurate occurrence records, using the program MAXENT (Phillips et al., 2004). The resulting distribution maps will be vital both for primate conservation and for educational outreach. This method would also be applicable in other countries where until now data on target taxa status over large areas are lacking.

Methods

Study Country

Laos (236,800 km^2) is a landlocked country located in the Indochinese peninsula. Habitats vary from lowland dry dipterocarp, semi-evergreen, evergreen to upper montane forests, with large areas of karst and small areas of permanent wetlands. Elevation ranges from 50 to ca. 2800 m a.s.l.. The country has a tropical climate with strongly seasonal rainfall in most of it. There are three levels of legal forest status, each under different management schemes: (i) Conservation Forests (aimed for protection of biodiversity; it is the highest level of protection and corresponds to the National, Provincial and District Protected Areas – NPAs, PPAs, DPAs), (ii) Protection Forests (aimed for protection of watersheds - ProtectFAs), (iii) Production Forests (aimed for sustainable socio-economic development) (Robichaud et al., 2001; National Assembly of Lao, PDR, 2007).

Species Distribution Modelling

I use the maximum entropy general-purpose machine learning method, which has been adapted and specifically developed as a software (MAXENT, v. 3.3.3k) for species distribution modelling (Phillips et al., 2004; Phillips et al., 2006). The method combines biological data of species occurrence with environmental

characteristics to estimate a probability of distribution of maximum entropy (i.e. closest to uniform), subject to the set of constraints provided (Phillips et al., 2006).

Biological Data

Occurrence data for each taxon were retrieved from selected literature and from biologists' personal data (Table 3.1; Appendix 3.1). A highly conservative approach was taken to record inclusion because recent critical national status reviews of several primate species identified significant numbers of errors in reports of those species: *Macaca arctoides; M. assamensis; Pygathrix nemaeus; Trachypithecus francoisi sensu lato; T. phayrei; T. germaini sensu lato; Nomascus leucogenys/N. siki/N. assamensis/N. gabriellae* (Boonratana et al., 2011; Coudrat et al., 2012; Duckworth et al., 2010; Duckworth, 2008; Steinmetz et al., 2011; Timmins et al., 2013a; Timmins et al., 2013b; Timmins and Duckworth, 2013). Thus, only the species subject to such reviews are analysed here, and records post-dating those reviews were taken only from the few sources known to be credible.

Table 3.1: Total number of occurrence localities (retrieved from the literature or biologists data) for each species and number of localities used in the model after autocorrelation correction at 5km^2

Species	Total	localities pruned for autocorrelation (10km^2)	Source
M. assamensis	76	37	Timmins and Duckworth, 2013; Coudrat, 2012a; Phiapalath, 2009
M. arctoides	77	27	Duckworth et al., in prep; Coudrat, 2012a; Phiapalath, 2009
T. francoisi (s.l.)	35	19	Duckworth et al., 2010; Steinmetz et al., 2011
T. phayrei	14	14	Timmins et al., 2013a
T. germaini (s.l.)	16	11	Timmins et al., 2013b; Coudrat, 2011
P. nemaeus	138	51	Timmins and Duckworth, 1999; Coudrat et al., 2012; Phiapalath, 2009
H. lar	11	9	Boonratana et al., 2012
H. pileatus	14	10	Round, 1998
N. concolor	10	6	Duckworth, 2008; Geissmann, 2007; Johnson et al., 2005
N. leucogenys/siki/ annamensis/gabriellae	37	26	Duckworth, 2008; Coudrat, 2012a; Ruppel, pers. Data

For all species, recent confirmed records (~ 1990-today) representing exact (i.e. degree, minute, second) or approximate (i.e. degree, minute) geographic co-ordinates of sightings or of forest camps around which species were heard or seen are included. Records stemming from village reports, of live or dead animals in human possession that were not at the site of capture, and of field sightings not known to the nearest minute, are excluded. Geographic coordinates of villages around which species are confirmed to occur in the surrounding forests are excluded from the analysis as this would not represent the habitat of the species. The only exception to the two latter rules is for *H. lar*, for which only one exact locality was available. Thus, reliable-sounding village reports are included and locality points were inferred by arbitrarily

placing them (using Google Earth) in the nearest forest to the village where it was reported (Boonratana et al., 2012). This restriction means that the species' predicted distribution should be interpreted even more cautiously than for the others.

All resulting localities were first projected into ArcGIS 9.3. To reduce problematic spatial autocorrelation (i.e. multiple records within one restricted area, likely to result in over-fitting of the model; Dormann et al., 2007; Merckx et al., 2011; Veloz, 2009), occurrence points were pruned by arbitrarily including only one occurrence point per 10 km^2.

Species for which taxonomy remains unclear and field identification is therefore complex are combined (these groups are referred to as 'species' hereafter):

- **(i)** *Nomascus spp*: i.e *N. leucogenys, N. siki* and *N. assamensis/gabriellae*;
- **(ii)** *Trachypithecus francoisi sensu lato*: i.e. *T. (f.) hatinhensis*, *T. (f.) ebenus*, *T. (f.) laotum* and *T. (f.)* spp. (Duckworth et al., 2010);
- **(iii)** *T. germaini sensu lato*: i.e. *T. germaini/T. margarita*(Timmins et al., 2013).

Species for which 1990s–2000s records have not been through a national review were not modelled (*Nycticebus pygmaeus, N. bengalensis, Macaca leonina, M. mulatta* and *M. fascicularis*).

Environmental Data

I selected 25 environmental variables for their relevance for primate ecology (Table 3.2). Nineteen are derived from monthly min/max temperature and precipitation data averaged as annual trends for the period 1950-2000 (Hijmans et al., 2005; http://www.worldclim.org/current). Elevation was retrieved from the CGIAR Consortium for Spatial Information (http://srtm.csi.cgiar.org/). Land cover from 2009 was retrieved from the European Space Agency (http://due.esrin.esa.int/globcover/), which includes 17 categories within Laos.

Vegetation continuous field (i.e. percent forest cover) was obtained from the Global Land Cover Facility (http://glcf.umiacs.umd.edu/data/vcf/). Slope was derived from elevation and distance from water and villages were derived from villages and watercourse features using Euclidean distances in ArcGIS 9.3. The same geographic extent (Laos), cell size (0.008333 dd) and geographic coordinate system (GCS WGS 1984) were selected for each layer.

A biotic variable was added to the final model of *T. phayrei*. The presence of *P. nemaeus* may limit the southern distribution of *T. phayrei* (Timmins et al., 2013a). The potential distribution of *P. nemaeus* obtained from the final model was included into the final model of *T. phayrei*.

Table 3.2: The 25 environmental variables included in the MAXENT analysis to model the habitat suitability in Laos of ten Lao primate species (or species-group)

Environmental variable	Description
1 - Bio01	Annual Mean Temperature
2 - Bio02	Mean Diurnal Range (Mean of monthly (max temp - min temp))
3 - Bio03	Isothermality (Bio02 / Bio07) (*100)
4 - Bio04	Temperature Seasonality (standard deviation *100)
5 - Bio05	Max Temperature of Warmest Month
6 - Bio06	Min Temperature of Coldest Month
7 - Bio07	Temperature Annual Range (Bio05 - Bio06)
8 - Bio08	Mean Temperature of Wettest Quarter
9 - Bio09	Mean Temperature of Driest Quarter
10 - Bio10	Mean Temperature of Warmest Quarter
11 - Bio11	Mean Temperature of Coldest Quarter
12 - Bio12	Annual Precipitation
13 - Bio13	Precipitation of Wettest Month
14 - Bio14	Precipitation of Driest Month
15 - Bio15	Precipitation Seasonality (Coefficient of Variation)
16 - Bio16	Precipitation of Wettest Quarter
17 - Bio17	Precipitation of Driest Quarter
18 - Bio18	Precipitation of Warmest Quarter
19 - Bio19	Precipitation of Coldest Quarter
20 - Elevation	
21 - Slope	Derived from Elevation data in ArcGIS
22 - Distance from water	Derived from river polylines in ArcGIS, using Eucledean Distance tool
23 - Distance from villages	Derived from village points in ArcGIS, using Eucledean Distance tool
24 - Land cover	17 categories within Laos, from 2009
25 - MODIS continuous vegetation field	Percentage forest cover from 2010

Model Building

For each species, a 10-fold cross-validation replication run type was used (Kohavi, 1993) where a sample of data is randomly allocated for the test data at each of the ten replications. All other settings were set as default (Phillips and Dudik, 2008).

I applied a background sample bias into the models: in presence-absence models, random points are drawn from the geographic area considered to represent the range of environmental conditions throughout. This allows MAXENT to model a particular pattern in the distribution of the presence records in relation to environmental variables, referred to as pseudo-absence or background data (Phillips. et al., 2009). Presence records are often biased to a few areas that have received intensive sampling effort, resulting in environmental bias (Phillips. et al., 2009). Weighing this against the environmental variation across the entire geographical range can produce erroneous predictive models. Therefore, rather than using background data from the entire country, a selection of only the areas that have been surveyed (i.e. where occurrence data are available) can be applied as background (Phillips et al., 2009). This technique improves model performance for MAXENT (Phillips et al., 2009). Our bias background consisted of the districts of Laos that included occurrence points of all the species modelled (with value of 1, while un-surveyed areas were attributed 'no data' value).

Model Evaluation

The model's performance was assessed using four methods: **(1)** the area under curve (AUC) of the receiver-operating characteristic (ROC), **(2)** the null-model (Raes and Steege, 2007), **(3)** the Boyce Index, and **(4)** Pearson et al.'s jackknife validation method.

The AUC of ROC is provided in the model outputs. It is obtained by plotting *sensitivity* on the x-axis and 1–*specificity* on the y-axis, with *sensitivity*

representing the proportion of correct prediction of actual presence (true-positive, or absence of omission), whereas 1-*specificity* is the proportion of falsely predicted presence (false-positive, or commission error) for all possible thresholds of the probability (threshold independent evaluation). In presence-only models, the AUC value represents the probability that the model scores a presence site (test locality) higher than a random background site (Phillips et al., 2006). The value ranges from 0.5 to 1−a/2, where a is the fraction of pixels covered by the species' distribution which remains unknown, thus renders inadequate the interpretation of AUC (Phillips et al., 2006; Raes and Steege, 2007; Yost et al., 2008;). Nevertheless, it remains the most commonly used evaluation parameter and is therefore presented here. An AUC value closer to 1 indicates that the model predicts better than random, while a value of 0.5 indicates that the prediction is no better than random (Phillips et al., 2006). Any biases in the data included with respect to the true occurrence patterns of the species are carried through into this assessment: thus, a high AUC does not indicate that the model is necessarily giving a good prediction of the real pattern - merely that it explains all the records it does have, credibly.

Given the recent criticism of using AUC for presence-only model evaluation (Raes and Steege, 2007; Yost et al., 2008), I use some alternatives. I use a null-model (Raes and Steege 2007) that tests a model's AUC value against a null distribution of expected AUC values based on random occurrence data from the geographic area considered (Raes and Steege, 2007). More concretely, it tests if the relations between species occurrence and environmental variables at these locations are stronger than expected by chance. The exact same number of occurrence points available for each species were randomly drawn from the geographic area and replicated 999 times. These null-distributions were run separately in MAXENT with the same settings detailed above. This resulted in 999 AUC values of the null-model for each of the four species. AUCs of the null-models were ranked and the position of the real species' AUC was tested against the 95% confidence interval (C.I.) of the null-model's AUC values. The species' model is considered performing better than expected by chance if its

AUC value is ≥ 95% CI null-model's AUCs (Raes and Steege, 2007; Raes pers. comm., 2012).

The Boyce Index was first proposed by Boyce et al. (2002) to evaluate generalized linear models (GLMs) for resource-selection-function or habitat suitability models (Hirzel et al., 2006). The continuous habitat suitability scores obtained from the outputs (0 to 1) are reclassified into a number *i* of bins (classes). For each class, two frequencies of pixels are calculated: the Predicted Frequency and the Expected Frequency. The Predicted Frequency is the number of occurrence points predicted by the model falling into in the class *i* divided by the total number of occurrence points. The Expected Frequency is the number of grid cells included in class *i*, divided by the total number of grid cells in the whole geographic area considered. A Predicted-to-Expected ratio is then calculated for each class and a Spearman rank correlation coefficient *rho* evaluates if the ratio significantly increases as suitability increases, which would indicate the effective predictive power of the model (Hirzel et al., 2006). To avoid subjectively choosing a number of classes, a Continuous Boyce Index can be used, where it is recalculated within a moving interval of fixed width (e.g. 0.1) along the continuous suitability scores (Hirzel et al., 2006). A model's ability to effectively and consistently predict several levels of suitability is indicated by a significant p-value from the Spearman correlation test. I reclassified the models' outputs into 100 continuous classes of equal interval and calculated for each the P/E ratio (B_{100}). I then combined and reduced the 100 classes into 10 classes (B_{10}), as the Boyce Index is sensitive to large number of classes (Hirzel et al., 2006). Both results are presented.

Finally, I follow the jackknife validation method for samples n<30 described by Pearson et al. (2007), in which it is assessed if the model successfully predicts the n left-out localities (from the *n*-fold cross-validation run) within the area of suitability (under the minimum training presence threshold chosen) (Pearson et al., 2007). Success rate of prediction and a corresponding p-value were computed with the p-value Compute software made available by Pearson et al. (2007).

Outputs Analysis

From the probability habitat suitability maps created by MAXENT, I produce binary maps (i.e. suitable vs. non-suitable habitat) for each taxon. I used the 'minimum training presence logistic' threshold, which has been commonly used and has the advantage to maintain zero omission error and include all areas that are at least as suitable, under the characters used, as those where the species is known to occur (Hernandez et al. 2006; Pearson et al. 2007). The final potential distribution for each species was projected (WGS 1984 UTM Zone 48N) in ArcGIS 9.3. I use the latter software to perform all the spatial analysis described below (unless otherwise indicated). For species that are limited by geographic barriers, their predicted potential distribution was clipped accordingly: *H. lar* and *H. pileatus* potential distributions east of the Mekong river were omitted from the final map presented (only niche analysis is performed on their total predicted potential distribution).

Niche Analysis

I calculated mean values of environmental variables within the predicted potential distribution of each species. Pair-wise range overlap was evaluated in ENMTool (http://enmtools.blogspot.co.uk/; Warren et al., 2008) with Spearman correlation r test, applying a threshold at which habitat is considered suitable. I use the average of all species' 'minimum training presence logistic' threshold (=0.240). Niche similarity was tested pair-wise with the *I* statistic (Warren et al., 2008), which ranges from 0 (no overlap in habitat suitability) to 1 (complete overlap in habitat suitable).

Species Risk Assessment

I calculated the total predicted potential distribution size for each taxon and the proportion that lies within (i) National Protected Areas (NPA); (ii) Provincial and District Protected Areas (PPA-DPA); (iii) Protection forests (ProtecFA); and (iv)

Production forests (ProducFA). For each species, risk is assessed in terms of proximity to human settlements (i.e. villages, agriculture lands), accessibility to humans (i.e. main watercourses, roads) and vulnerability to hunting pressure (assessed from the literature and personal data) (Table 3.3). Distances to the features were calculated using Euclidean distances. The average distances to each feature were calculated for the potential distribution of each species. Risk measures were classified into three categories, representing the lowest (score of 1) to the highest risk (score of 3). For each species, the sum of the scores given for each measure is calculated.

Table 3.3: Seven criteria used to assess the intensity of threats faced by modelled species

score / Measures	1	2	3
Total predicted distribution size (km^2)	>30000	5000-30000	<5000
Mean distance to protected forests	up to 2km	2 - 5 km	> 5 km
Mean distance to roads/main tracks	>5 km	2 - 5km	< 2km
Mean distance to villages	>5 km	2 - 5km	< 2km
Mean distance to agriculture lands	>5 km	2 - 5km	< 2km
Short-term impact of hunting	low	medium	high
Risk level (final score)	At Lower Risk (6)	At Risk (7-12)	Critically At Risk (13-18)

Results

Model Validation

AUC values for all 10 species varied from 0.710 to 0.987; four with AUC> 0.9, five with AUC 0.8-0.9 and one with AUC 0.7-0.8. When tested against a null-model, only half of the species' models were deemed predicting better than expected by chance. However, both the Boyce Indices and the jackknife

methods validated all but one (*H. lar*, with Boyce Indices) species' models (Table 3.4).

Table 3.4: Results of the model validation tests: test AUC, null-model, Boyce Index and jackknife test

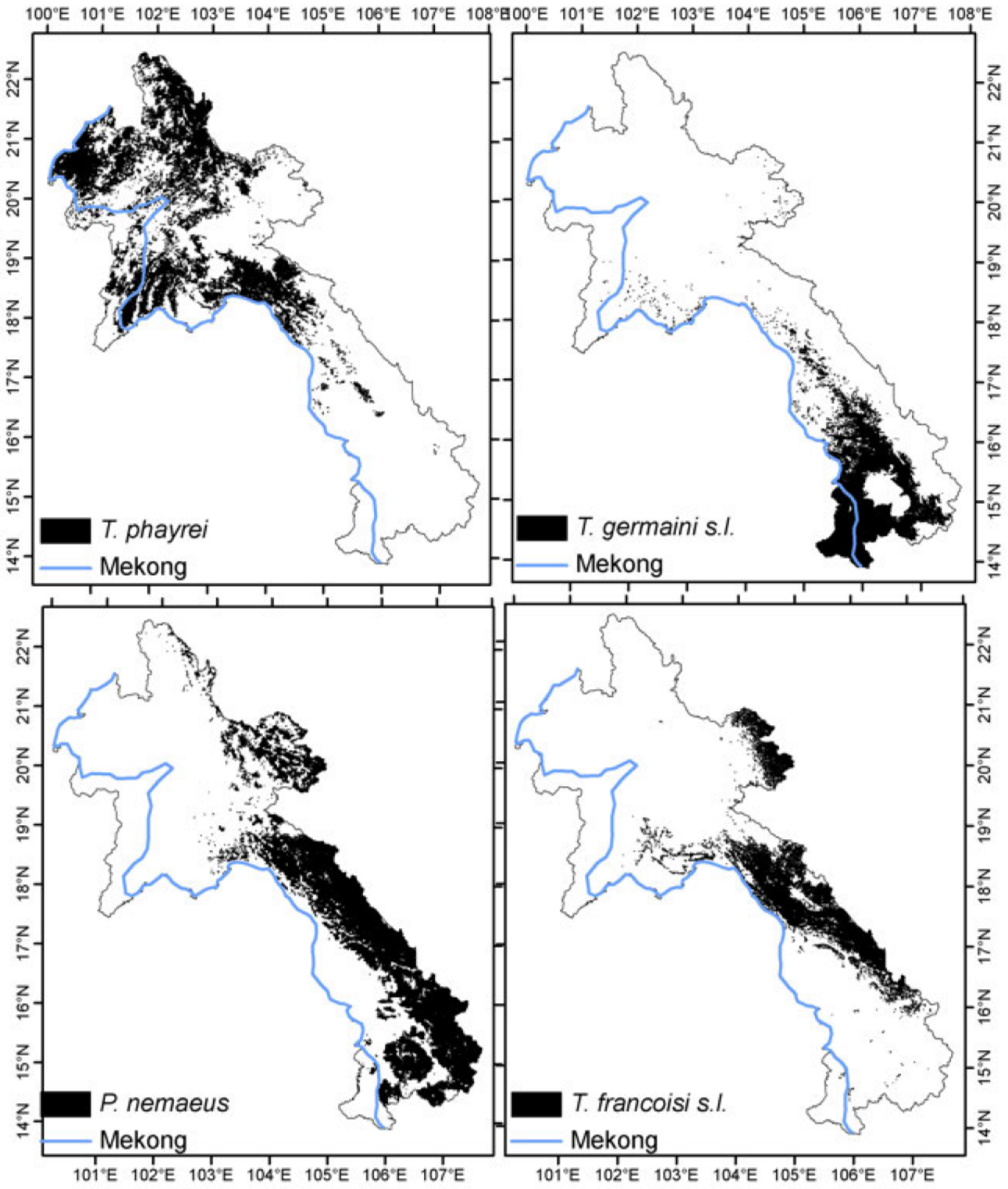
Species	Test AUC	null-model 95% C.I.	Boyce Index 100	Boyce Index 10	p-value jackknife test for n<30 (successes [a])
M. assamensis	0.818	0.862	0.203*	0.964**	--
M. arctoides	0.936*	0.891	0.236*	0.976**	0.000** (26)
P. nemaeus	0.829*	0.802	0.385**	0.976**	--
T. francoisi s.l.	0.892	0.925	0.218*	0.973**	0.000** (16)
T. germaini s.l.	0.885	0.902	0.169*	0.394	0.000** (8)
T. phayrei	0.863	0.869	0.229*	0.601*	0.000** (13)
H. lar	0.959*	0.882	0.123	0.459	0.000** (8)
H. pileatus	0.987*	0.898	0.250**	0.769**	0.000** (5)
N. concolor	0.959*	0.943	0.247**	0.847**	0.001** (3)
Nomascus spp	0.710	0.899	0.335**	0.985**	0.009** (18)

* model is significantly better than random: p<0.05
** model is significantly better than random: p<0.01
[a] successes: left-out localities that are successfully included within the prediction, under the minimum training presence threshold.

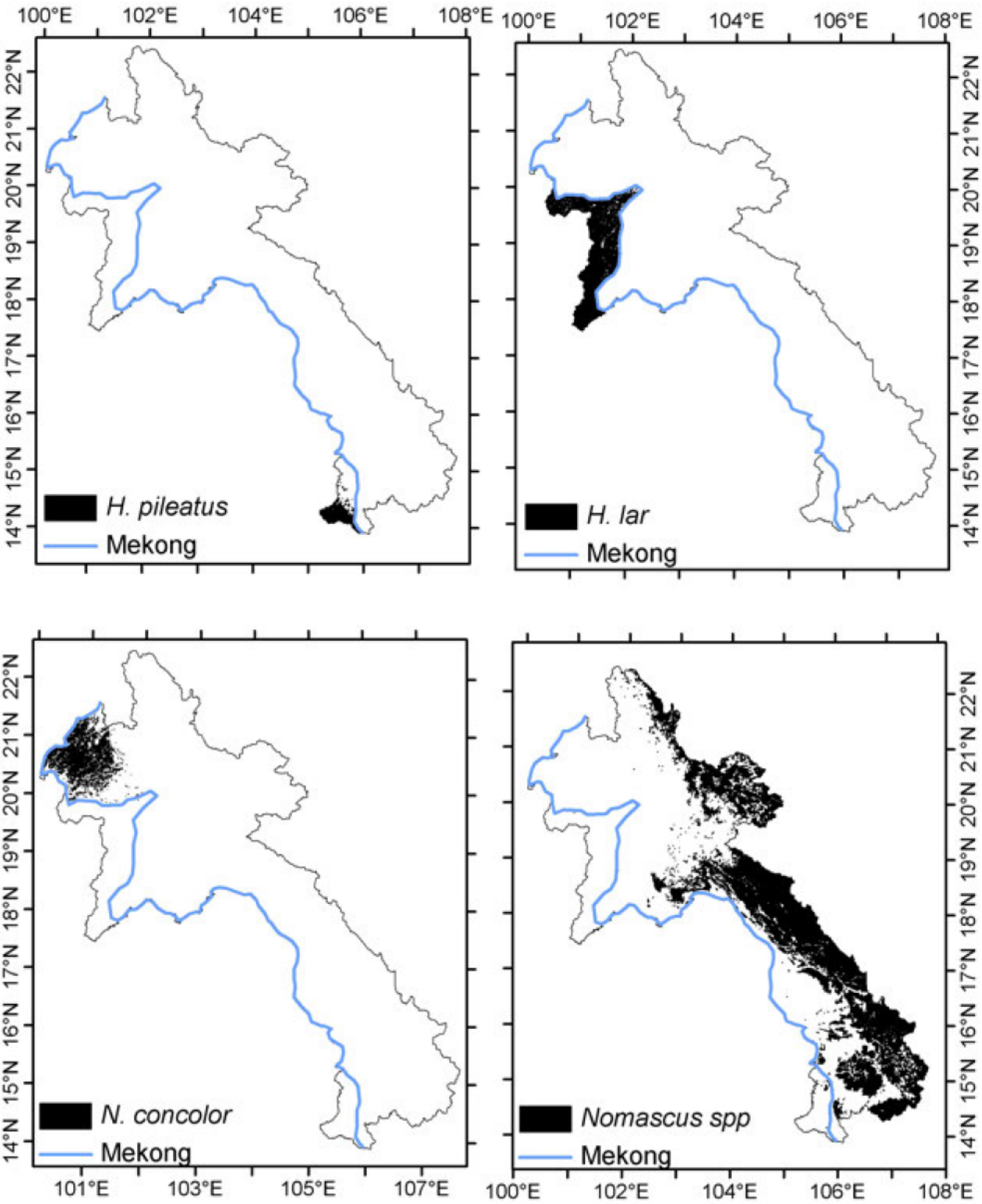
Species Niche Analysis

Predicted distributions for each species are presented in Figure 3.1. Average annual temperature within respective potential distributions of all species varied from 21°C (*M. arctoides*) to 27°C (*H. pileatus*), with an average of 23.1°C for all species. The annual precipitation across distributional range of all species averaged at 1969 mm. Species range from lowland, 50 m a.s.l. (*H. pileatus*, *T. germaini*) to up to 2780 m a.s.l. (*Nomascus spp, M. assamensis, M. arctoides, P. nemaeus*). *Macaca assamensis* and *T. francoisi* are predicted into the most rugged terrains, while *T. germaini* and *H. pileatus* into the flattest habitats. Predicted distributions of *N. concolor* and *T. phayrei* include the densest forest cover (>70%), whereas *H. pileatus* and *T. germaini* are predicted into the least vegetation covered areas (<50%) (Table 3.5).

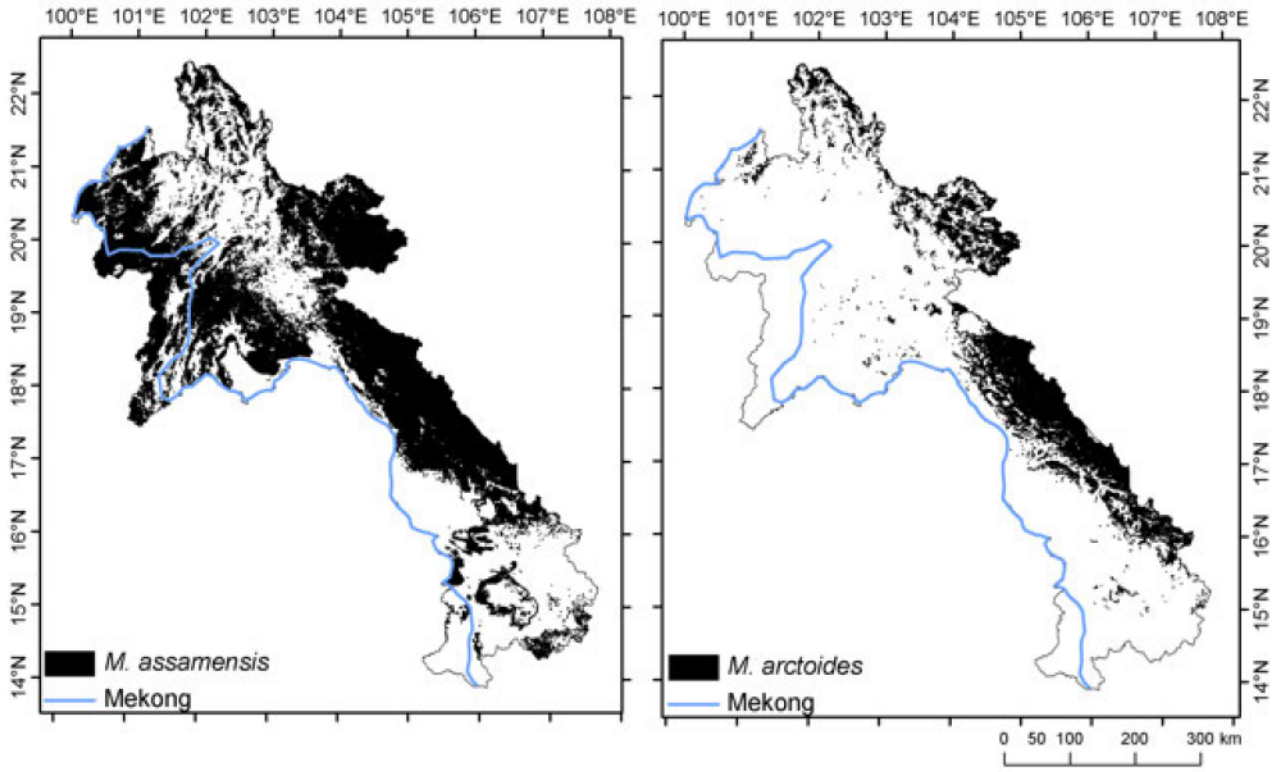
Overall, the predicted potential range of *Nomascus spp* overlaps the most with all other species, while *H. lar* is the most isolated species (lowest average range overlap) from all other species. *Hylobates pileatus* predicted potential range falls completely within that of *T. germaini* (r=1) (Figure3.1; Appendix 3.1a). Niche similarity test shows that *M. assamensis* shares the most similar niche to all other species, while *H. pileatus* has the most distinct niche from all other species. *Nomascus spp* and *P. nemaeus* together share the most similar niches (*I*=0.95). *Nomascus concolor* and *H. pileatus* inhabit the most distinct niches (*I*=0.01) (Figure 3.1; Appendix 3.1b).


T. phayrei
Mekong
T. germaini s.l.
Mekong
P. nemaeus
Mekong
T. francoisi s.l.
Mekong

a - Colobines


100°E
102°E
104°E
106°E
108°E
14°N
15°N
16°N
17°N
18°N
19°N
20°N
21°N
22°N
H. pileatus
Mekong
H. lar
Mekong
101°E
103°E
105°E
107°E
N. concolor
Mekong
Nomascus spp
Mekong

b - Gibbons



c - Macaques

Figure 3.1: Predicted potential distribution in Laos from MAXENT models for colobines **(a)**, gibbons **(b)** and macaques **(c)**.

Table 3.5: General niche description (averages) of each species according to their predicted distribution.

Species	Av an temp (°C)	Av an precip (mm)	Elevation (range) (m a.s.l.)	Slope (°)	veg. cover (%)	Top hab. (land 09) [a]	Top hab. (land 02) [a]
H. lar	23	1435	671 (192 – 2185)	4.66	56	MDF, OF	MDF, Bam
H. pileatus	27	1969	110 (50 – 168)	0.24	48	MDF	MDF, DDF
N. concolor	22	1597	823 (370 – 1488)	4.74	77	MDF	MDF, Bam
Nomascus spp	22	2247	774 (71 – 2780)	5.24	67	MDF, CEVF	MDF, EVF
M. assamensis	22	1864	800 (101 – 2780)	6.4	62	MDF, CEVF	MDF, EVF
M. arctoides	21	2080	857 (138 – 2780)	5.52	63	MDF, CEVF	MDF, EVF
P. nemaeus	22	2341	743 (82 – 2780)	5.28	68	MDF, CEVF	MDF, EVF
T. francoisi s.l.	23	2227	539 (137 – 1931)	6.11	56	MDF, CEVF	MDF, EVF
T. germaini s.l.	26	2085	214 (50 – 975)	1.77	49	MDF	MDF, DDF
T. phayrei	23	1842	604 (142 – 1466)	4.27	71	MDF, OF	MDF, Bam

MDF=upper Mixed Decidious Forest; **EVF**= upper Evergreen Forest; **DDF**= Dry Dipterocarp Forest; **Bam**= Bamboo; **OF**= Open Forest; **CEVF**= Coniferous Evergreen Forest

[a] top habitat types exclude crop/agriculture/unstocked forest lands.
'*land 09*' refers to the land cover classification from 2009 (from the European Space Agency);
'*land 02*' refers to the land cover from 2002 from the Geographic Department of the Lao, PDR.

Species Risk Assessment

Macaca assamensis has the largest predicted geographical distribution and *H. pileatus* the smallest. Similarly, the former has the largest proportion of predicted distribution falling within NPAs while the latter has the smallest distribution predicted proportion in NPAs. Species with the largest potential distribution in production forests are *H. lar* and *T. germaini* (Table 3.6). On average, the largest proportion for all species' predicted distributions fall in un-classified areas (34%), followed by within NPAs (27%), Protection FAs (17%), Production FAs (13%) and PPA-DPAs (9%).

Table 3.6: Size of predicted distributions for each species with percentage falling into NPAs, PPAs-DPAs, Protection FAs and Production FAs.

Species	Total area (km^2)	% in NPA	% in PPA-DPAs	% in Protection FA	% in Production FA
M. arctoides	29812.94	40.29	5.67	22.86	6.52
M. assamensis	97100.22	27.60	3.33	23.38	12.50
P. nemaeus	53751.68	35.16	4.57	22.65	11.12
T. francoisi sl	19759.91	36.29	9.26	20.06	4.90
T. germaini sl	25758.48	23.38	3.52	8.44	19.70
T. phayrei	39547.55	20.49	4.84	17.36	18.33
H. lar	12323.48	13.56	0.46	23.73	21.81
H. pileatus	1733.19	0.00	43.31	0.00	14.34
N. concolor	4962.45	37.56	5.53	8.88	13.96
Nomascus spp	57341.03	36.74	4.55	23.06	10.41

All species were assessed as At Risk in Laos with scores from 10 (*M. assamensis, M. arctoides*) to 16 (*T. germaini, H. pileatus*) (Table 3.7; Appendix 3.2).

Table 3.7: List of primates in Laos and their Global (IUCN, 2012a) and National (Duckworth et al., 1999; this study) status.

	Species	IUCN [2012a]	National [1999]	National (risk score*) [this study]
Macaques				
1	*M. fascicularis*	LC	PAR	n/a
2	*Macaca leonina*	VU	PAR	n/a
3	*Macaca mulatta*	LC	PAR	n/a
4	*Macaca assamensis*	NT	PAR	At Risk (8)
5	*Macaca arctoides*	VU	PAR	At Risk (9)
Colobines				
6	*P. nemaeus*	EN	AR	At Risk (10)
7	*T. phayrei*	EN	AR	At Risk (9)
	T. germaini s.l.			
8	*T. germaini s.s.*	EN	AR	At Risk (13)
9	**[***T. margarita***]**	unlisted	unlisted	
	T. francoisi s.l.			
10	*T. (f.) hatinhensis*	EN	PAR	
11	**[***T. (f.) laotum***]**	VU	PAR	At Risk (13)
12	**[***T. (f.) ebenus***]**	unlisted	unlisted	
Gibbons				
13	*N. concolor*	CR	AR	At Risk (12)
14	*N. leucogenys*	CR	AR	
15	*N. siki*	EN	unlisted	At Risk (9)
16	*N. gabriellae/annamensis*	EN	LK	
17	*H. pileatus*	EN	AR	At Risk (14)
18	*H. lar*	EN	AR	At Risk (12)
Lorises				
19	*N. pygmeaus*	VU	LK	n/a
20	*N. bengalensis*	VU	LK	n/a

* risk score ranges from 7 (lowest risk) to 21 (highest risk) (c.f. Appendix 3.2b)

n/a = not assessed; PAR=Potentially At Risk; AR=At Risk; LK=Little Known

[---] = monophyly of the species un-confirmed

Status is assessed for the species' groups [8-9], [10-11-12] and [13-14-15] in this study

Discussion

Model Performance and Limitations

I highlight the importance of using various validation methods for species distribution modelling. The most commonly used AUC values as a single validation method can be highly misleading, especially when sample size is very low and/or spatially strongly clustered generally resulting in high AUC values (Lobo et al., 2008). Alternative validation methods have increasingly been called for in the literature (e.g. Lobo et al., 2008; Raes and Steege, 2007). However, I show that these can give differing results, which may depend on the sample size and quality of the data used. The model prediction for *H. lar*, for instance, was based on inferred occurrence data points, from regions where the species had been confirmed (from sightings and/or reliable-sounding reports), which therefore may not depict the real ecological pattern of the species. Although the model was validated as excellent according to its test AUC (>0.9), its predictive power as indicated by the Boyce Index was low. The quality of the biological occurrence data used in modelling is crucial in determining the performance of the models (Lobo, 2008).

Modelling closely-related-species as a group is likely to result in lower predictive power if the different species within the group differ in their ecological niche. The lowest AUC values obtained for *Nomascus spp* could be a consequence of the different niches occupied by the putative species included in the group (*N. siki, N. leucogenys, N. annamensis/gabriellae*). Species with wider variation in their environmental niche generally result in lower AUC values (Hernandez et al., 2006). This was the case with *T. germaini s.l.,* where the Boyce Index method indicated that the model's predictive power was low. In contrast, taxa included in *T. francoisi s.l.* may share a similar niche as the model obtained for the group resulted in good predictive power.

When modelling species with limited occurrence data at a national scale, spatial autocorrelation and sample bias must be taken into consideration to

avoid potential model over-fitting. I used both spatial reduction of occurrence points and a background sample bias to address this issue, which resulted in larger and ecologically more accurate predicted areas. However, when only restricted habitats are surveyed for some species the potential predicted distribution and niche are likely unrepresentative of the actual suitable habitat of these species. This is the case in this study for *H. pileatus*, for which localities are from a single survey at one site (Round, 1998).

In any case, it is important to scrutinise distributions obtained from ecological niche modelling studies, especially so when these are used for conservation management decisions (Loiselle et al., 2003). The known ecology of the studied-species should be used to cross-validate models and visual assessment of the predictive maps with expert opinion remain crucial in models selection and evaluation (Pearce et al., 2001). For instance, the decision to include a new variable (competition with *P. nemaeus*) into *T. phayrei* final model increased its accuracy given the known distribution of the species in Laos (Timmins et al., 2013a).

Species Distribution and Niche

Given the uncertainties that always remain in species distribution models (Elith et al., 2002), outputs should always be interpreted as areas of potential suitable habitat rather than exact delimitation of distribution. The maps and niche analysis generally concurs with what is known of the species in Laos from previous research and National status (Coudrat et al., 2012; Duckworth et al., 2010; Duckworth, 2008; Duckworth et al., 1999; Steinmeitz et al. 2011; Timmins et al., 2013a; Timmins et al., 2013b; Timmins and Duckworth, 2013). However the models predicted both *T. francoisi s.l.* and *P. nemaeus* in north-eastern Laos (Houaphan and Xiang Khouang Provinces, along Vietnam border) where they are not known to occur. These areas have been poorly, if ever, surveyed. Deuve (1972) mentions that *T. delacouri* (part of *T. francoisi s.l.*) might occur in this region. The species is today only known to occur at the same latitudes in neighbouring Vietnam (Nadler et al., 2012). As for *P.*

nemaeus, its northern limit both in Laos and Vietnam still remain uncertain, although it is believed to range up to ~ 19°N (Coudrat et al., 2012; Nadler et al., 2003). An historical (up to 1988) record of *P. nemaeus* is indicated in Nadler et al., (2003) and Kirkpatrick (1998) from around Pu Hoat Nature Reserve (19°38' - 20°00'N) bordering Huaphan Province in Laos; although no reference is assigned to this record and so it cannot be seen as confirmed. Likewise, the IUCN (2012) distribution range for *P. nemaeus* indicates it is extent at the same latitude as the latter record in Vietnam (northern-most Nghe An Province) bordering Laos. *T. francoisi s. l.* and *P. nemaeus* predicted presence in these areas northeast of Laos may indicate either that (i) habitat is suitable but other variables restrict their distribution there, (ii) they may historically have occurred there, or (iii) due to lack of surveys in the region, even in historical times, populations of the species are yet to be detected there.

Additional environmental and biotic factors not included in the models certainly also influence or have reshaped distribution of primate species in Laos as currently observed. Undoubtedly, the high hunting pressure that face all primates species in the country (Duckworth et al., 1999; Nooren and Claridge, 2001) has reduced species range, already leading to some local extinctions (e.g. Boonratana et al., 2012; Coudrat et al., 2012; Duckworth, 2008). The situation in reality is likely to be more critical than presented here, especially for colobines and gibbons. *Hylobates lar*, for example, although largely predicted by the model within its suitable habitat range, is today extremely restricted and fragmented (Boonratana et al., 2012). The same is deemed, to some extent, for all other primate species. Similarly, forest cover likely has reduced (since the 2009 land cover used in the model) making way for large development projects, resulting in loss of habitat.

Risk Assessment

Macaque species scored amongst the lowest risk. Both species assessed inhabit rugged and mountainous areas, which remain widespread in the

country and are more difficult to access and are further from human settlement (Timmins and Duckworth, 2013). Areas not predicted in northern-central Laos may be an artefact of a sampling bias. *Macaca arctoides*, being principally ground-dwelling, is more at risk from ground snares, which are commonly used even in remote and dense forest areas, than are the more arboreal species. A relatively low risk score for *P. nemaeus* and *Nomascus spp* is attributable to a wider distribution, yet current populations are heavily restricted by hunting and habitat loss (Coudrat et al., 2012).

Furthermore, by assessing *Nomascus spp* as a group rather than at species level, the status is far less critical than it would be to individual species. In neighbouring Vietnam, populations are fragmented, and at high risk from hunting and deforestation (Rawson et al., 2011). Laos holds the largest population of *N. leucogenys* (Duckworth, 2008) and *P. nemaeus* (Coudrat et al., 2012) and may do so for *N. siki.* The current real distribution of *H. lar* in Laos, known to be extremely restricted (Boonratana et al., 2012) means that its current status is surely worse than depicted by the analysis. The different taxa included in *T. francoisi s.l.* are morphologically distinct (Duckworth et al., 2010; Steinmetz et al., 2011), but their separation as different species has never been studied and would require genetic analysis including several samples for each form. If separated into different taxa, each would result in a more restricted distribution and consequently a higher risk score status. However, the association of some forms with difficult-to-access large karst forests prevents hunting pressure in these habitats. Populations inhabiting these habitats can be considered currently at lower risk than other forms found in evergreen forests.

Given their predicted restricted range and niche being more prone to human encroachment, both *T. germaini* and *H. pileatus* ranked amongst the highest risk level. More than half of their predicted range falls into unclassified and production forests. *Trachypithecus germaini* has already been assessed as 'the rarest and most threatened monkey' in Laos (Timmins et al., 2013b; p. 7). It is known to persist in a small (180 ha) semi-evergreen forest patch in Dong Phou

Vieng NPA, where the species has been protected from hunting by a formerly strong, but now tenuous, local belief system (Coudrat, 2011; Timmins et al., 2013b). In other areas with no such cultural beliefs, the species has been extirpated from overexploitation (Timmins, 2009). The largest and possibly only remaining population of *H. pileatus* is found in Dong Khanthung PPA, which receives little protection due to lack of resources.

It is important to note that the scores given in this study do not necessarily represent the current status of the species due to over prediction of their distribution and the absence of anthropogenic factors included in the model. This shows the importance of including critical assessment of such predictive models, if it is to be used in conservation projects. Nonetheless, this study allowed highlighting the major gaps in our knowledge on Lao primate species that should be addressed as priorities in future research in the country.

Conclusions: Implications and Next Steps

Modelling studies are useful as a starting point and investigative method to explore the possible distribution, niche and conservation status of little known species. This method can be applied to these countries where few biological data have been collected so far due to restricted survey effort because of past or on-going political unrest. Given the rapidly declining conservation prospects of many species, it is important that such models are used. But our results highlight that these models' uncertainties and the need for a critical assessment in terms of our current knowledge from field data.

Future conservation-oriented research on primates in Laos should focus on taxonomy and biogeography of several taxa due to the uncertainty still remaining, which will lead to re-evaluation of their conservation status:

- *T. francoisi s.l.*: at least three different forms exist in Laos within the *T. francoisi* species-complex and their taxonomic status is unknown.
- *T. germaini s.l.*: it has been suggested that mainland silvered leaf monkey (*T. germaini s.l.*) should be divided into two species, possibly

separated by the Mekong River: *T. germaini senso stricto* and *T. margarita,* west and east of the Mekong, respectively. Morphological variations have been observed in individuals ranging west and east of the river (Moody et al., 2011; Hoang et al., 2012). This would suggest the two species of silvered langurs would occur in Laos.

- *P. nemaeus:* all of the occurrence localities used in this study for doucs were treated as *P. nemaeus*, yet a gradual morphological variation from north to south within the range of *P. nemaeus* has been observed (Timmins and Duckworth, 1999; Coudrat et al., 2012). This means that potential hybridisation with the two other douc species that range in Vietnam could potentially exist. Genetic samples of several individuals with morphological variation should be carried out.
- pale-cheeked crested gibbons *(Nomascus spp*): the range limits of the three pale-cheeked crested gibbons of Laos (i.e. *N. leucogenys, N. siki, N. gabriellae/annamensis*) are still unclear and the recently described new species remains to be confirmed (*N. annamensis*) (Van Ngnoc Thinh et al., 2010). Acoustic analysis for *Nomascus spp* has been identified as an efficient method for gibbon phylogenetic analysis (Geissmann, 1995; Konrad and Geissmann, 2006) and is logistically easier to implement than genetic analysis. Acoustic samples should be collected systematically in the field throughout their range.

For all species field validation of our predictive maps is essential. Opportunistic records will allow some progress, but the slow pace at which they are generated means that targeted surveys would be highly beneficial. Future potential survey areas include:

- north-eastern Laos, in Houaphan and Xieng Khuang Provinces along the Vietnam border, particularly in karst areas, where potentially new colobine populations could be found;
- the other major karst complex of Laos' northern highlands;
- hilly parts of Champasak Province west of the Mekong, to collect more data on *T. germaini s.l.* and *H. pileatus*;

- lowland areas of southern Lao outside the NPA system where conditions are predicted to be (or at least have been) suitable for *T. germaini s.l.*;
- Northern Laos west of the Mekong where too few data were available for *H. lar*, which is restricted in Laos to this area.

This analysis reiterates the importance of Laos for primate conservation, yet confirms the threatened status of all taxa assessed and the same rigorous review of localities points should be done for the species not assessed, although they are considered at relatively lower risk, currently. Given the restricted resources available in the country for conservation action, attention should generally focus on areas that maintain the largest populations (Coudrat et al., 2012), but for some taxa other considerations of achievability may be more important, such as *T. germaini s.l.*: given this species' apparent absence from interior semi-evergreen and dry-dipterocarp forests, there may be no large blocks of suitable habitat designated for conservation management. Thus, the existing cultural protection in Dong Phouvieng NPA is probably the best starting point for the conservation of the species in Laos.

Appendix 3.1a: Range overlap between each species' predicted distributions. This is calculated after applying a threshold value at which the species are considered 'present' (I used the average of all species' minimum presence training threshold as computed in Maxent [=0.240]) and using the formula ($N_{x,y}$/min(N_x, N_y)), where $N_{x,y}$ is the number of grid cells in which both species are predicted to occur and N_x and N_y are the number of grid cells in which species X and species Y are predicted to be present (Warren et al., 2010). Values present the range overlap of the species with the smallest range of each pair. Overlap > 0.5 is highlighted.

Species	***H. lar***	***H. pileatus***	***N. concolor***	***Nomascus spp***	***M. artoides***	***M. assamensis***	***P. nemaeus***	***T. francoisi s.l.***	***T. germaini s.l.***	***T. phayrei***
H. lar	--									
H. pileatus	0.00	--								
N. concolor	0.08	0.00	--							
Nomascus spp	0.00	0.00	0.00	--						
M. artoides	0.00	0.00	0.00	**0.96**	--					
M. assamensis	0.04	0.00	0.02	**0.75**	0.85	--				
P. nemaeus	0.00	0.00	0.00	**0.86**	0.91	**0.54**	--			
T. francoisi s.l.	0.00	0.00	0.00	**0.66**	0.48	**0.60**	0.44	--		
T. germaini s.l.	0.00	**1.00**	0.00	0.05	0.00	0.02	0.02	0.02	--	
T. phayrei	**0.67**	0.00	**0.86**	0.22	0.02	0.15	0.05	0.23	0.05	--

Appendix 3.1b: Pair-wise niche similarity test (*I* statistic) between all species' predicted distribution. Niche similarity *I* > 0.5 is highlighted. *M. assamensis* share the most similar niche to all other species, while *H. pileatus* has the most distinct niche from all other species.

Species	*H. lar*	*H. pileatus*	*N. concolor*	*Nomascus spp*	*M. artoides*	*M. assamensis*	*P. nemaeus*	*T. francoisi s.l.*	*T. germaini s.l.*	*T. phayrei*
H. lar	--	0.09	**0.64**	0.32	0.17	**0.55**	0.22	0.23	0.35	**0.65**
H. pileatus	0.09	--	0.01	0.09	0.02	0.06	0.10	0.05	**0.51**	0.09
N. concolor	**0.64**	0.01	--	0.34	0.25	**0.52**	0.23	0.27	0.22	**0.72**
Nomascus spp	0.32	0.09	0.34	--	**0.84**	**0.88**	**0.95**	**0.81**	**0.55**	**0.66**
M. artoides	0.17	0.02	0.25	**0.84**	--	**0.80**	**0.87**	**0.78**	0.32	0.41
M. assamensis	**0.55**	0.06	**0.52**	**0.88**	**0.80**	--	**0.82**	**0.83**	**0.53**	**0.73**
P. nemaeus	0.22	0.10	0.23	**0.95**	**0.87**	**0.82**	--	**0.81**	**0.52**	**0.52**
T. francoisi s.l.	0.23	0.05	0.27	**0.81**	**0.78**	**0.83**	**0.81**	--	0.49	**0.55**
T. germaini	0.35	**0.51**	0.22	**0.55**	0.32	**0.53**	**0.52**	0.49	--	**0.52**
T. phayrei	**0.65**	0.09	0.72	**0.66**	0.41	**0.73**	**0.52**	**0.55**	**0.52**	--
Average	**0.36**	**0.11**	**0.36**	**0.60**	**0.50**	**0.63**	**0.56**	**0.53**	**0.45**	**0.54**

Appendix 3.2a Mean distances to human settlements, main watercourses and forested area under some level of protection for each species' potential distribution within Lao, PDR.

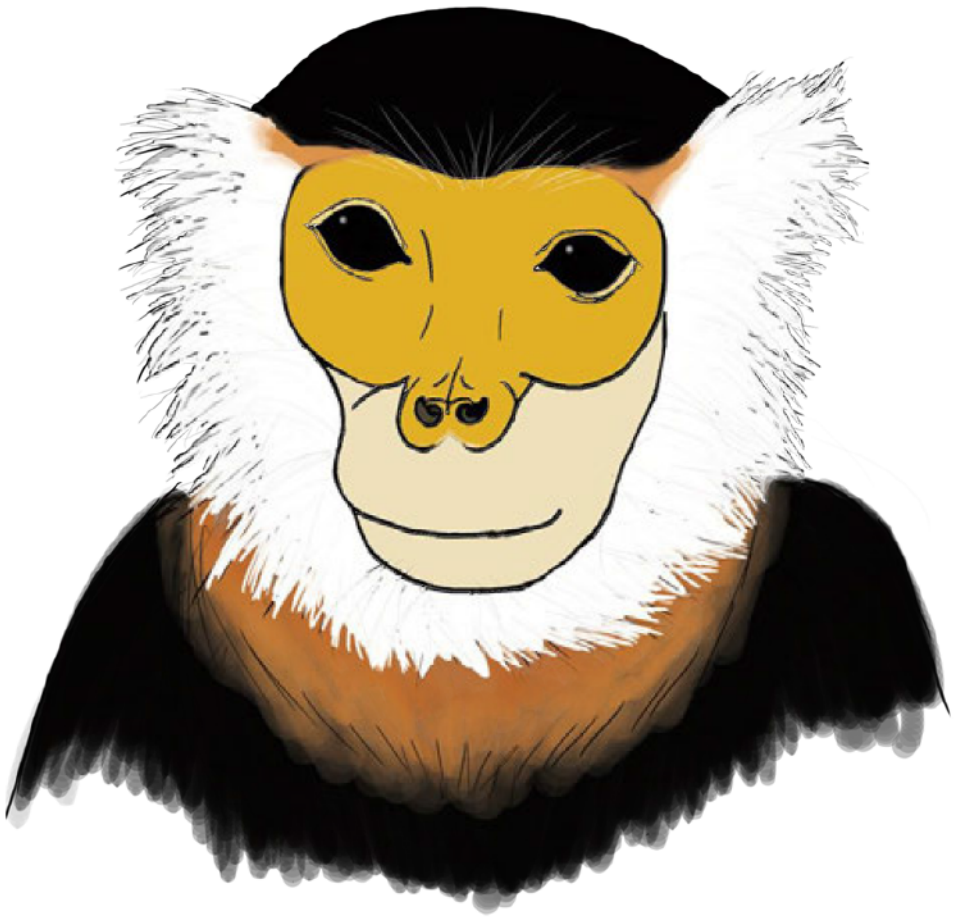
Measure / species	(i) Total area (km^2)	(ii) Distance to road	(iii) Distance to villages	(iv) Distance to agriculture land	(v) Distance to protected forests	(vi) Hunting pressure vulnerability
M. arctoides	29812.94	3.28	5.92	6.23	1.70	Medium
M. assamensis	97100.22	2.75	5.15	5.28	3.52	Low
P. nemaeus	53751.68	3.35	5.81	6.69	2.49	high
T. francoisi sl	19759.91	2.67	4.07	4.75	1.81	high
T. germaini sl	25758.48	2.14	4.42	2.84	5.57	high
T. phayrei	39547.55	2.67	5.22	5.28	5.10	high
H. lar	12323.48	2.25	4.30	3.62	5.68	high
H. pileatus	1733.19	1.47	6.05	3.20	4.01	high
N. concolor	4962.45	2.44	4.96	7.71	3.10	high
Nomascus spp	57341.03	3.73	6.59	6.76	2.23	high

Appendix 3.2b Risk assessment scoring according to criteria set (Table 2) and measures used (App. II.1) for each species' potential distribution.

Measure	*M. arctoides*	*M. assamensis*	*P. nemaeus*	*T. francoisi sl*	*T. germaini sl*	*T. phayrei*	*H. lar*	*H. pileatus*	*N. concolor*	*Nomascus spp*
i	2	1	1	2	2	1	2	3	3	1
iii	2	2	2	2	2	2	2	3	2	2
iv	1	1	1	2	2	1	2	1	2	1
v	1	1	1	2	2	1	1	2	1	1
vi	1	1	1	2	2	1	2	2	1	1
vii	2	1	3	3	3	3	3	3	3	3
sum	**9**	**8**	**10**	**13**	**13**	**9**	**12**	**14**	**12**	**9**

CHAPTER 4

CONSERVATION OF THE WORLD'S LARGEST POPULATION OF RED-SHANKED DOUCS IN LAOS: COMBINING DISTANCE SAMPLING AND HABITAT SUITABILITY MODELLING TO ESTIMATE THEIR DENSITY



Introduction

Within the tropics, Southeast Asia encompasses the largest proportion of endemic mammals and is also where mammals are the most threatened from extinction (Sodhi et al., 2009). A consensus has been reached among the scientific community that the region is facing a biodiversity crisis and therefore requires strategic conservation planning and implementation (Sodhi et al., 2004; Koh and Sodhi, 2010; Duckworth et al., 2012).

As a vital step to the planning procedure, estimating animal population abundance via surveys can have several implications in addressing biodiversity crises (Ogutu et al., 2006; Hassel-Finnegan et al., 2008). Identifying populations of importance is a key step into setting conservation priorities and is necessary to monitor population status over time (Plumptre and Cox, 2006). Recurrent lack of resources put into conservation of lesser known yet highly threatened species means that knowledge of the conservation status of many taxa is based on one-off short-term surveys or remains to be ground-truthed at all.

The red-shanked douc (*Pygathrix nemaeus*) is an Endangered (IUCN, 2012a) Asian colobine among a monophyletic group of two other douc species (*P. nigipes* and *P. cinerea*), all three endemic to one or more of the countries of Laos, Cambodia and Vietnam. *P. nemaeus* occurs in Vietnam and Laos and perhaps Cambodia (Rawson and Roos, 2008; Coudrat et al., 2012). With remaining populations across Vietnam stated at no more than ~30 individuals (Bach Ma National Park - NP; Nadler, 2010) to ~2000 individuals (Phong Nha-Ke Bang NP; Haus et al., 2009), combined with constant hunting pressure on douc species for traditional medicine, local consumption and international trade, conservation of the species in Vietnam is uncertain. The largest population of *P. nemaeus* is known to occur in Laos, in particular in the central-eastern part of the country, within the Annamite mountain range in foothills and some adjacent lowland areas (Coudrat et al., 2012; Timmins and Duckworth, 1999). No population estimate exists, however, for this highly

charismatic species and hunting pressure in these remote, relatively large and dense forests severely and increasingly threatens populations (Coudrat et al., 2012). Baseline density estimates of *P. nemaeus* in these regions will allow long-term monitoring of the population and, by which, assessment of conservation success.

To provide solid baseline data for the conservation of this species, I conducted line-transect surveys over one year in 2011-2012 in Nakai–Nam Theun National Protected Area (NPA). I combine species distribution modelling and distance sampling method (Buckland et al., 2001) to estimate the density, population abundance and biomass of *P. nemaeus* within the area. I use this approach to suggest a conservation action plan for the world's largest-known remaining population of red-shanked douc.

Methods

Study Area

Nakai–Nam Theun NPA, ~3550 km^2, is located in the central-east of Laos within the Annamite mountain range. It remains largely forested with around 90% of forest cover (Robichaud et al., 2009) with a variety of habitat types from mixed semi-evergreen/coniferous, upper montane, dry-evergreen and wet evergreen forests (Timmins and Evans, 1996). Elevation throughout the NPA ranges from ~500 m to c. 2300 m a.s.l. Annual precipitation ranges from 1865 mm to 2620 mm and annual mean temperatures from 14°C to 24° C, with extremes of 4°C to 32°C. Nakai–Nam Theun NPA is crossed by five main rivers (Figure 4.1). There are land delimitation zones around the thirty-one enclave villages for local use of forest products (see Wildlife and Aquatic Law and Forestry Law; (National Assembly Laos, 2007a; 2007b).

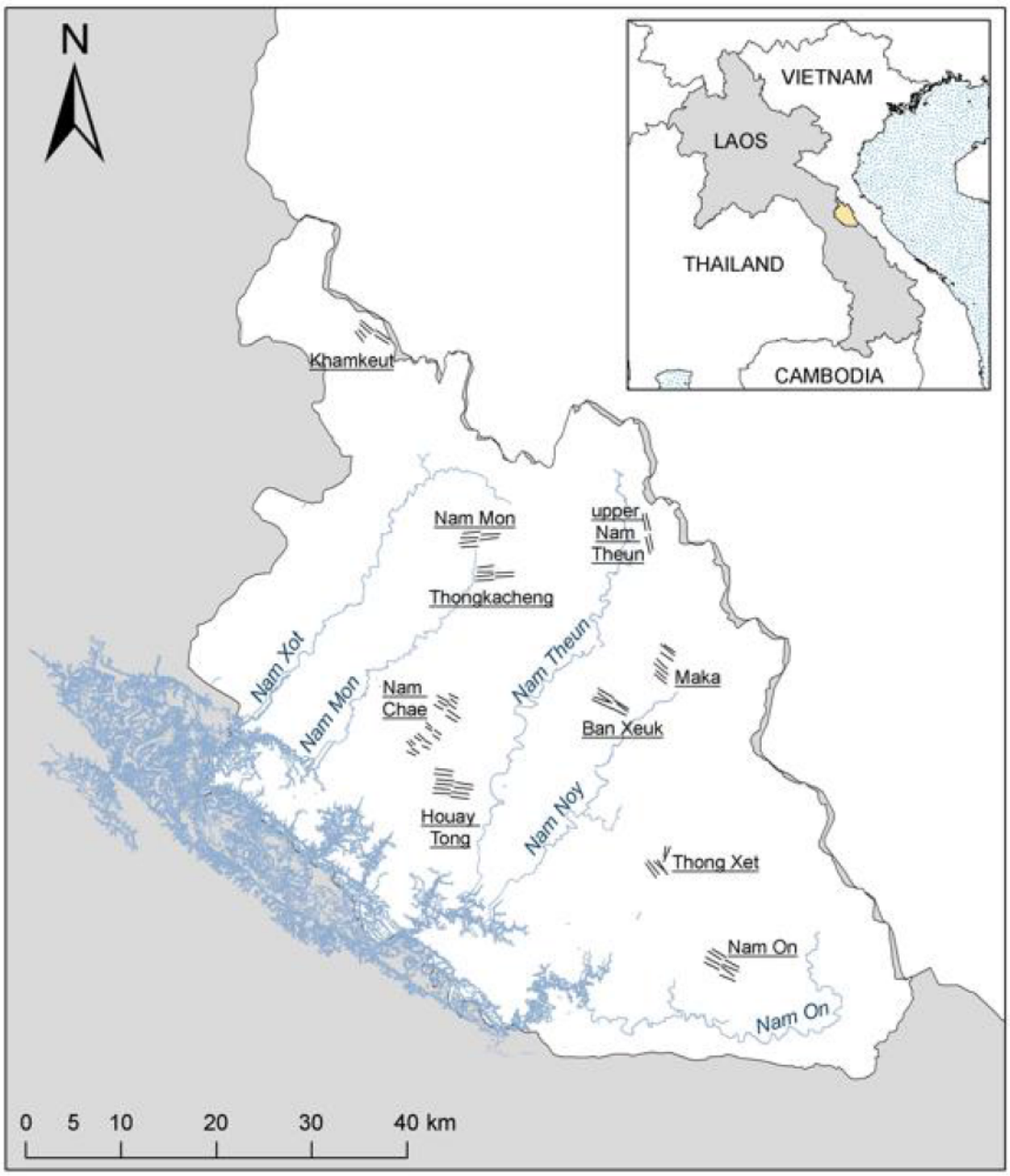


Figure 4.1: Sites visited within Nakai–Nam Theun NPA in 2011-2012, showing the 81 transects walked (represented as straight line from start point to end point).

The heterogeneity of habitats makes the wildlife community in Nakai–Nam Theun NPA one of the most diversified in the country and the region, with numerous Globally Threatened key species, including large mammals only recently discovered, over 430 species of birds, nine species of primates and key carnivore species (Timmins and Evans, 1996). This places the area as one

of the priorities for wildlife conservation in Laos and the Indo-Burma region (Robichaud et al., 2001; Tordoff et al., 2012).

Data collection

From 2011-2012, I visited 10 different study sites across the NPA (Figure 4.1). I chose study sites in terms of their relative accessibility (2 to 4-day travel to set camp). I arbitrarily pre-set transects on a 1:50,000 topographic map of the study site (totalling 81 transects over the NPA). For logistic constraints, I set transects, which were 1 to 2 km long and ~400-500 m apart, approximately perpendicular to a watercourse. I kept the pre-set bearing for each transect, using a compass, except when going around occasional obstacles (e.g. rivers with no crossing point, large fallen tree trunks) (Figure 4.1). In each study site, I walked four to 20 transects, some of which were replicated two to three times, resulting in a total of 176 transects and 310 km walked (Table 4.1). The uneven number of transects and replications between sites was either due to (i) methodology adjustment following the first field trip, (ii) time constraints or (iii) poor weather conditions. I followed distance sampling line transect methodology (Buckland et al., 2001, 2010): at each group sighting of *P. nemaeus*, I recorded the perpendicular distance from animal to transect with a laser range finder (sometimes calculated from sin[animal-transect angle]*animal-to-observer distance), GPS coordinate, time and, whenever possible, a group size estimate. Dense canopy, movement of the animals (often involving group split) and group spread prevented an exact assessment of the centre of the group (traditionally more adequate for the model; Marshall et al., 2008), I therefore always attempted to record distance to an animal at the centre of all other visible individuals (possibly the group edge). I kept a low speed along transects; most of the time the rugged terrain greatly slowed the walk (walks varied from ~1h30 to ~5h30). I occasionally stopped to rest along the transects, but attempted to limit time spent at each resting location. Groups of two to four people walked the transects.

Table 4.1: Study sites visited in Nakai–Nam Theun NPA from 2011-2012 with total number of transects, survey effort (km) and number of observations at each site.

study sites	Dates	Area size (km^2)*	transects (replications)	Total survey effort**	obs.
Nam Chae	29 Jan – 2 Feb 2011	19.82	20 (x1)	21.47	3
Ban Xeuk	17 Feb – 6 Mar 2011	4.21	6 (x3) 1 (x1)	36.16	2
Maka	13 Mar – 31 Mar 2011	6.05	7 (x3) 1 (x2)	40.29	2
Thong Xet	18 Jul – 3 Aug 2011	4.97	6 (x1)	10.55	3
Khamkeut	16 Sept – 28 Sept 2011	4.69	6 (x1)	9.80	0
Nam One	19 Oct – 4 Nov 2011	6.57	8 (x3)	42.45	13
Nam Theun	11 Jan – 23 Jan 2012	1.96	4 (x3)	22.08	3
Houay Tong	10 Feb – 27 Feb 2012	9.71	10 (x3)	58.02	14
Thongkacheng	12 Mar – 24 Mar 2012	4.54	6 (x3)	34.38	9
Nam Mon	25 Mar – 5 Apr 2012	4.99	6 (x3)	35.01	13
		67.50	**176**	**310.21**	***62

* estimated size of study site obtained via Maximum Convex Polygon around transects.

** total survey effort includes replications

*** Seven observations that may have been a same group previously counted on the same transect walk, were discarded from the analysis: N=55

Species Distribution Modelling

I use the maximum entropy general purpose machine learning method, which has been adapted and specifically developed as a software (MAXENT v. 3.3.3k) for species distribution modelling (Phillips et al., 2004, 2006). The method combines biological data of species occurrence (presence-only data; e.g. GPS coordinates) with environmental characteristics (e.g. GIS layers with a grid of values for the geographic area considered) to estimate a probability distribution by finding the probability distribution of maximum entropy (i.e. closest to uniform), subject to the set of constraints provided (i.e. environmental characteristics where the species occurs) (Phillips et al., 2006).

I used a 10-fold cross-validation replication run type (Kohavi, 1993) with the program's default parameters (Phillips and Dudik, 2008).

I include 25 variables in the model: 19 bioclimatic layers (Hijmans et al., 2005), elevation, land cover (from 2002, with 14 categories), percentage of forest cover, slope, distance from water and villages. To avoid model over-fitting (Dormann et al., 2007; Veloz, 2009; Merckx et al., 2011), occurrence data were corrected for spatial autocorrelation by selecting one locality per 2 km^2, resulting in n=36 occurrence points used in the model (N=82, including opportunistic sightings outside transects). Outputs are processed and analysed in ArcGIS 9.3. I assess the model's predictive power with the area under curve (AUC) of the receiver-operating characteristic (ROC) and the Boyce Index (Boyce et al., 2002; Hirzel et al., 2006). To estimate the size of the distribution range of *P. nemaeus* in Nakai–Nam Theun NPA, I created a binary map using the 'minimum training presence threshold'.

Distance sampling

I use DISTANCE 6.0 to analyse survey data with the Conventional Distance Sampling Engine (Thomas et al., 2010). I pooled all data collected over the study period (Table 4.1). I removed from the analysis the observations that may have been double counts of the same group on the same transect (i.e. of the total 62 observations, seven were discarded: N=55 are used in the analysis). As group count was difficult to assess due to poor visibility and fleeing behaviour, I model group density rather than individual density and estimate population density *post hoc* with the mean group size calculated from my observations. Transects that were replicated are analysed together as single lines and their survey effort correspond to the transect's length, times the number of replications (Buckland et al., 2010) (Table 4.1).

I follow Buckland et al. (2001: 135) line transect analysis steps. I plotted the data (perpendicular distances) in a frequency histogram of 10 m intervals to select five interval cut-off points (0; 20 m; 40 m; 60 m; 80 m and 104 m

corresponding to my largest observation) and create a grouped data set. I then ran six models with different combinations of key function and adjustment terms: (1) half normal + cosine, (2) half normal + simple polynomial, (3) half normal + hermite polynomial; (4) uniform + cosine; (5) uniform + simple polynomial; (6) uniform + hermite. I selected the best model according to the Akaike Information Criteria (AIC), X^2 goodness of fit statistical test (GoF Chi-pValue), and coefficient of variation (Coef. Var.) of the density estimates (Buckland et al., 2001).

Results

Species Distribution Modelling

My predicted model yielded a test AUC of 0.789. The Boyce Index validation method with 100 classes indicated a significant ($p<0.01$) predictive power ($r=0.511$). The resulting predicted distribution range (under the minimum presence training threshold) has a size of 1578 km^2, 44.4 % of the total area (Figure 4.2).

a **b**

Figure 4.2: (a) Habitat suitability model for *P. nemaeus* in Nakai–Nam Theun NPA obtained from MAXENT. Continuous logistic suitability was reclassified as to obtain the binary map, under the *minimum training presence threshold*, resulting in a suitable habitat of 1578 km^2. **(b)** Enclave villages and eight major habitat types in NNT NPA (from the National Geography Department of Lao PDR, 2002; current agricultural land has likely expended around village clusters.

Distance sampling

The model with the half-normal key function and cosine adjustment fitted the data the best and resulted in a mean density of 2.8 groups/km^2 (Table 4.2). Using the latter group density and the size of predicted suitable habitat in Nakai–Nam Theun NPA, I estimated a potential for *ca.* 4900 groups within the NPA (Table 4.3) with the assumption of a uniform group density over the potential predicted distribution in the NPA.

Table 4.2: Distance analysis results for the different models performed with all observations (N=55) and data grouping with five intervals (cut-off points [m]: 0; 20; 40; 60; 80; 104).

Model (key function + adjustment term)	Density estimate (confi. limit)		Coef. Var.	Prob. detect. (conf. limit)		Delta AIC*	AIC	GoF Chi-pValue
half-normal+cosine	**2.81**	**(1.94 - 4.08)**	**0.19**	**0.30**	**(0.24 - 0.38)**	**0.00**	**131.74**	**0.38**
half-normal+polynomial	2.72	(1.85 - 4.01)	0.20	0.31	(0.24 - 0.40)	2.57	134.30	0.11
uniform+cosine	2.66	(1.81 - 3.91)	0.20	0.32	(0.25 - 0.41)	2.57	134.31	0.12
uniform+polynomial	2.28	(1.56 - 3.33)	0.19	0.37	(0.29 - 0.47)	6.17	137.91	0.02
half-normal+hermite	2.07	(1.44 - 2.98)	0.18	0.41	(0.33 - 0.50)	8.12	139.86	0.01
uniform+hermite	1.63	(1.12 - 2.36)	0.19	0.52	(0.42 - 0.65)	15.93	147.67	0.00

*Delta AIC=model AIC - lowest AIC of all models
GoF=Goodness of Fit

Table 4.3: Abundance estimates using density from Distance analysis and range size in Nakai–Nam Theun NPA from MAXENT model.

Parameters	estimated	
mean encounter rate (gp/km) [a]	0.2	(0 – 1.7)
group density (gp/km^2)	2.8	(1.9 – 4.1)
mean group size	13	(4 – 30)
individual density (ind/km^2)	36.4	
biomass (kg/km^2) [b]	400.4	
size of potential distribution range in NNT (km^2) [c]	1578	
population in NNT (groups)	4418	(2998 – 6470)

[a] average of the encounter rates of each single transect walk
i.e. $\sum_i^{n=176}$[number of sightings/transect walk$_i$ length] / total number of walks n; calculated for the total number of observations (62)
[b] based on mean body size of 11 kg (7 - 15 kg) (Nadler et al., 2003)
[c] under the minimum presence training threshold

Discussion

Survey limitations

My analysis yielded an average density of 2.8 groups per km^2 of *P. nemaeus* and 4418 groups in Nakai–Nam Theun NPA with our distribution model of an estimated *c.* 1600 km^2 of suitable habitat. My habitat suitability model may be underestimated due to survey bias (Phillips et al., 2009) mainly in the central regions; it should therefore be considered as a conservative estimate. Given their suspected multi-level social organisation, involving regular travel of more

than one group together, group size can vary widely (4 to ~30 in our study, excluding solitary animals) (Hoang, 2007; Rawson, 2009). Distance sampling for primates has long been used for several species; however, it has been problematic to evaluate the reliability of the results since true density is rarely possible to be known. In addition, using this method for primates can be challenging due to their behaviour, the difficulty of obtaining large enough and random sample sizes in rainforest habitats, often leading to violation of the technique's assumptions (i.e. groups on or very close to the line are detected with certainty; groups are detected at their initial location; detections on the line are independent; distance measurements should be from the line to the centre of the group; distances are measured accurately; survey design should include an adequate sample of randomly distributed lines in the study region; Buckland et al., 2010). I caution that my results may not represent the true density of the species in the area due to logistic difficulties. My study, however, included a large number transects with replications (N=176), spread across the area, resulting in a suitable number of observations for the models.

Other assumptions may have been violated: (1) Forest density meant that visibility sometimes prevented us to obtain distance to the group centre, but rather to the first animal seen, which would lead to overestimation of density (Marshall et al., 2008; Buckland et al., 2010). (2) Some groups may also have remained undetected due to the disturbance from transects cutting on the first walk, occasional noisy movement through denser habitat (e.g. bamboo) and/or poor weather conditions in some areas (e.g. Khamkeut site). Indeed, our detection probability was a low 30% rather than what is perceived to be the average of about 60% (Walsh, 2000). A commonly observed behavioural response to threat of doucs involves hiding in trees motionless of at least some individuals of the group; this means that the species may have still been be detected, even though potentially aware of the observers' approach. For the majority of our detections, the species started fleeing just when sighted or moments after. On fewer occasions, the animals were detected while already fleeing, although I was still able to confirm identification of the species.

Indeed, the total of the 126 diurnal primate detections (i.e. 12 gibbons, 52 macaques, 62 doucs) could be confirmed to at least genus; doucs being the easiest to identify, cued from their striking coat colour, colobine-like locomotion and calls. (3) Detection of groups most of the time involved fleeing behaviour, possibly resulting in distances that differed from the original position of the animals, affecting the density estimate (Marshall et al., 2008). (4) While the time spent walking transects could have led to double counting of some groups, I compensated this limitation by discarding all sightings that I suspected may have been counted twice on the same transect (as assessed from the direction of group flee from previous sighting). Overall, the limitations of my study may counterbalance between a potential over-estimation and under-estimation of the density.

The difficulties of surveying primates are common and independent from the surveyor's skills. Although alternative survey designs have been suggested to overcome these issues (Buckland et al., 2010), they remain a challenge to implement in practice and it is highly likely that most primate density-estimate-studies involve violations of some of the method's assumptions to some extent. Estimated densities can still be indicative of relative abundance and be compared between studies when survey biases are similar. Hence, it is essential to assess potential violations of assumptions in all distance sampling studies. Distance sampling remains to date the best method to estimate density of monkeys, including colobines (Buckland et al., 2010).

Population of P. nemaeus *in Nakai–Nam Theun NPA, importance and implications*

My study provides the only available density estimate for *P. nemaeus* in Laos. It falls in the range of other Asian colobines elsewhere in Southeast Asia (Table 4.4). Detection frequencies from surveyed areas also can be indicative of the relative abundance of a species in an area, which is in general proportionally equivalent to group density estimates (Table 4.4).

Table 4.4: Comparison of colobine density estimates in other areas in Southeast Asia. Note that methodologies differed between studies, and often can lead to violation of some the assumptions of Distance Sampling method, please refer to the specific studies for details on methodologies.

species	Area (country)	overall detection frequency*	group density (gp/km^2)	reference
P. nemaeus	Nakai–Nam Theun **NPA (Lao)**	**0.20**	**2.8**	**This study**
P. nemaeus	Him Namno NPA (Lao)	0.32	--	Phiapalath, 2009
P. nemaeus	Phong Nha-Khe Bang NP (Vn)	0.04	0.25	Haus et al., 2009
P. nemaeus	Son Tra NP (Vn)	--	0.31[a]	Dinh Thi Phuong Anh et al., 2010; Lippold and Vu, 2008
P. nigripes	Seima CF (Cam)	0.51	7.06[b]	Pollard et al., 2007; O'Kelly and Nut, 2010
T. phayrei	Phu Khieo WS (Thai)	0.26	3.4[c]	Borries et al., 2002
T. phayrei	Phu Khieo WS (Thai)	0.26	3.4	Hassel-Finnegan et al., 2008
T. hatinhensis	Phong Nha-Khe Bang NP (Vn)	0.08	0.5	Haus et al., 2009
P. potenziani	S. Peleonan, Siberut (Indo)	0.64	3.2	Waltert et al., 2008
P. potenziani	N. Peleonan, Siberut (Indo)	0.33	1.8	Quinten et al., 2009
P. hosei	Kalimantan, Borneo (Indo)	--	2.3[d]	Nijman, 2004
S. concolor	N. Peleonan, Siberut (Indo)	1.59	21.1	Quinten et al., 2009
S. concolor	S. Peleonan, Siberut (Indo)	1.80	16.2	Waltert et al., 2008

* Overall detection frequency = overall total number of sightings/total km walked

[a] inferred from 13 groups encountered over a total forested area of 41.9 km^2

[b] Mean group density for yearly estimates from 2005 to 2010

[c] calculated with strip transect method D=n/2wl (NRC, 1981)

[d] result for primary hill forest survey; estimated with effective distance method (Whitesides et al., 1988)

The conservative suitable habitat modelled for the species in Nakai–Nam Theun NPA, estimated at *ca.* 1600 km^2 (and contiguous beyond, in Vietnam), most likely represents in itself the largest suitable habitat for the species compared to forested areas where it occurs in Vietnam (and Cambodia), and probably one of the largest in Laos. In Vietnam, populations of *P. nemaeus* considered the largest remaining are already relatively small (Table 4.4). This is hardly surprising given their bleak status in the country, resulting from

continuous deforestation and high hunting pressure (Coudrat et al., 2012; Blair et al., 2011; Lippold and Vu, 2008). The species is already locally extinct in several areas in Vietnam. The population of limestone-dominated habitat Phong Nha-Ke Bang National Park may at least stay naturally protected in its central parts, where inccessibility prevents over-hunting. The population of Son Tra National Reserve however is located in an increasingly human-dominated landscape and the species will only be maintained there with on-going conservation projects focussed on the species (Lippold and Vu, 2008; Dinh Thi Phuong Anh et al., 2010; Ulibari and Streitcher, 2013). If no action is taken, the same situation is likely to follow in Laos, at least in the most accessible areas, while (i) the species gains in value in the international trade, due to its increasing rarity and (ii) human population increases, putting more pressure on the species and its natural habitat.

In Seima Biodiversity Conservation Area - SBCA, eastern Cambodia, a population of the closely-related black-shanked douc (*P. nigripes*) is estimated at a density of ~7 groups/km^2 (Pollard et al., 2007; O'Kelly and Nut, 2010), the largest in the world and considered secured through the long-term conservation efforts in the area and low hunting pressure on this particular species (WCS, 2009; O'Kelly and Nut, 2010). The discovery of this remarkably large population was covered widely in the media, which helped promote the importance of the area for wildlife conservation. Following, in 2009, a core area within SBCA was designated as the Seima Conservation Forest by the Cambodian government where a successful conservation project has been implemented ever since (Evans et al., 2012). This example demonstrates the importance of communicating, nationally and internationally, findings from studies like this for species conservation. I believe a similar case could and indeed must be made for Nakai–Nam Theun NPA.

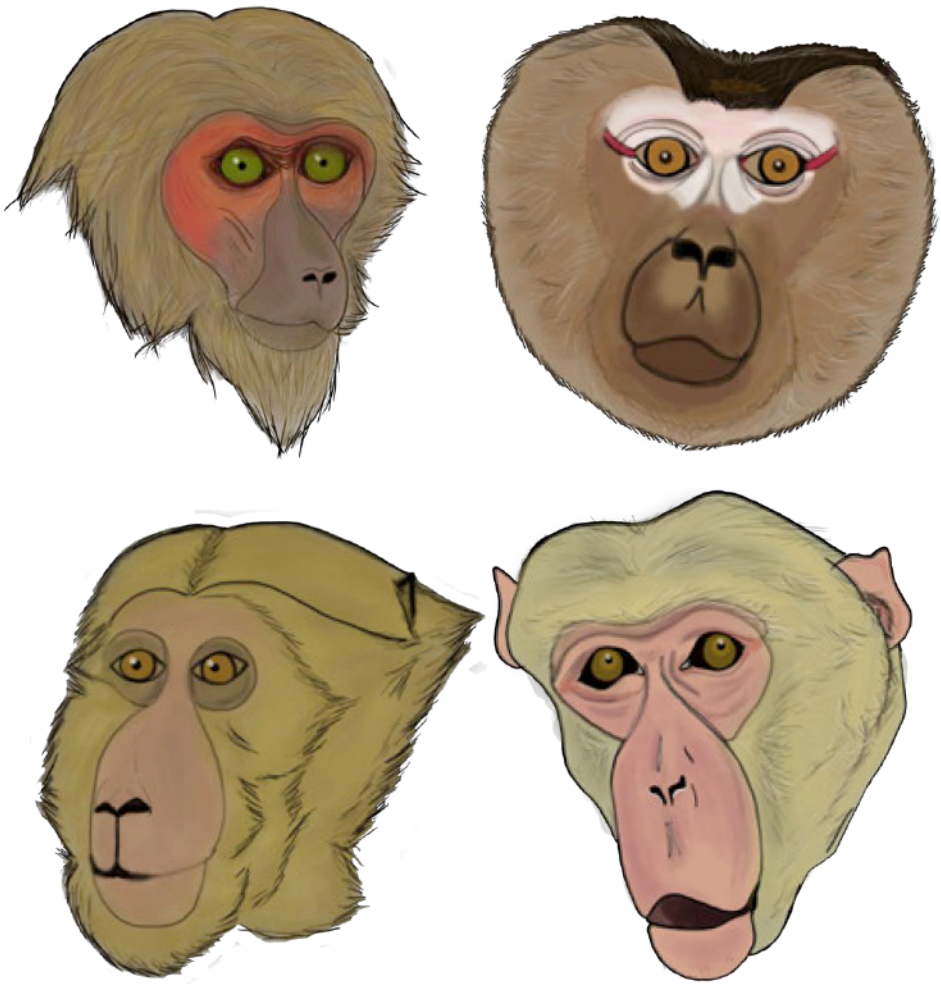
The population of *P. nemaeus* in Laos is no doubt the world's largest remaining and the best hope for its conservation (Coudrat et al., 2012) but is nonetheless far from being secured at this stage, due to lack and/or failure of management strategies. Wildlife in Nakai–Nam Theun NPA has been under

dramatic hunting pressure from local and Vietnamese hunters both for local consumption and a lucrative international trade (Nooren and Claridge, 2001; Robichaud et al., 2009). The demand from Vietnam and China specifically for colobines' bones used in traditional medicine (Nooren and Claridge, 2001), means that as douc populations are decreasing in Vietnam at an alarming rate, threat on Lao populations (especially at the Vietnam border) are likely to be increasing. Doucs are fairly often traded in Laos (Davidson et al., 1997; Nooren and Claridge; Phiapalath, 2009; Coudrat et al., 2012).

The recent Action Asia Programme established to tackle the on-going South-east Asian species extinction crisis, denotes the crucial importance of effective site-based species-focussed projects (Duckworth et al., 2012). No species-specific conservation project for *P. nemaeus* currently exists in Laos. To respond to this gap, a long-term conservation project is planned in the near future in Nakai–Nam Theun NPA (Coudrat, 2012b), which will be the country's first long-standing research project on this still little-known species and will secure conservation of the species by applying best conservation practices (Sunderland et al., 2012). Such a long-term conservation and research project will ensure the global survival of the species as well as of other co-existing threatened and unique species of the Annamite mountain range. The latter region is among the key biodiversity areas of the Indo-Burma hotspot that deserve special conservation attention (Tordoff et al., 2012).

CHAPTER 5

MODELLING NICHE DIFFERENTIATION OF CO-EXISTING, ELUSIVE AND MORPHOLOGICALLY SIMILAR SPECIES: A CASE STUDY OF FOUR MACAQUE SPECIES IN NAKAI-NAM THEUN NATIONAL PROTECTED AREA, LAOS



Introduction

Environmental niche models are increasingly used to understand species' habitat use, to study their evolutionary biogeography, and to predict their geographic distribution at regional or national scales in relation to their environment (e.g. Bojorquez-Tapia et al., 1995; Raxworthy et al., 2007; Buermann et al., 2008; Parolo et al., 2008; Martinez-Freiria et al., 2008; Pineda and Lobo, 2009). These models constitute useful tools to predict suitable habitat of species in areas where their distribution is little known.

Species misidentification is a common issue during field surveys, especially so when dealing with morphologically similar species that flee when sighted (e.g. Timmins et al., 1998; Duckworth et al., 2010; Timmins and Duckworth, 2013). Camera-traps, in contrast, can capture clear images that allow detailed examination of morphological difference between such species and result in reliable species occurrence data (necessary for environmental niche modelling). In addition, camera-traps increase the probability of records of elusive species, compared to field surveys (e.g. Duckworth et al., 2005; Tobler et al., 2008) making the technique particularly valuable when direct data collection in the field is logistically challenging, financially constrained and time consuming. Such data are furthermore rarely readily available to the scientific community. Although the importance of camera-trap data is acknowledged for understanding species' ecology (Moruzzi et al., 2002; Di Bitetti et al., 2010; Peirera et al., 2012) these data have rarely been used in combination with species niche modelling (e.g. Jenks et al., 2012). Taking this further, combining camera-trapping data and species niche modelling provides a powerful technique to explore the ecological relationships of co-existing, cryptic and morphologically similar species (e.g. macaques, small cats, civets, ungulates).

In this study, I focus on macaque species. Four macaque species occur in the study area, Nakai-Nam Theun National Protected Area (NNT NPA), Laos: rhesus (*Macaca mulatta*), Northern pig-tailed (*M. leonina*), Assamese (*M.*

assamensis) and stump-tailed (*M. arctoides*) macaques. Each has been previously confirmed from field sightings (Timmins and Evans, 1996) and camera-traps (WMPA unpubl. data). Field identification confusion can occur between species, however, and this is further emphasized by the unreliable and mis-identification of macaques by villagers living alongside the species' habitat (Timmins and Duckworth, 2013). Fooden (1982) predicted ecological segregation across their range amongst these species, but until now this has rarely been studied in the field (Eudey, 1991; Rodman, 1991; Borries et al., 2002), and never in Laos, where all four taxa are under threat from hunting. The predictive distribution of macaque species in NNT NPA will help us understand the difference in ecological niche between these four species. I use confirmed identified camera-trap photos from 2006-2011 and field records from 2011-2012 to model their distribution using the maximum entropy (MAXENT) statistical method.

Methods

Study Area

Nakai-Nam Theun National Protected Area (NNT NPA), ~3550 km^2, is located in the central-east of Laos within the Annamite mountain range (Figure 5.1). The area remains largely forested (~80%), despite 31 enclave villages (Robichaud et al., 2009) with mixed semi-evergreen/coniferous, upper montane, dry-evergreen and wet evergreen forests (Timmins and Evans, 1996). Elevation throughout the NPA ranges from ~200 m to c. 2300 m a.s.l. Annual precipitation ranges from 1865 mm to 2620 mm and annual mean temperatures from 14°C to 24° C, with extremes of 4°C to 32°C (Hijmans et al., 2005).

Biological and Environmental Data

Occurrence data for macaque species come from camera-trap and transect survey data. From 2006 to 2011 systematic camera-trapping was carried out

in the area by the Nam Theun 2-Watershed Management and Protection Authority (WMPA unpubl. data; Johnson and Johnston, 2007). Camera-trap sampling was designed as to be as representative as possible of the different habitats in NNT NPA for long-term monitoring of its wildlife (Johnson and Johnston, 2007; Johnson et al., 2005). I examined all photos taken over the study period and selected all photos of macaque species to identify them at species level. I identified species in light of their respective morphology, clearly observed on photos, and validated my identifications with expert opinion (Timmins R.J.). In addition, I conducted transect surveys in 2011-2012 within the area during which I recorded all diurnal primate species. Given the difficulty to identify macaque species in the field due to poor visibility and fleeting behaviour of the animals, I use only confirmed species records (i.e. involving observation of species-typical characteristics) for the analysis. Ten different sites were sampled with camera-traps from 2006 to 2011, with a total of 20216 camera trap-days and ten sites were visited for transect surveys in 2011-2012, totalling 310 km walked (Table 5.1; Figure 5.1). I obtained a total of 48, 38, 34 and 14 locality points for *M. arctoides*, *M. assamensis*, *M. leonina* and *M. mulatta*, respectively (Table 3.2).

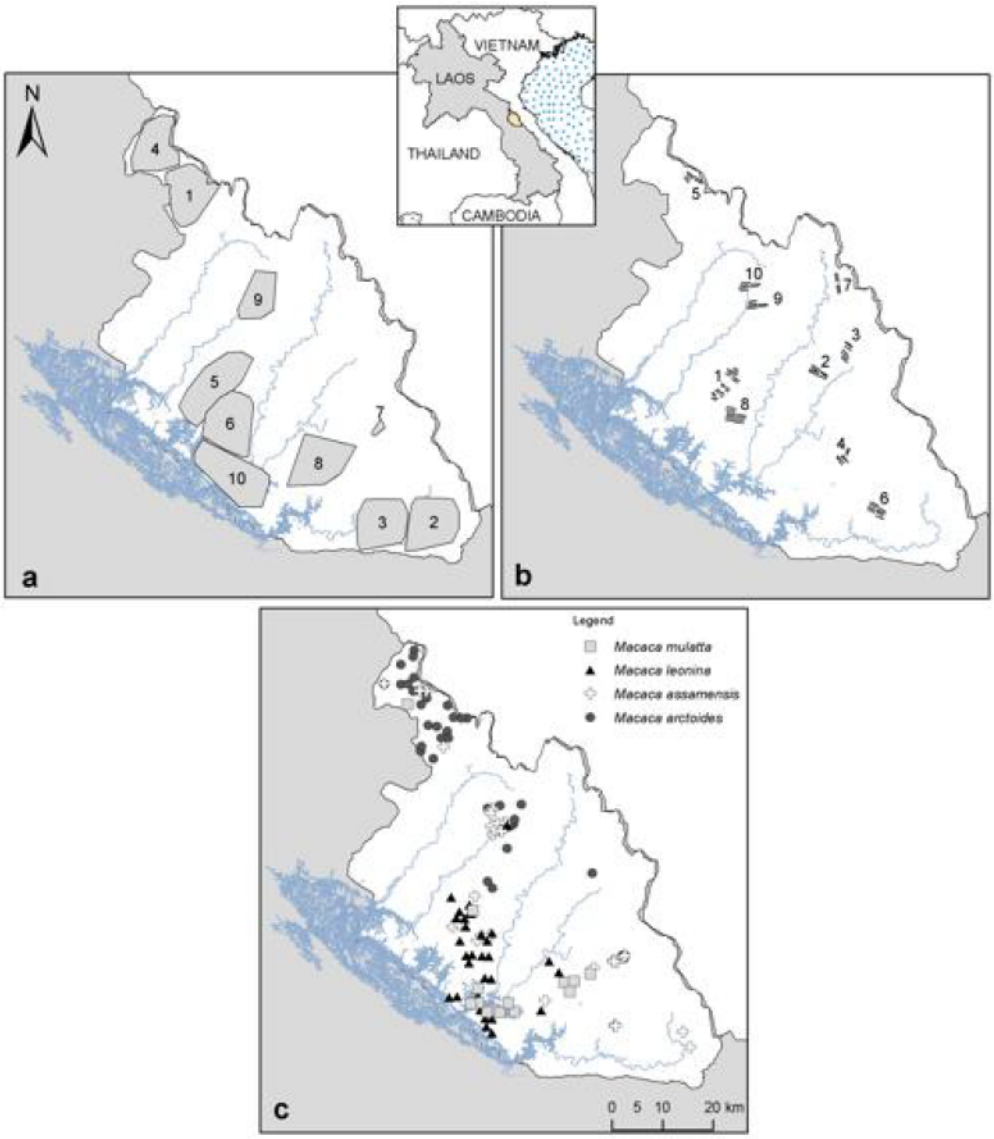


Figure 5.1: (a) Camera-trap sampling effort from 2006-2011 (sampling areas obtained with a minimum convex polygon around camera-traps set; c.f. Table 5.1); (b) transect surveys from 2011-2012, total km walked, including replications are presented in Table 5.1; (c) Macaques species occurrence localities used for the models.

Table 5.1: Details of camera-trapping and transect survey effort in Nakai-Nam Theun NPA from 2006 to 2012.

Camera-trap surveys				**Transect surveys**			
Site # on Fig. 1	**survey period**	**Total cameras[a]**	**Camera-trap-day**	**Site # on Fig. 1**	**Survey period**	**Nb. transects (rep.)**	**km walked**
1	Mar – May 06	49	2181	1	29 Jan – 2 Feb 11	20 (x1)	21
2	Oct – Nov 06	49	1638	2	17 Feb – 6 Mar 11	6 (x3) 1 (x1)	36
3	Dec 06 – Feb 07	49	1705	3	13 Mar – 31 Mar 11	7 (x3) 1 (x2)	40
4	Mar – May 07	48	2134	4	18 Jul – 3 Aug 11	6 (x1)	11
5	Nov 07 – Jan 08	50	2308	5	16 Sept – 28 Sept 11	6 (x1)	10
6	Jan – Mar 08	47	1846	6	19 Oct – 4 Nov 11	8 (x3)	42
7	Apr – Aug 08	32	1687	7	11 Jan – 23 Jan 12	4 (x3)	22
8	Nov 08 – Jan 09	22	1174	8	10 Feb – 27 Feb 12	10 (x3)	58
9	Mar – May 09	3	183	9	12 Mar – 24 Mar 12	6 (x3)	34
10	Nov – Dec 09	40	1636	10	25 Mar – 5 Apr 12	6 (x3)	35
9	Mar – May 10	45	2405				
1	Dec 10 – Jan 11	33	1319				
TOTAL	**Mar 06 – Jan 11**	**467**	**20216**	**TOTAL**	**Jan 11 – Apr 12**	**176**	**310**

[a] Only one camera was set at each locality (i.e. no paired cameras)

Table 5.2: Occurrence from camera-trap and transect survey data used for the distribution modelling of each species. Note: Of a total of 114 independent images of macaque species, only two remained unidentified, while of the 55 sightings of macaques during our transect surveys, 33 remained unidentified. Species were identified by examining respective specific morphological characteristics.

Species	Occurrence from camera-trap	Occurrence from confirmed sighting	**Total**
M. mulatta	14	0	**14**
M. leonina	31	3	**34**
M. assamensis	22	16	**38**
M. arctoides	45	3	**48**

I used 25 environmental variables in our models, of which 19 are derived from monthly min/max temperature and precipitation data averaged as annual trends for the period 1950-2000 (30 arc-second/1km^2 resolution;

<http://www.worldclim.org/current>; Hijmans et al., 2005). I retrieved elevation layer from the CGIAR Consortium for Spatial Information (<http://srtm.csi.cgiar.org/>). Land cover data were generated by the Lao National Geographic Department in 2002 and includes 24 categories from which 14 (upper evergreen, upper mixed deciduous, pine, mixed broadleaf-coniferous, unstocked, bamboo, ray, savannah, scrub, rice paddy, rock, grassland, swamp, water bodies) are found within the boundary of NNT NPA. I obtained vegetation continuous field (i.e. percent vegetation cover) from the Global Land Cover Facility (<http://glcf.umiacs.umd.edu/data/vcf/>). I derived slope from elevation and distance from water and villages from villages and watercourse features using Euclidean distances in ArcGIS 9.3. The same geographic extent, cell size (90 m; this resolution is considered adequate given in general a >1km^2 home range size of macaque species; Thierry, 2010) and projected coordinate system (WGS 1984 UTM Zone 48N) were selected for each layer and species localities.

Species Distribution Modelling

To model the potential distribution and niche of macaque species in NNT NPA, I used the maximum entropy general purpose machine learning method, which has been adapted and developed as a software (MAXENT) for species distribution modelling (Phillips et al., 2004; Phillips et al., 2006) and identified as one of the best methods for species niche modelling (Elith et al. 2006). MAXENT version 3.3.3k is used to perform the analysis (http://www.cs.princeton.edu/~schapire/maxent/). The method combines biological data of species occurrence (presence only data) with environmental characteristics (e.g. GIS layers with a grid of values for the geographic area considered) to estimate the probability distribution of maximum entropy (i.e. closest to uniform), subject to the set of constraints provided (i.e. environmental characteristics where the species occurs) (Phillips et al., 2006).

Model Building

For each species, I used a ten-fold cross-validation replication run type (Kohavi, 1995) where a sample of the occurrence localities is randomly allocated for test data (for model evaluation) at each of the ten replications. I set all other settings as default as they perform well and are robust for a large range of datasets tested, which our data can compare to (Phillips and Dudik, 2008).

Model Evaluation

I assessed the performance of the models using four methods: (i) the area under curve (AUC) of the receiver-operating characteristic (ROC) (ii) the use of a null-model (Raes and Steege, 2007), (iii) the Boyce Index method (Boyce et al., 2002), (iv) and the jackknife validation method (Pearson et al., 2007) for our smallest sample only. In addition, results outputs are interpreted in term of known ecology of the study species at National scale, published by experts (c.f. Discussion).

The AUC of ROC is provided in the model outputs. It is obtained by plotting *sensitivity* on the x-axis and 1–*specificit*y on the y-axis, with *sensitivity* representing the proportion of correct prediction of actual presence (true-positive, or absence of omission), whereas 1-*specificity* is the proportion of falsely predicted presence (false-positive, or commission error) for all possible thresholds of the probability (threshold independent evaluation). In presence only models, the AUC value represents the probability that the model scores a presence site (test locality) higher than a random background site (Phillips et al., 2006). The value ranges from 0.5 to 1–$a/2$, where a is the fraction of pixels covered by the species' distribution that remains unknown, thus renders inadequate the interpretation of AUC (Phillips et al., 2006; Raes and Steege, 2007; Yost et al., 2008). Nevertheless, it remains the most commonly used evaluation parameter and is presented here. An AUC value closer to 1

indicates that the model predicts better than random, while a value of 0.5 indicates that the prediction is no better than random (Phillips et al., 2006).

Given the recent critics of using AUC for presence only model evaluation (Raes and Steege, 2007; Yost et al., 2008), I used other methods to evaluate the performance of the model outputs. A recently developed alternative is the null-model, which was introduced by Raes and Steege (2007). The method tests the AUC value of the model against a null distribution of expected AUC values based on random occurrence data from the geographic area considered. More concretely, it tests if the relations between species occurrence and environmental variables at these locations are stronger than expected by chance (Raes and Steege, 2007). The exact same number of occurrence points available for each species (48, 38, 34 and 14; cf. Table 5.2) were randomly drawn across NNT NPA and replicated 999 times. These null-distributions were run separately in MAXENT with the same settings detailed above. This resulted in 999 AUC values of the null-model for each of the four species. AUCs of the null-models were ranked and the position of the real species' AUC was tested against the 95% confidence interval (CI) of the null-model's AUC values. The species' model is considered performing better than expected by chance if its AUC value is ≥ 95% CI null-model's AUCs (Raes and Steege, 2007).

In addition, I apply the Boyce Index validation method (Boyce et al. 2002; Hirzel et al., 2006) to the models. The continuous habitat suitability scores obtained from the outputs (0 to 1) are reclassified into a number *i* of bins (classes). For each class, two frequencies of pixels are calculated: the Predicted Frequency and the Expected Frequency. The Predicted Frequency is the number of occurrence points predicted by the model falling into the class *i* divided by the total number of occurrence points. The Expected Frequency is the number of grid cells included in class *i*, divided by the total number of grid cells in the whole geographic area considered. A Predicted-to-Expected (P/E) ratio is calculated for each class and a Spearman rank correlation coefficient *rho* (1-tailed test) evaluates if the ratio significantly increases as suitability

increases ($p<0.05$) (Hirzel et al., 2006). Our models' outputs were reclassified into 100 continuous classes of equal interval and I calculated a P/E ratio for each class. Statistical tests were performed with SPSS.v.17.

Finally, for the smallest sample (*M. mulatta*; n=14), I followed the jackknife validation method for samples n<25 described by Pearson et al. [30], in which it is assessed if the model successfully predicts the n left-out localities (one locality at each of the 14 replications) within the area of suitability (under the minimum training presence threshold chosen). This is assessed with a pValue based on the test statistic *D; D*=$\sum X_i$ $(1-P_i)$, where X*i* is the success-failure variable indicating if the *i*th left-out locality is included or not in the predicted area and P*i* is the probability of success (Pearson et al., 2007). The pValue is computed with *pValue compute* program (Pearson et al., 2007).

Output Analysis

To produce a binary map (i.e. suitable vs. non-suitable habitat), I used the '*minimum training presence logistic*' threshold, which has been commonly used when occurrence data are highly reliable, such as here, given the confirmed species identification and records in their primary habitat. This threshold has the advantage to maintain zero omission error and include all areas that are at least as suitable as those where the species is known to occur (Hernandez et al., 2006; Pearson et al., 2007). The final potential distribution for each species was projected (WGS 1984 UTM Zone 48N) in ArcGIS 9.3.

I calculated mean values of environmental variables within the predicted distribution of the four species. Predicted suitable habitat of the four species is also tested pair-wise for their similarity using two different statistical tests that compare the logistic habitat suitability scores provided in MAXENT's model outputs: Schoener's D (Schoener, 1968) and *I* statistic (Warren et al., 2008). Their value ranges from 0 (no overlap in habitat suitability) to 1 (complete overlap in habitat suitability); they are calculated using the

ENMTool (Warren et al., 2008). Range overlap is also quantified with ENMTool with the formulae ($N_{x,y}$/min[N_x, N_y]), where $N_{x,y}$ is the number of grid cells where both species x and y are predicted to occur and N_x and N_y are the number of grid cells where respectively species x and y are predicted (Warren et al., 2008). I apply a threshold at which habitat is considered suitable, using the average of all four species' 'Minimum training Presence logistic' threshold (=0.171).

Results

Model validation

The four species' models obtained AUC values ranging between 0.8 to 0.9. When tested against a null-model, two of our models (*M. arctoides* and *M. leonina*) performed significantly higher than random ($p<0.05$). Comparatively, the Boyce Index validation test indicated a significant model prediction for the four species. The model for *M. mulatta* also showed a significant predicting success rate ($p<0.01$) when evaluated with Pearson et al.'s jackknife method (Table 5.3).

Table 5.3: Model validation with test AUC values, null-model, Boyce Index and jackknife methods.

Species	Species-model's test AUC	Null-model's 95% C.I. training AUC	pValue Boyce Index (Spearman's *rho*)	pValue Jackknife test (*D* statistic)
M. arctoides	0.902*	0.783	0.000**	-
M. assamensis	0.803	0.811	0.001**	-
M. leonina	0.895*	0.820	0.000**	-
M. mulatta	0.779	0.817	0.039*	0.001**

** species-model performed better than expected by chance, $p<0.05$

** species-model performed better than expected by chance, $p<0.01$

Species distribution models outputs

Predicted geographical distribution varies between the four macaque species but shows areas of overlap, in accordance with occurrence records collected (Table 5.4). The four species have a general predicted distribution with *M. arctoides, M. assamensis, M. leonina* and *M. mulatta*, respectively along a geographic gradient (Figure 5.2). Both *M. assamensis* and *M. arctoides* are predicted predominantly in evergreen and mixed-deciduous forests and the farthest from village settlements (average of 13 and 16 km, respectively). *M. leonina* and *M. mulatta* are predicted mainly in evergreen and mixed broadleaf-coniferous forest. The latter two species are predicted the closest to villages (average of 6 and 8 km, respectively).

Table 5.4: Number of locations (GPS coordinate) that are common between the four species; obtained from the total occurrence points of each species used for the model (c.f. Table 5.1).

Species	*M. arctoides*	*M. assamensis*	*M. leonina*	*M. mulatta*
M. arctoides	--	7	1	0
M. assamensis		--	0	0
M. leonina			--	3
M. mulatta				--

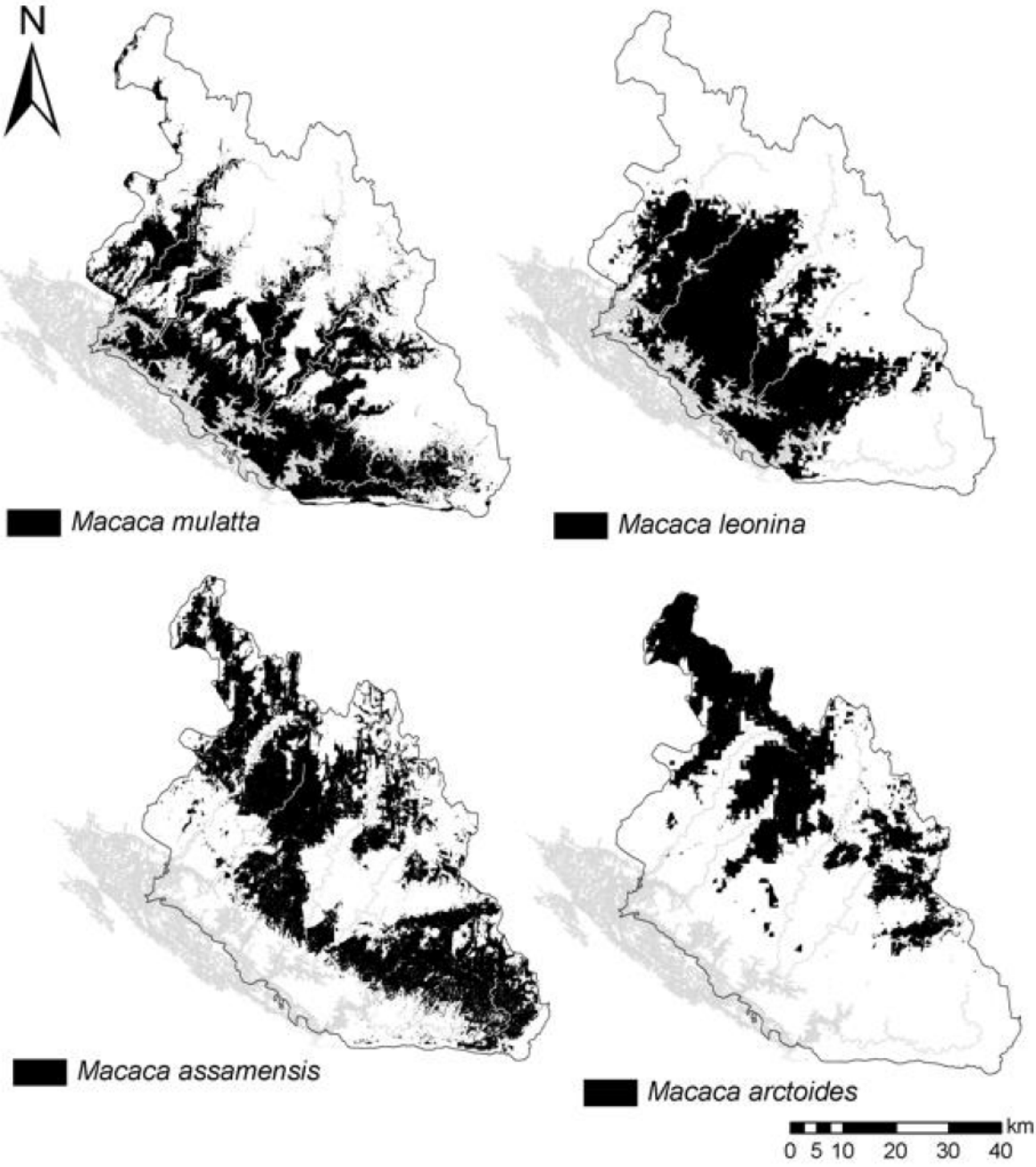


Figure 5.2: Predicted distribution of the four species of macaques occurring in NNT NPA (predicted distribution size: *M. arctoides* 877 km^2; *M. assamensis*: 1476 km^2; *M. leonina* 1305 km^2; *M. mulatta* 1289 km^2).

As per respective predicted species distribution, there is a gradual change throughout the NPA in predicted mixed-species range overlap. Using the average of the four species' minimum training presence threshold, the largest overlap is between *M. arctoides* and *M. assamensis* (overlap index: 0.77), and the smallest between *M. arctoides* with *M. mulatta* and *M. leonina* (0.12) (Table 5.5). The predicted distribution of *Macaca assamensis* overlaps the most (average of 0.54) with all other species, resulting from a widespread predicted distribution across the area (Table 5.5).

Table 5.5: Range overlap index between the four macaque species using a threshold of presence of 0.171; range overlap between species x and y = ($N_{x,y}$/min[N_x, N_y]), where $N_{x,y}$ is the number of grid cells where both species x and y are predicted and N_x and N_y are the number of grid cells where respectively species x and y are predicted.

Species	*M. arctoides*	*M. assamensis*	*M. leonina*	*M. mulatta*
M. arctoides	--	0.77	0.12	0.12
M. assamensis		--	0.51	0.35
M. leonina			--	0.78
M. mulatta				--
Average	**0.33**	**0.54**	**0.45**	**0.42**

In accordance with the predicted distribution overlaps between species, the niche similarity statistical tests indicate that the predicted suitable habitat of *M. arctoides* and *M. assamensis* as the most closely comparable, while the one of *M. arctoides* as the most distant from *M. leonina* and *M. mulatta* (Table 5.6). Further to the respective gradual geographic distribution predicted, environmental characteristics within their potential distribution differ between the four species with *M. mulatta* and *M. arctoides* at the two extremes. While *M. mulatta* is modelled predominantly in a wetter and hotter niche at lower elevations and on flatter terrain, *M. arctoides* is predicted to inhabit drier and colder areas, at the highest elevations and terrain with steepest slopes (Figure 5.3).

Table 5.6: Pair-wise niche similarity statistical test (*D*, *I*) scores.

Species	test	*M. artoides*	*M. assamensis*	*M. leonina*	*M. mulatta*
M. artoides	*D*	--	0.55	0.20	0.22
	I	--	0.83	0.41	0.47
M. assamensis	*D*		--	0.39	0.40
	I		--	0.66	0.70
M. leonina	*D*			--	0.52
	I			--	0.79
M. mulatta	*D*				--
	I				--

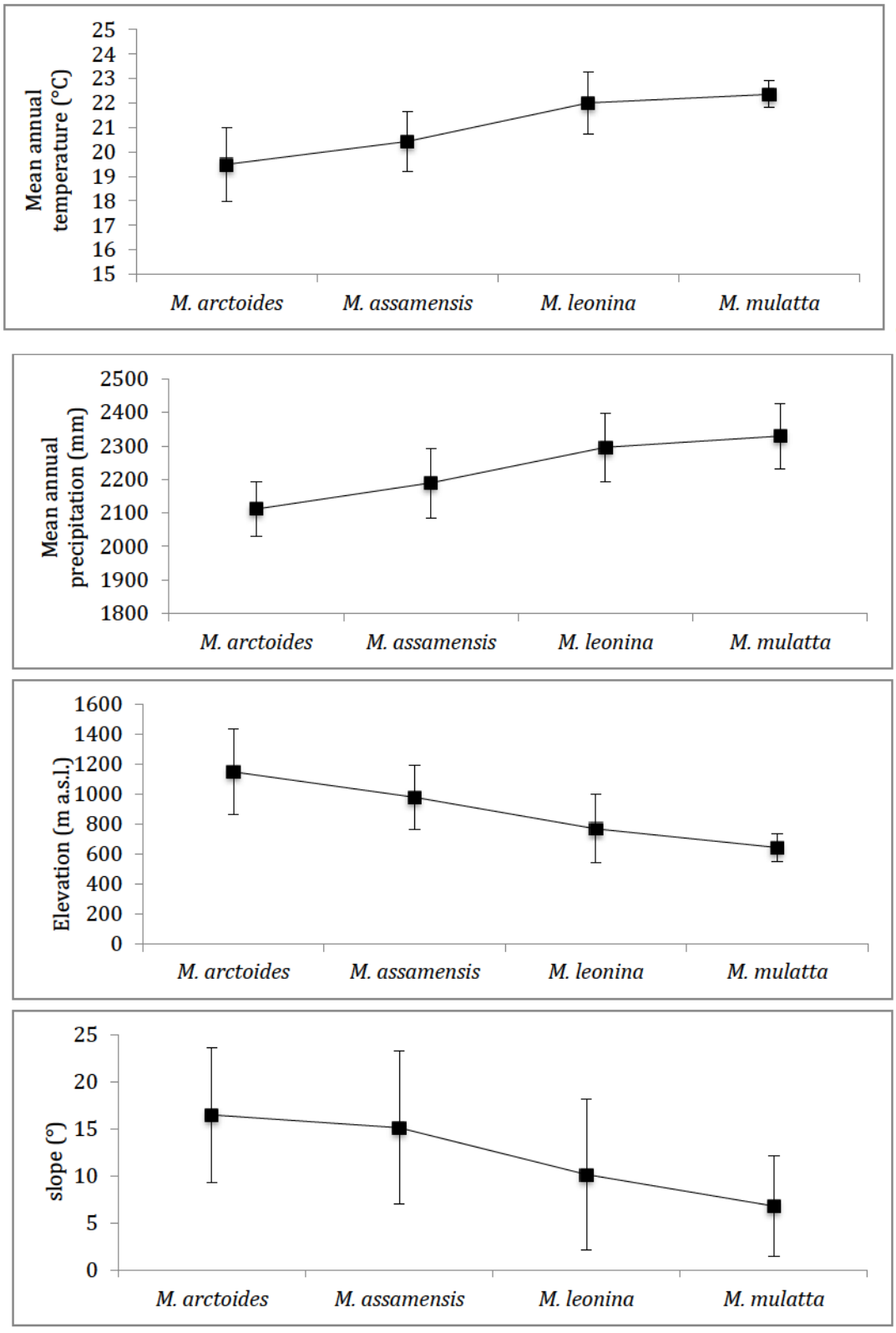


Figure 5.3: mean (and standard deviation) annual temperature (a), annual precipitation (b), elevation (c) and slope (d) in respective predicted distribution of each macaque species, based of their binary predicted distribution under the minimum presence threshold.

Discussion

Macaques' predicted distribution and niches

The potential distributions obtained from the models in this study indicate a niche differentiation between the four species occurring in NNT NPA. The four species' distributions alternate in parapatry and sympatry throughout the NPA as species are constrained along a gradient variation in environmental parameters.

Potential distribution of *Macaca mulatta* is mostly predicted in lowland (mean elevation 645 m a.s.l.) and flat terrain in mixed broadleaf-coniferous and evergreen habitat, and closely associated with water sources. It is the main species for which distribution is predicted around village clusters and main rivers, which is also the case across the country (Duckworth et al., 1999). *Macaca leonina* is found mainly in the west and avoids higher elevations and colder climate further east. *Macaca assamensis* is the most widespread species across the NPA. As a result, its habitat range overlaps and shares the most similarities with all other taxa. In Laos, it is the most common macaque species in mountainous areas and is also found at lower elevations in limestone formations (Timmins and Duckworth, 2013). *Macaca arctoides* is distributed the furthest east in NNT NPA, along the Lao-Vietnam border. Its niche is characterised by the highest elevations (mean 1098 m. a.s.l.) and the most rugged terrain. It inhabits mostly dense evergreen and mixed-deciduous forests at cooler annual temperatures.

Macaques are the most widespread group of monkeys in Southeast Asia (Abegg and Thierry, 2002). Most species from the genus have only diverged phylogenetically during the Pleistocene (~2 mya), resulting in similar morphologies observed today (brown colour, similar size; ~6.5 to 12.2 kg for our study species; Eudey, 1980; Thierry, 2010). Identification success of macaques species during field surveys was relatively low, as previous

researchers have found (Timmins and Duckworth, 2013). Thus, camera traps proved essential here for our modelling of their ecological niches. Despite morphological similarity, however, Fooden (1982) suggested that throughout Southeast Asia macaque species are ecologically and/or geographically segregated, resulting from interspecific competition. Ever since, macaques' ecological segregation at a local scale had rarely been studied (Eudey, 1991; Rodman, 1991; Borries et al., 2002) and never using a habitat suitability model.

Due to their proximity to human settlements, *M. mulatta* and *M. leonina* are at risk from hunting; macaques are indeed hunted for food in NNT NPA and macaque bones are commonly encountered in poacher camps in the NPA (Coudrat CNZ pers. data). Wildlife is mainly hunted using ground snares, set widely in the area (Coudrat CNZ pers. data). Distances from villages are not necessarily good predictors of hunting pressure in this case, as Vietnamese poachers commonly cross the international border for hunting (Coudrat CNZ pers. data). Two of the four species are classified as globally threatened in the IUCN Red List (VU *M. arctoides* and VU *M. leonina*) (IUCN, 2012a). Although species distribution models are effective to explore species' niche, these can be subject to prediction uncertainties and should be used as baseline studies to further investigate local species' habitat that can be validated and refined *post hoc* with additional field data (Wintle et al., 2005). Anthropogenic factors are, for instance, rarely well represented in models: species may have been extirpated from areas that have been deforested or under severe pressure of hunting. It is also important to note that the respective predicted distributions of the four species may have been influenced by the sampling bias across the area, resulting in unpredicted regions where the species may occur (Phillips et al., 2009). Nonetheless, the use of reliable biological data for the models makes the predictions and analysis highly informative (Blanco et al., 2012).

Model performance

I demonstrate the value of MAXENT in ecological studies (Martinez-Freiria et al., 2008; Thorn et al., 2009; Chunco et al., 2012), and in this case for examining the ecological nice of sympatric taxa. MAXENT has been demonstrated as one of the best methods to handle small sample sizes (Hernandez et al., 2006; Wisz et al., 2008). Although the method has been improved in the past few years (Phillips and Dudik, 2008), new issues have been identified and assessed to improve the predictions of MAXENT's models (e.g. Graham et al., 2008; Parolo et al., 2008; Phillips et al., 2009; Pineda and Lobo, 2009). I note that methods both for model selection and model validation still need to be refined. No consensus exists on variable selection methods; in any case, variables should be selected in terms of the species' ecology and represent the complexity of the ecosystem, avoiding over- or under-parameterization (Warren and Steifert, 2011). I remark that the AUC value is not reliable on its own for model validation. Our four models were significantly better than random as indicated by the Boyce Index and by the jackknife method for *M. mulatta*, but only indicated a significant predictive power for two species when tested against a null-model. This highlights the uncertainties of model predictions and the need of using several validation methods in species niche modelling. The smallest AUC values for *M. assamensis and M. mulatta,* not validated by the null-model method, may be due to their ecological and geographical wider range which is commonly observed for such species (Phillips et al., 2004; McPherson and Jetz, 2007).

Implications

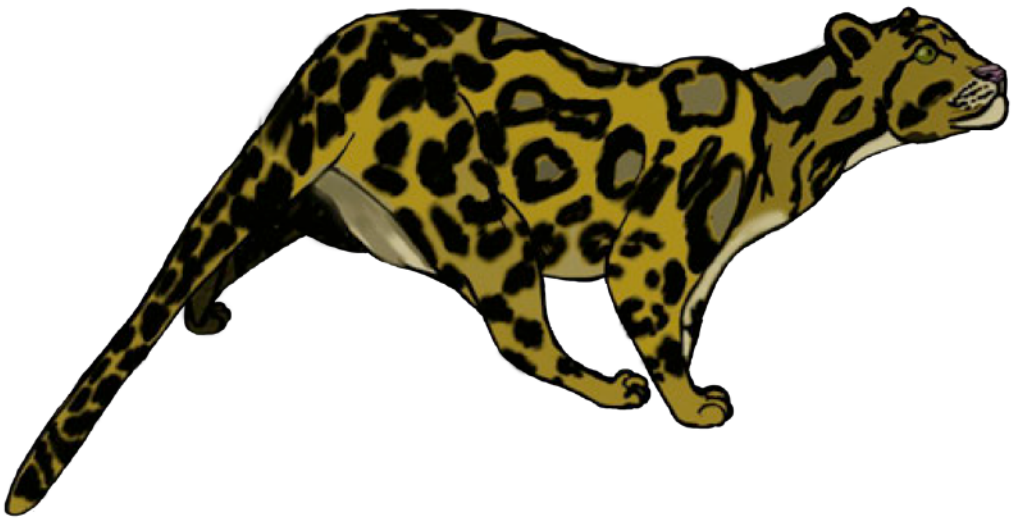
In Laos and elsewhere in Southeast Asia, several species have rarely been directly observed in the field or are difficult to identify and differentiate from other taxa from signs only or when briefly sighted. Some of these species have mostly been recorded with camera traps only (e.g. saola *Pseudoryx nghetinhensis:* Hardcastle et al., 2004; large-antlered muntjac *Muntiacus vuquangensis:* Johnson and Johnston, 2007; Annamite striped rabbit

Nesolagus timminsi: Surridge et al., 1999; Sumatran striped rabbit *N. netscheri*: McCarthy et al., 2012; Owston's civet *Chrotogale owstoni*: Johnson et al. 2006; several small to medium-sized cats: Mohamed et al., 2009; Wilting et al., 2012). Of these species, all are classified by the IUCN (2012a) as globally threatened or remaining Data Deficient. Potential species distributions are crucial for species management planning of threatened species, especially in the context of the biodiversity crisis well known in Southeast Asia (Sodhi et al., 2004; Duckworth et al., 2012), where 'protected' status of most forested areas does not imply long-term viability and protection of habitar or species (Catullo et al., 2008; Yen et al., 2005).

Camera-trapping can increase elusive-species records with a relatively reduced and more systematic (less biased) sampling effort (Kelly, 2008). These accumulated occurrence data, when combined with species distribution modelling, can be used to examine unresolved species' niches and potential distributions, which will have crucial implications for future research and species management and conservation. The analysis presented can be used as such by relevant management authorities and biologists for macaques in NNT NPA. These techniques can be applicable to even the most remote regions and the least known species and call for more wide availability and open access to such long-term camera trap data.

CHAPTER 6

LOW ABUNDANCE OF SMALL AND MEDIUM-SIZED WILD CAT SPECIES IN HEAVILY-HUNTED LARGE PRIMARY FORESTS: A CASE STUDY OF NAKAI-NAM THEUN NATIONAL PROTECTED AREA, LAOS



Introduction

Wildlife surveys across many parts of the Lao People's Democratic Republic (Lao PDR or Laos) in the 1990s improved knowledge of the country's wildlife status and distribution (Duckworth et al., 1999). Yet information on wild cats firmly identified to species remains scarce, mainly due to the difficulty to detect these generally inconspicuous animals with the common general-wildlife-survey methods (direct day-time and night-time observation). Most information collected purportedly about cats is from signs (tracks and scats, both difficult to identify at species level by visual inspection), interview reports from villagers (that similarly cannot be confirmed at species level for small cats and are often demonstrably unreliable) and/or live or dead animals found in markets or villages (for which the exact, and often even the general, locality whence they came is uncertain). Field sightings, although rare, did occur, however, for some species in the 1990s (e.g. Duckworth, 1996; 1997; 1998; Showler et al., 1998; Duckworth et al., 2005; 2010) but direct field sightings by competent faunal surveyors in the 2000s are extremely rare, other than perhaps of leopard cat.

Automatically triggered cameras-traps have been increasingly used in the past two decades and represent the most reliable technique to estimate density or an index of status of cats worldwide (e.g. Karanth, 1995; Karanth and Nichols, 1998; Yasuda, 2004; Maffei et al., 2004; Kawanishi and Sunquist, 2004; Soisalo and Cavalcanti, 2006; Heilbrun et al., 2006; Jackson et al., 2006; Shek et al., 2007; Tobler et al., 2008; Royle et al., 2009; Lynam et al., 2009). This method has increased the chances to record elusive animals and has been determinant in the status clarification of various Lao species poorly known across their small world ranges (e.g. saola *Pseudoryx nghetinhensis*: Robichaud and Stuart, 1999; Hardcastle et al., 2004; large-antlered muntjac *Muntiacus vuquangensis*: Dersu, 2007; Johnson and Johnston, 2007; Duckworth *et* al., 2010; Rasphone 2010; Annamite striped rabbit *Nesolagus timminsi*: Surridge et al., 1999; Johnson and Johnston, 2007; Duckworth et al., 2010; Owston's civet *Chrotogale owstoni*: Johnson et al., 2006; Sivilay et al.,

2011). Conservation projects in Laos started using camera-traps in the late 1990s in a few forest areas, with larger-scale deployment in the 2000s to attempt population monitoring and to inform conservation management (Nam Et-Phou Louey NPA: Johnson et al., 2009; Nakai-Nam Theun NPA: WCS, 1997; Robichaud and Stuart, 1999; Johnson and Johnston, 2007; WMPA, unpubl. data; Laving-Laveun Provincial PA: Duckworth et al., 2010).

Laos may hold up to eight wild cat (Felidae) species, with status according to the *IUCN Red List of Threatened Species* (IUCN, 2012a): Least Concern (LC) leopard cat *Prionailurus bengalensis*, Near Threatened (NT) Asian golden cat *Catopuma temminckii*, Vulnerable (VU) marbled cat *Pardofelis marmorata*, VU clouded leopard *P. nebulosa*, Endangered (EN) tiger *Panthera tigris* and NT leopard *Panthera pardus* are all confirmed (though last records of tiger dates back from the late 1990s). The occurrence of EN fishing cat *Prionailurus viverrinus* and LC jungle cat *Felis chaus* remains unconfirmed although at least the latter is highly likely to occur, or to have done so until recently (Duckworth et al., 2005; Duckworth et al., 2010). Data on small and medium-sized cat species (~2 – 20kg, non-*Panthera*) are scarce and their national status has been classified as either 'At Risk' or 'Little Known' in Laos, excepting leopard cat, which in the 1990s was clearly widespread and common (Duckworth et al., 1999). Little information has been generated since the 1990s; records with credible species-level identification and known locality were only made from camera-traps, and only rarely in most of the few areas thus surveyed, excepting Nam Et Phou Louey NPA with a large number of records (Johnson et al., 2009). The small number of recent records of non-*Panthera* cat species in Laos certainly reflects at least in part the scarcity of field surveys after 1999, but there is also the greatly concerning possibility it could indicate current low densities of these animals in the country's forests.

Nakai-Nam Theun National Protected Area (NNT NPA), central-eastern Laos, was found to hold six cat species in 1996–1997 (WCS, 1997; Duckworth, 1998), supplemented by plausible reports of fishing cat and jungle cat in nearby areas (Duckworth et al., 2005; Duckworth et al., 2010). In 2005,

relating to the imminent construction of a hydroelectric power dam at the edge of the NPA, a governmental organisation authority (the Nam Theun 2 Watershed Management Protection Authority – NT2 WMPA) was specifically created to manage, protect and monitor habitats, wildlife and local communities in the area. Part of their mandate is to monitor the area's wildlife systematically via transect and camera-trap surveys.

The area is one of the largest blocks of contiguous forest in mainland South-east Asia outside Myanmar and Cambodia, but supports the high levels of hunting typical of much of Laos and Vietnam. Ground snares, principally made out of wire (and alternatively of rope or natural material, e.g. vines), are the hunting technique the most used in NNT NPA; they are found almost throughout the NPA, even in some of the most remote areas, and are primarily set by Vietnamese hunters (Coudrat, 2012a). The low cost and effort combined with a relative high catch render the use of snares attractive to hunters in many regions of the world (Noss, 1998; Fa et al., 2001). Ground snares are non-selective and wasteful, with high proportion of caught animals lost to scavengers, predators or decomposition (Noss, 1998). Snares are typically made out of wires set along man-made or natural animal trails (Noss, 1998; Newton et al., 2008; Coudrat, 2012a). In NNT NPA, thousands can be collected during a short field trip at one site, and the remains of trapped animals are often encountered (Coudrat, 2012a; W.G. Robichaud pers. comm., 2011). Therefore, the current status of cats in NNT NPA is particularly informative about the regional risks they may face from hunting.

I present the records of non-*Panthera* cat species from the camera-trap surveys in NNT NPA from 2006 to 2011. In addition, I review other 1990s-present records from NNT NPA and adjacent Nakai Plateau and corridor area. This information will help evaluating the state of these species' population in this large, mostly little-degraded and legally protected forest block in Laos.

Methods

Nakai-Nam Theun National Protected Area (Figure 6.1) is ~3550 km^2 with altitudes ranging from ~500 to >2200 m a.s.l.. Around 80% of the area remains covered in forest (Robichaud et al., 2009). It is dominated by old growth mainly undisturbed dry-evergreen forest, with other localised habitat including pine/semi-evergreen, upper-mountain and wet-evergreen forest (Timmins and Evans, 1996). Thirty-one villages are located within the NPA; each village is allocated subsistence-use forest areas, where they are allowed to collect non-timber forest products, including some common wildlife species according the Wildlife and Aquatic Law and Forestry Law (National Assembly Laos, 2007a; 2007b). The area shares an international border with Vietnam of ~150 km, about one-third of which is contiguous with a forested National Park on the Vietnamese side (Vu Quang National Park). The remaining adjacent land in Vietnam is unprotected.

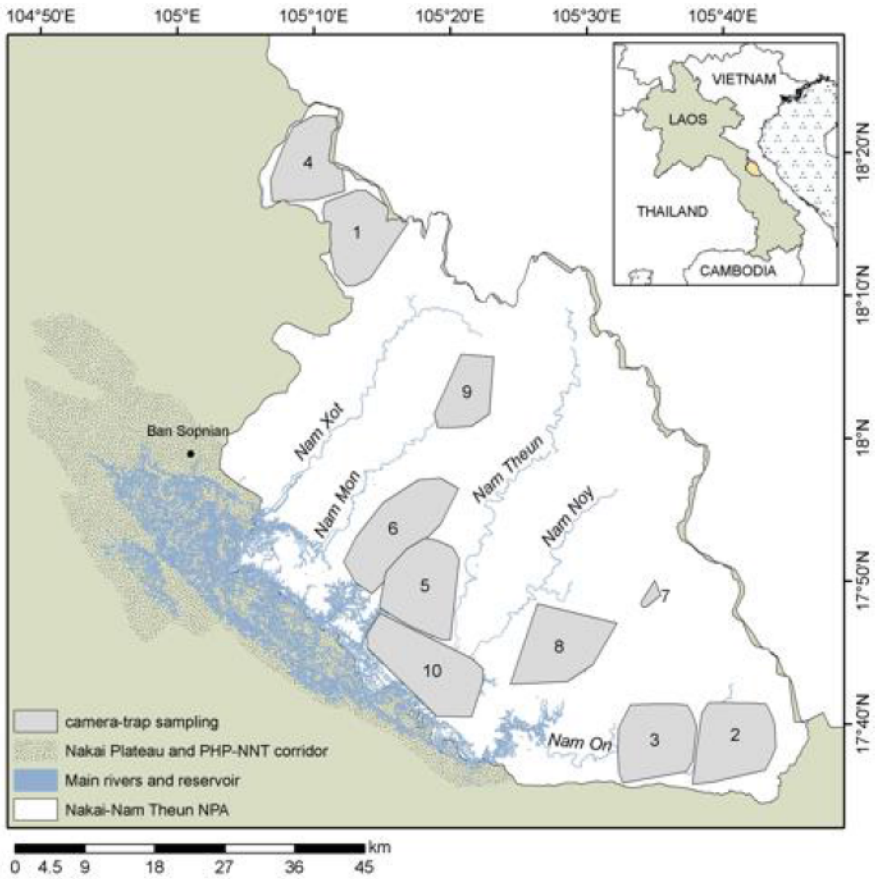


Figure 6.1: Camera-trap sampling areas in Nakai-Nam Theun NPA in 2006-2011.

The Nakai Plateau and Phou Hinpoun–Nakai-Nam Theun NPAs corridor (PHP-NNT), from which records are also reviewed (Table 6.4), are indicated on the map.

Numbers for each area indicate chronological order of sampling (c.f. Table 6.1)**: 1**: Khamkeut - Nam San; **2**: Nam On – Boualapha; **3**: Nam On – Gnomalath; **4**: Khamkeut - Tong Pae; **5**: Nam Chae – Makfuang; **6**: Nam Chae – Navang; **7**: Phou Vang - Houay Nam Heuy; **8**: Tong Xet; **9**: Nam Mon – Tong Kacheng; **10**: Nam Theun – reservoir.

I analysed camera-trap data obtained from systematic survey during 2006 to 2011 conducted in NNT NPA. Sampling design, training and surveys were done by the Wildlife Conservation Society-Lao Program (Johnson et al., 2005; Johnson and Johnston, 2007). From March 2006 to January 2011, camera-traps were set in 10 different survey blocks within NNT NPA's boundaries (Table 6.1; Figure 6.1). Three to 50 passive infrared cameras were set in a survey block, each camera being in general ~1km apart. Each was positioned on trees at a height of ~45 cm and in an optimal location near active animal trails or watercourse, without the use of lure or bait. Each camera was programmed to operate 24 hours per day and take photos at least 20-seconds apart. Most of the cameras (96.8%) were film-based with a maximum capacity of 36 photos, therefore the survey effort ceased once 36 photos had already

been taken. The remaining digital cameras had a large capacity of >600 photos, which was never reached before removal of the camera. Thus, survey effort for each camera is calculated from the day of the first photo taken to the day of the last photo taken. Total survey effort (camera-trap days, CTD) is the sum of all cameras' survey effort. Data from faulty cameras (i.e. cameras for which only the first test-photo was taken and thus no possibility to calculate camera-trap days) were removed from the analysis. For each camera, available data include: camera ID number, sampling area name, GPS coordinates of location, elevation (m a.s.l. taken with GPS unit), date and time of each photo taken.

Table 6.1: Details of camera-trapping survey effort in Nakai-Nam Theun NPA from 2006 to 2011.

Area (# on map)	time period	Total cameras[a]	CTD	Total photos taken[b]
Khamkeut - Nam San (1)	Mar-May 06	49	2181	1109 *
Nam On - Boualapha (2)	Oct-Nov 06	49	1638	357 *
Nam On - Gnomalath (3)	Dec 06-Feb 07	49	1705	344
Khamkeut - Tong Pae (4)	Mar-May 07	48	2134	721 *
Nam Chae - Makfueng (5)	Nov 07-Jan 08	50	2308	624 *
Nam Chae - Navang (6)	Jan-Mar 08	47	1846	601 *
Phou Vang - Houay Nam Heuy (7)	Apr-Aug 08	32	1687	1013
Tong Xet (8)	Nov 08-Jan 09	24	1217	344 *
Nam Mon - Tongkacheng (9)	Mar-May 09	3	183	1222
Nam Theun - reservoir (10)	Nov-Dec 09	40	1636	585 *
Nam Mon - Tongkacheng (9)	Mar-May 10	45	2405	2219 *
Khamkeut - Nam San (1)	Dec 10-Jan 11	33	1319	126
TOTAL	**Mar 06-Jan 11**	**469**	**20259**	**9265**

* survey-blocks in which cat species (non-*Panthera*) were recorded
[a] faulty cameras are excluded
[b] Includes test, unidentified and photos with no objects
CTD=camera trap days

I checked all photos taken (N=9265) during the survey time period to select and identify the non-*Panthera* cat species (referred to as 'cat species', hereafter) photo records (Table 6.2). Photo records of the same species are considered independent when taken more than 30 minutes apart (as there were no cases of apparently different individuals or social units of a same species at a camera-trap within half-an-hour) (O'Brien et al., 2003; Johnson et

al., 2006). Records of cat species from this formal camera-trap surveying are represented on Figure 6.2. Other cat species records (field sightings, remains, pre-2006 camera-traps) for NNT NPA and adjacent areas are also presented in Table 6.4. These are retrieved from survey reports, grey-literature or incidental reports.

Results

A total of 469 camera-trap-sites (excluding those with faulty cameras) were used from March 2006 to January 2011 within NNT NPA, within 10 different sampling blocks, of which two were replicated once each (Table 6.1). Survey effort (given in camera trap days, CTD) over the survey period totals 20259 during which 9265 photos were taken (including tests, unidentified, non-object and object photos) (Table 6.1). Each sampling block covered from ~5 hectares (NM-TKC Mar-May 09) to ~50 km^2 (NC-NV Jan-Mar 08).

Table 6.2: Photos of cat species (non-*Panthera*) taken with camera-traps in Nakai-Nam Theun NPA in 2006-2011.

#	sp	Area	Date	Time	Geographic coordinates[a]		Altitude (m a.s.l.)	CTD of cam	Total pic [b]
1	AGC	KK-NS	18 Mar 2006	18h09	18° 13' 2.199" N	105° 14' 45.253" E	1356	55	33
2	LC	KK-NS	11 Apr 2006	18h21	18° 11' 19.452" N	105° 13' 17.960" E	981	55	27
3	LC	NO-BP	16 Nov 2006	19h26	17° 40' 0.093" N	105° 39' 29.087" E	719	34	7
4	LC	NT-re	21 Nov 2006	19h19	17° 43' 56.993" N	105° 21' 34.479" E	547	51	6
5	LC	NT-re	6 Dec 2006	17h45	17° 40' 35.291" N	105° 21' 28.341" E	562	49	13
6	LC	KK-TP	5 Apr 2007	17h34	18° 18' 59.601" N	105° 7' 21.993" E	1152	51	24
7	LC	NC-MF	25 Nov 2007	00h19	17° 51' 24.135" N	105° 18' 31.653" E	553	46	5
8	LC	NC-MF	11 Dec 2007	17h11	17° 50' 4.814" N	105° 18' 4.438" E	757	48	31
9	LC	NC-NV	2 Feb 2008	19h13	17° 51' 38.257" N	105° 13' 48.798" E	674	46	6
10	MC	NC-NV	26 Feb 2008	10h46	17° 52' 29.795" N	105° 13' 24.601" E	785	46	3
11	LC	TX	24 Nov 2008	18h49	17° 46' 12.617" N	105° 28' 0.319" E	734	54	21
12	LC	TX	18 Jan 2009	12h28	18° 4' 46.416" N	105° 26' 20.054" E	686	55	19
13	LC	NM-TKC	8 Mar 2010	-	18° 3' 21.985" N	105° 21' 51.557" E	1424	55	36
14	LC	NM-TKC	25 Mar 2010	23h41	18° 5' 59.070" N	105° 20' 46.110" E	1175	54	25
15	LC	NM-TKC	28 Mar 2010	00h30	18° 3' 19.687" N	105° 21' 45.089" E	1369	49	30
16	CL	NM-TKC	29 Mar 2010	19h39	18° 2' 34.625" N	105° 22' 17.446" E	1398	54	36
17	CL	NM-TKC	31 Mar 2010	05h56	18° 0' 55.928" N	105° 21' 29.796" E	1077	51	36
18	CL	NM-TKC	3 Apr 2010	04h44	18° 3' 38.328" N	105° 22' 3.973" E	1567	54	30
19	CL	NM-TKC	8 Apr 2010	22h45	18° 3' 38.328" N	105° 22' 3.973" E	1567	54	30
20	LC	NM-TKC	9 Apr 2010	23h32	18° 4' 53.893" N	105° 21' 5.375" E	1352	54	36
21	CL	NM-TKC	11 Apr 2010	05h51	18° 4' 54.028" N	105° 21' 55.727" E	1494	54	20

[a] GPS Datum: WGS 1984

[b]Total of photos taken by the camera (incl. photo(s) of cats)

CTD of cam=camera trap days of the camera

Species (sp): **AGC**=Asian golden cat; **LC**=leopard cat; **MC**=marbled cat; **CL**=clouded leopard

Area: **KK-NS**=Khamkeut, Nam San; **NO-BP**=Nam On, Boulapha; **NT-re**=Nam Theun, reservoir; **KK-TP**=Khamkeut, Tong Pae; **NC-MF**= Nam Chae, Makfueng; **NC-NV**= Nam Chae, Navang; **TX**=Tong Xet; **NM-TKC**= Nam Mon, Tongkacheng.

Of the 9265 photos, 21 were of independent photo records of non-*Panthera* cat species (Table 6.2). These involved four species: Asian golden cat (AGC, 1 photo), leopard cat (LC, 14 photos, 14 trap sites), clouded leopard (CL, 5 photos, 4 trap sites) and marbled cat (MC, 1 photo) (Table 6.2, 6.3; Figure 6.2); there were no photos of *Panthera* cats. These were recorded in eight different sampling areas (Table 6.1, 6.2). None of the trap sites (N=469) recorded more than one species of cat. Most photo records were taken from late afternoon (~17h) to early morning (~6h); two photos were taken during day-time (10h46 and 12h28 of a marbled cat and a leopard cat, respectively) (Table 6.3).

Table 6.3: number (nb) of sites, photo records, altitude and times of cat species recorded in NNT NPA during 2006-2011 camera-trapping survey.

Species	nb sampling areas where recorded (N=10)	nb trap-sites (N=469)	nb independent photos	time range
Leopard cat	8	14	14	17h11-12h28
Clouded leopard	1	4	5	19h39-05h56
Asian golden cat	1	1	1	18h09
Marbled cat	1	1	1	10h46

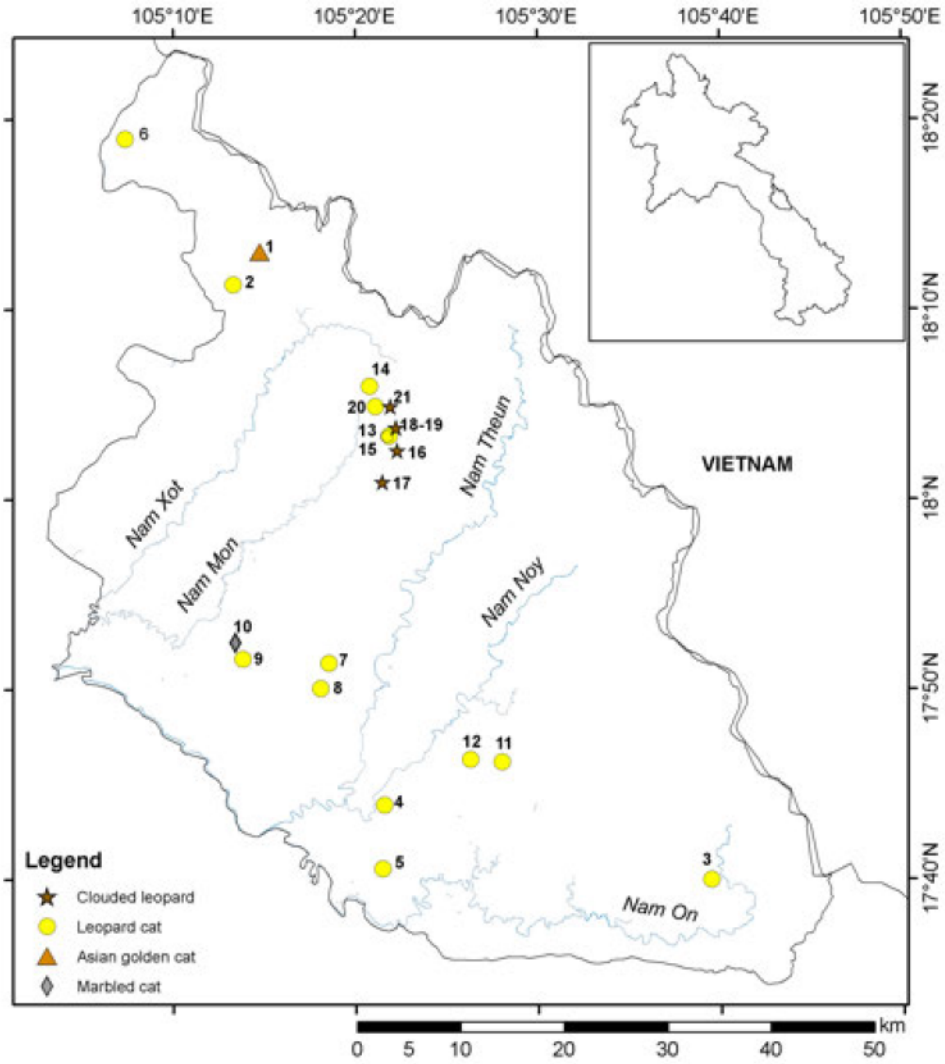


Figure 6.2: Locations of photo records of cat species within Nakai-Nam Theun NPA during the 2006–2011 survey period (no. indicates the chronological order of the image record, c.f. Table 6.2)

Figure 6.3: Four species of cats that were camera-trapped during the 2006–2011 survey period in Nakai-Nam Theun NPA. **a**: clouded leopard, 29 Mar 2010, 19h39, 18° 2' 34.625" N 105° 22' 17.446" E; **b**: Asian golden cat, 18 Mar 2006, 18h09, 18° 13' 2.199" N 105° 14' 45.253" E; **c**: leopard cat, 5 Apr 2007, 17h34, 18° 18' 59.601" N 105° 7' 21.993" E; **d**: marbled cat, 26 Feb 2008, 10h46, 17° 52' 29.795" N 105° 13' 24.601" E. Photos credit © WMPA

Table 6.4: Records (sightings, remains, and pre-2006 camera-trap photographs) of non-*Panthera* wild cat species in Nakai-Nam Theun NPA and the adjacent Nakai plateau (most, perhaps all, plateau records came from that portion now in the NPA); [] = Unconfirmed.

Species		evidence	location	date, time	reference
leopard cat	*Prionailurus bengalensis*	captive	Ban (=village) Vangkouay, Ban Nathon, Ban Tong Xat	2006-2007	Nanthavong C. pers. obs.
		dead in snare	Khamkeut district	2006	Nanthavong C. pers. obs.
		sights (5)	Nakai Plateau	Feb 94, dusk; Feb 94, day; 1 Mar 94, dawn; 3 Feb 96, 20h55, 21h55	Duckworth, 1997
		sights (2)	Navang road	30 Apr 96, 03h30; 12 May 96, 22h35	Duckworth, 1998; Duckworth, 1997
clouded leopard	*Pardofelis nebulosa*	camera-trap	upper Navang road	5 Mar 97, 19h00	WCS, 1997
		sight	Navang road	14 May 96, 00h50	Duckworth, 1998
		skin	Ban Sopnian, Nakai Plateau	1995	Evans et al., 2000
Asian golden cat	*Catopuma temminckii*	[sight]	Ban Nameo-Tong Khouang/Xet trail	14 Dec 99, 13h45	Robichaud and Stuart, 1999
		camera-trap	Lower Navang road	22 Feb 97, 22h20	WCS, 1997
marbled cat	*Pardofelis marmorata*	sight	Navang road	9 May 96, 14h50	Duckworth, 1998
		[skin]	Ban Sopnian, Nakai Plateau	1995	Evans et al., 2000; Dersu, 2008

Discussion

Surveys in Nakai–Nam Theun NPA during the 1990s confirmed the presence of at least six cat species, including four non-*Panthera* species. From March 2006 to January 2011, systematic camera-trapping within the area photographed all of these four non-*Panthera* species (although neither of the *Panthera* species): VU marbled cat *Pardofelis marmorata*, VU clouded leopard *P. nebulosa*, NT Asian golden cat *Catopuma temminckii* and LC leopard cat *Prionailurus bengalensis*. Given the high total survey effort, the frequency of records for the four species was very low: lower than any other camera-trap survey, for which the results were traced, in South-east Asia where these have been regularly recorded in hill evergreen forest superficially similar to that in NNT NPA (Table 6.5). These numbers are likely to indicate a low density of these species in NNT NPA, rather than any methodological factor causing them to be overlooked since the same cameras captured a wide range of animal sizes from rodents, small-carnivores to ungulates (WMPA, unpubl. data). In addition, other camera-trapping studies that used similar methodology had frequent records of cat species (e.g. Datta et al., 2008; Brodie and Giordano, 2012; Johnson et al., 2009)

The leopard cat (Figure 6.3c) was the most photo-recorded species with 14 independent photos, each from a different trap site. This species has the widest global distribution range of all small Asian cats and is generally found from sea level up to 3000 m a.s.l. in various habitat types (Sunquist and Sunquist, 2002; Sanderson et al., 2012). In Laos, it has been the cat species most widely and commonly recorded in the country (Duckworth et al., 2005). In the early and mid 1990s, over 25 records of the species (sightings, captive and remains) occurred including 12 direct sightings during field surveys (Duckworth, 1997). Our photo records occurred between altitudes of 500-1500 m, in semi-evergreen and evergreen forest. Throughout Laos, it has been found from 200 to *ca.* 2300 m a.s.l. (likely not actual altitudinal range limits) and from heavily degraded to almost undisturbed (semi-) evergreen forests (Duckworth, 1997; Johnson et al., 2009).

The species is evidently largely nocturnal in NNT NPA, as indicated by earlier records elsewhere in the country (Duckworth, 1997; Johnson et al., 2009).

The clouded leopard (Figure 6.3a) was camera-trapped on five independent photos, from four trap sites. Its status and distribution in Laos is little known; its National distribution has been hypothesised through nationwide village interviews but there are too few firm locality records to confirm this (Duckworth et al., 1999). Numerous confusions during village discussions, however, with skins or other readily identifiable parts indicate low reliability, so its occurrence in most of Laos has to be seen as unconfirmed, although plausible. Camera-trap surveys confirmed its presence in Nam Et-Phou Louey NPA and Nam Kading NPA (Johnson et al., 2006). Only two certain direct sightings in the wild by surveyors have ever occurred; one in NNT NPA (Duckworth, 1998; Table 6.4) and one in Dong Ampham NPA (Davidson et al., 1997, Schaller, 1997). Its status in Laos is considered 'At Risk' (Duckworth et al., 1999).

The Asian golden cat (Figure 6.3b) was photographed only once in the northeast of NNT NPA during 2006–2011. It was camera-trapped also in 1997 (WCS, 1997) and possibly sighted in 1999 (Robichaud and Stuart, 1999). In Laos, the species' distribution remains uncertain but it probably occurs across the country in suitable habitat. It appears to inhabit various habitat types, from lowlands to at least 2300 m a.s.l., and nationally was the second-most frequently recorded small cat (from sightings and remains) during the 1990s (Duckworth et al., 1999; Johnson et al., 2009). The species has been camera-trapped in Nam Kading NPA (WCS-Laos, unpubl. data in Johnson et al., 2009) and was the most photographed cat species in Nam Et-Phou Louey NPA between 2003 and 2006 (Johnson et al., 2009). The species' National status is considered 'Little Known' in Laos (Duckworth et al., 1999).

Similarly, the marbled cat (Figure 6.3d) was only recorded once. It may be rare in Laos. It has been previously sighted in the field on two occasions: once each in

NNT NPA and in Nam Xam NPA (Duckworth, 1998, Showler et al., 1998). In Nam Kading NPA, it was photo-recorded from four sites out of a total 95 camera-trap sampling sites (WCS-Laos, unpubl. data in Johnson et al., 2009) whereas in Nam Et-Phou Louey NPA, the 2003-2006 camera-trap survey yielded 39 independent images from 24 trap sites (Johnson et al., 2009), the largest camera-trap-record of the species for the country. The species seems primarily diurnal and have an affinity with hilly (~700-2000 m a.s.l.) evergreen forest. Due to the paucity of information available on the species, its status in considered 'Little Known' in Laos (Duckworth et al., 1999).

Of the two other unconfirmed small or medium-sized cats of Laos, the jungle cat is unlikely to occur within NNT NPA given its association with open, deciduous, grassland areas. These habitats are rare in the NPA, and prone to greater risk of overhunting than are forests. The species has been reported from the adjacent Nakai Plateau in lowland pine/dipterocarp forest in several sources, but none gave any compelling evidence to be taken seriously. Reports from villagers cannot be conclusive for the species as the same general Lao wording – '*meo paa*', literally jungle/forest cat – is commonly used for non-domestic cats (Duckworth et al., 2005). It was sighted in open flat land in 1999 in degraded mixed deciduous forest in Boulapha District, outside the southern part of the NPA (Duckworth et al., 2005). No details for this record have ever been published though the observer is confident with his identification (R.J. Tizard in litt., 2012).

The fishing cat is generally assumed to inhabit dense wetlands, primarily in lowland areas (Sunquist and Sunquist, 2002; Mukherjee et al., 2010), but the single plausible though unconfirmed sighting of the species occurred to the north of NNT NPA, in what was then the Nam Theun Extension proposed NPA in habitat similar to NNT NPA, hilly evergreen forest (Duckworth et al., 2010). Given the apparent rarity of the species throughout the country, and absence of remains or live animals records, if it has ever occurred in NNT NPA, it may now not be present.

The presented records for NNT NPA and eastern adjacent areas probably represent all confirmed records of cats in the NPA for 1990s-2011 period; if any have been missed, their number is very few. Despite regular field visits in NNT NPA (transect surveys, camera-trap setting and removal trips, patrolling, research) by management staff and other researchers since 2005, none of the above cat species has ever been directly sighted in its habitat since then, although the conspicuous behaviour of such teams renders sightings fairly unlikely. Captive leopard cats were seen occasionally in villages, mostly infants, reportedly caught after killing the mother for food, during 2006-2007 (C. Nanthavong, pers. obs.). The only confirmed direct sightings of wild cats of any size in NNT NPA date back to 1996: during a 3½-week direct-observation survey for large mammals, two leopard cats, one clouded leopard, one marbled cat and one tiger were seen (Duckworth, 1998). Surveyors of other groups had two leopard and two additional tiger sightings in that year. All these sightings occurred along an intended logging road (which had been legally terminated, before construction had finished and before it was ever used for logging) above Ban Navang, in Nam Chae-Navang zone (Duckworth, 1998).

Although the methods used in 1996–1997 and during 2006–2011 in NNT NPA were different, relevant survey effort was far higher in the latter period than the former, and should have produced many records of cats judging by the rates at which they were recorded in 1996 by direct observation and in 1997 by exploratory camera-trapping. During many direct-observation-based surveys in Laos in the 1990s, no other survey area produced records of cats at anywhere near the rate found in NNT NPA in 1996, other than for leopard cats (Duckworth et al., 1999, where all 1992–early 1999 Lao cat records with clear locality and using credible methods are listed, except for Leopard Cats, which were too commonly found for such detail; individual records up to the end of 1996 were given in Duckworth [1997]). Most comparably Nam Et–Phou Louey NPA also had a direct-observation-based survey (but involving very little spotlighting) in the 1990s

(Davidson, 1998), and then intensive camera-trapping in the 2000s (Johnson et al., 2009). The 1990s survey recorded no direct sightings of cats, the camera-trapping, many. In part, the large number of sightings along the Navang logging road in NNT NPA reflected the exceptional visibility within little-degraded forest, but probably as importantly, it was possible through the very low hunting levels then in that area: the observer could at that time stand under trees holding monkeys, gibbons or yellow-throated martens *Martes flavigula* without their showing evasive action, and muntjacs *Muntiacus* walked along the road within 50 m of the surveyor (Duckworth in litt., 2012).

The 2000s' extremely low encounter rates of cats in NNT NPA probably partly reflect their actual status in the area, and thus a major decline since the 1990s. In comparison, leopard cat and clouded leopard were recorded on 183 and 10 occasions, respectively (independent photos) in 112 km^2 Deramakot forest reserve in Borneo during a relatively short 1916 trap nights in 2008-2009, and marbled cat sighted twice during a 45-day survey (Mohamed et al., 2009). Hunting in this area does not seem to threaten wildlife populations (Lagan et al., 2007). In Taman Negara National Park, peninsular Malaysia, camera-trapping survey accumulated 14054 camera-trap-nights in 1999-2001, which recorded 62, 37, 16 and 16 independent images of leopard cat, Asian golden cat, clouded leopard and marbled cat, respectively. No evidence of poaching in the 600 km^2- study site visited in this national park was found, and the density of tigers there was found to be still relatively high (Kawanishi and Sunquist, 2004). Asian golden cat, marbled cat and leopard cat were also among the most commonly photographed species of all small-carnivores recorded (48, 39 and 24 independent photos, respectively) in Nam-Et Phou Louey NPA (NEPL NPA), north-eastern Laos, during a survey effort of 8499 camera trap-days conducted in 2003-2006 (Johnson et al., 2009) (Table 6.5). Conservation management in the latter area started in 2000 with permanent technical assistance from the Wildlife Conservation Society-Lao Program (Johnson et al., 2010). Although illegal hunting does occur in NEPL NPA (Johnson et al., 2010) it is nowhere near the intensity found in NNT NPA; during a 5-month field

survey in 2010 within the area (19 sites visited spread across the entire NPA) not a single snare was encountered (Scotson, 2010), which would be inconceivable in NNT NPA.

Table 6.5: Comparison of camera-trap records of small cat species in Southeast Asia.

Area (country)	survey period	CTD	species	Independent photos	reference
Nakai-Nam Theun National Protected Area (Lao)	2006-2011	20259	LC	14	**This study**
			AGC	1	
			CL	5	
			MC	1	
Nam-Et Phou Louey National Protected Area (Lao)	2003-2006	8499	LC	24	Johnson et al., 2009
			AGC	48	
			MC	39	
Tangkulap-Pinangah and Segaliud Lokan Forest Reserves, Sabah (Malay)	Apr-Sept 2009; Jan-Apr 2010	5328	CL	44	Wilting et al., 2012
Maliau Basin Conservation Area, Sabah (Malay)	Jan-Apr 2010	2003	CL	59	Brodie and Giordano 2012
Taman Negara National Park (Malay)	1999-2001	14054	LC	62	Kawanishi and Sunquist, 2004
			AGC	37	
			CL	16	
			MC	16	
Deramakot Forest Reserve, Sabah (Malay)	Jul 08-Jan 09	1916	LC	183	Mohamed et al., 2009
			CL	10	
Namdapha National Park (India)	Oct 2006- Jan 2007	1537	CL	768	Datta et al., 2008

CTD = camera-trap days; LC=leopard cat; AGC=Asian golden cat; CL=clouded leopard (spp.); MC=marbled cat

In other parts of Asia where hunting is a major threat, camera-trap encounter rates of wild cats also indicated a decline of these populations (e.g. Rao et al. 2005; Datta et al. 2008; Rao et al., 2010). However, in Namdapha National Park, north-east India, although it was found that the relative abundance of wildlife species was lower than in other South-east Asian areas where hunting pressure is lower, clouded leopard was still recorded on 768 occasions over 1537 camera-trap days (Datta et al., 2008). Hunting in the latter area is mainly carried out with guns

and cross-bows (Datta et al., 2008) contrarily to NNT NPA, where ground snares are the primary hunting technique.

As wildlife has dramatically decreased throughout Vietnamese forests due to deforestation and overharvesting (Bennett and Rao, 2002; Milner-Gulland et al., 2003; Sodhi et al., 2004; Sodhi et al., 2009), targeted species have gained in trade value and therefore suffer increased hunting pressure. Illegal hunting in NNT NPA by Lao villagers has increasingly been intended for trade, not local consumption. Lao villagers sell wildlife to Vietnamese, who regularly visit their villages, within the NPA (Nooren and Claridge, 2001; Johnston, 2010; Coudrat, 2012a). There is no evidence that any of these non-*Panthera* cats are specifically targeted by trade-driven hunters in NNT NPA, or elsewhere in Laos (equally, it is not known that they are not), but the main method used, snaring, is non-selective and catches many individuals of untargeted species and is likely to have been responsible for the decrease of cat populations within the area. All wild cat species in Laos are classified under the *Prohibition category* of the Lao hunting regulation, which groups species "rare, near extinct, high value and are of special importance in the development of social-economic, environmental, educational, scientific research" (National Assembly Laos 2007: Article 11: 4), their hunting is not permitted at any time or anywhere. However, these rules are either not known by villagers but more likely not enough enforced and illegal activities not well prevented.

Wild cats are regularly encountered in the trade in Southeast Asia (e.g. Duckworth et al., 1999; Nooren and Claridge, 2001; Shepherd and Nijman, 2008). For example, several Lao cat species are openly sold in Myanmar, in Tachilek city, at the Lao-Thai-Myanmar border (Shepherd and Nijman, 2008); provenance of vendors' stock is uncertain, but at least some may come from Laos. The demand for wildlife hunted in Laos indeed comes principally from neighbouring countries (in particular Thailand, Vietnam and China) (Srikosamatara et al., 1992; Compton et al., 1999; Nooren and Claridge, 2001; Singh et al., 2006). Wild cats are generally used as trophies (e.g. stuffed, skins, pelts) or medicine (processed body parts)

(Martin, 1992; Le Trong Trai, 2007; Shepherd and Nijman, 2008; Ashwell and Walston, 2008).

NNT NPA provides the evidence that even in the large primary forest blocks remaining in Southeast Asia, extinctions of these cat species may not be prevented at the protected area-level where hunting occurs unsustainably. This area illustrates the so-called 'empty forest' syndrome occurring in heavily hunted regions (Redford, 1992; Harrison, 2011). NNT NPA is among the key biodiversity areas of the Indo-Burma hotspot (Tordoff et al., 2012). Given the few Lao NPAs currently receiving external funding and that have received technical assistance to develop conservation plans, the area still represents one of the country's NPAs with the best potential to preserve rare and threatened animals, including wild cats, if management strategies are well adapted and implemented. Illegal hunting with snares, set up by both Vietnamese and Lao hunters need to be urgently controlled. To be achieved successfully, given the large area, priority zones need to be designated to focus all available resources. Only long-term conservation planning and its dependent actions in the area will ensure the survival of these species.

CHAPTER 7

CAMERA-TRAP DATA IN NAKAI-NAM THEUN NATIONAL PROTECTED AREA, CENTRAL-EASTERN LAOS, REVEAL ITS DIVERSITY OF SMALL CARNIVORES AND ITS IMPORTANCE FOR CONSERVATION OF KEY SPECIES

Introduction

Over two decades ago, part of the Indochinese region (namely, 'Northern Vietnam [including adjacent areas in China, Laos and Thailand]'; Schreiber et al., 1989: 75) was listed as one of the most important areas for the global conservation of small carnivores (Mustelids and Viverrids). The authors notably recommended increasing research on the distribution, status and taxonomy of these species, which has generally remained lacking in the region until now. Within Laos, small carnivores' diversity, distribution and status (here defined as Viverrids, Prionodontids, Mustelids, and Herpestids) remain little known. Countrywide wildlife surveys conducted in the 1990s provided preliminary information on the group (Duckworth, 1997; Duckworth et al., 1999), although survey intensity and methodology were unlikely to record all species possibly present at any given site visited (Duckworth, 1997). At least 21 species occur in the country (Table 7.1) including five Globally Threatened and three Near Threatened (IUCN, 2012a). In the past decade, systematic and intensive camera-trap surveys in a few National protected areas have collected extensive data on ground-dwelling species (Johnson and Johnston 2007; DERSU, 2008; Johnson et al., 2009; Duckworth et al., 2010; WCS Lao Programme unpublished data). Although camera-traps are unlikely to record the total small carnivore species community of an area, the technique has proven effective for some ground species and long-term surveys might be suitable for monitoring population status. For instance, the Owston's civet (*Hemigalus owstoni*) that had only ever been recorded in Laos from market animals, captives and reported from villagers, and never seen directly in the field (Sivilay et al., 2011) was for the first time recorded in the wild in Laos with camera-traps in Nam Et-Phou Louey National Protected Area (NPA), north-eastern Laos, (Johnson et al., 2009), Nakai-Nam Theun NPA, central-eastern Laos (Johnson and Johnston, 2007) and Phou Chomvoy Provincial Protected Area (Sivilay et al., 2011).

Data collected from camera-trap surveys often remain unpublished and not readily available, although they offer invaluable information. When combined,

countrywide data from such surveys can depict the geographical and ecological national distribution of these species and provide insight into their general behaviour and morphological characteristics. A long-term wildlife monitoring program using camera-traps was initiated in 2006 in Nakai-Nam Theun NPA (NNT NPA) (Johnson et al., 2005; Johnson and Johnston, 2007). I present records of small carnivores (excluding small cats) from the period 2006-2011. The characteristics of the camera-trapping methodology (without using bait) focussing on ground-dwelling animals means that results will not present the comprehensive species diversity occurring in NNT NPA.

Table 7.1: Confirmed small carnivore (excluding Felidae) species in Laos.

Species	General National distribution	Global status (IUCN, 2012a)	National status (1999)*	Lao hunting regulation category (NA, 2008)**
Mustelidae				
yellow-bellied weasel (*Mustela kathiah*)	N, S	Least Concern	Little Known	*not listed*
Siberian weasel (*Mustela sibirica*)	C	Least Concern	Little Known	*not listed*
stripe-backed weasel (*Mustela strigidorsa*)	N, C	Least Concern	Little Known	Prohibited
yellow-throated marten (*Martes flavigula*)	N, C, S	Least Concern		*not listed*
hog badger (*Arctonyx collaris*)	N, C, S	Near Threatened	Little Known	Managed
large-toothed ferret badger (*Melogale personata*)	C, S	Data Deficient	Little Known	Managed
small-toothed ferret badger (*Melogale moschata*)	N, C	Least Concern	Little Known	Managed
Eurasian otter (*Lutra lutra*)	N	Near Threatened	At Risk	Prohibited
smooth-coated otter (*Lutrogale perspicillata*)	N, S	Vulnerable	At Risk	Prohibited
Oriental small-clawed otter (*Aonyx cinereus*)	N, C, S	Vulnerable	At Risk	Prohibited
Viverridae				
large Indian civet (*Viverra zibetha*)	N, C, S	Near Threatened		Managed
large spotted civet (*Viverra megaspila*)	C, S	Vulnerable	At Risk	Prohibited
small Indian civet (*Viverricula indica*)	N, C, S	Least Concern		Managed
common palm civet (*Paradoxurus hermaphroditus*)	N, C, S	Least Concern		Managed
masked palm civet	N, C, S	Least Concern		Managed

(*Paguma larvata*)				
binturong (*Arctictis binturong*)	N, C	Vulnerable	At Risk	Managed
small-toothed palm civet (*Arctogalidia trivirgata*)	N, C, S	Least Concern		Managed
Owston's civet (*Chrotogale owstoni*)	N, C	Vulnerable	Little Known	Prohibited
Prionodontidae				
spotted linsang (*Prionodon pardicolor*)	N, C, S	Least Concern	Little Known	Prohibited
Herpestidae				
small Asian mongoose (*Herpestes javanicus*)	N, C, S	Least Concern		Managed
crab-eating mongoose (*Herpestes urva*)	N, C, S	Least Concern		Managed

N= north, C= center, S= south
References used: Duckworth et al., 1999 (includes historical records – i.e. pre-1990s); Tizard, 2002; Robichaud, 2010; Sivilay et al., 2011.
* National status not indicated means that the species is considered secure in the medium-long term (Duckworth et al., 1999)
** Prohibited: hunting of the species is not allowed at any time and place; Managed: hunting is permitted in specified zones and seasonally only

Methods

Study area

Nakai-Nam Theun National Protected Area (NNT NPA) (Figure 7.1) is ~3550 km^2 with altitudes ranging from ~500 to >2200 m a.s.l.. Around 90% of the area remains covered in forest (Robichaud et al., 2009). It is dominated by old growth mainly undisturbed dry-evergreen forest, with other localised habitat including pine/semi-evergreen, upper-mountain and wet-evergreen forest (Timmins and Evans, 1996). Thirty-one villages are located within the NPA; each village is allocated subsistence-use forest areas, where they are allowed to collect non-timber forest products, including some common wildlife species according the Wildlife and Aquatic Law and Forestry Law (National Assembly Laos, 2007a; 2007b).

Camera-trap data

Camera-trap data were obtained from systematic survey during 2006 to 2011 conducted in NNT NPA by NT2 WMPA staff. The sampling technique was designed and training provided by the Wildlife Conservation Society-Lao Program (Johnson et al., 2005; Johnson and Johnston, 2007). From March 2006 to January 2011, camera-traps were set in 10 different survey blocks within NNT NPA's boundaries (Table 7.1; Figure 7.1). Three to 50 passive infrared cameras were set in a survey site (a single camera set per locality), each camera being in general ~1 km apart. Each was positioned on trees at a height of ~45 cm (initially targeted for large mammals), beside animal trails or small streams and/or at other open understorey locations arbitrarily chosen, without the use of lure or bait. Each camera was programmed to operate 24 hours per day and take photos at least 20-seconds apart. Most of the cameras (96.8%) had a maximum capacity of 36 photos, therefore the survey effort ceased once 36 photos had already been taken. The remaining cameras had a large capacity of >600 photos which was never reached before removal of the camera. Thus, survey effort for each camera is calculated from the day of the first photo taken to the day of the last photo taken. Total survey effort (camera-trap days, CTD) is the sum of all cameras' survey effort. Data from faulty cameras (i.e. cameras for which only the first test-photo was taken and thus no possibility to calculate camera-trap days) were removed from the analysis. For each camera, available data include GPS coordinates of location, elevation (m a.s.l. taken with GPS unit), date and time of each photo taken.

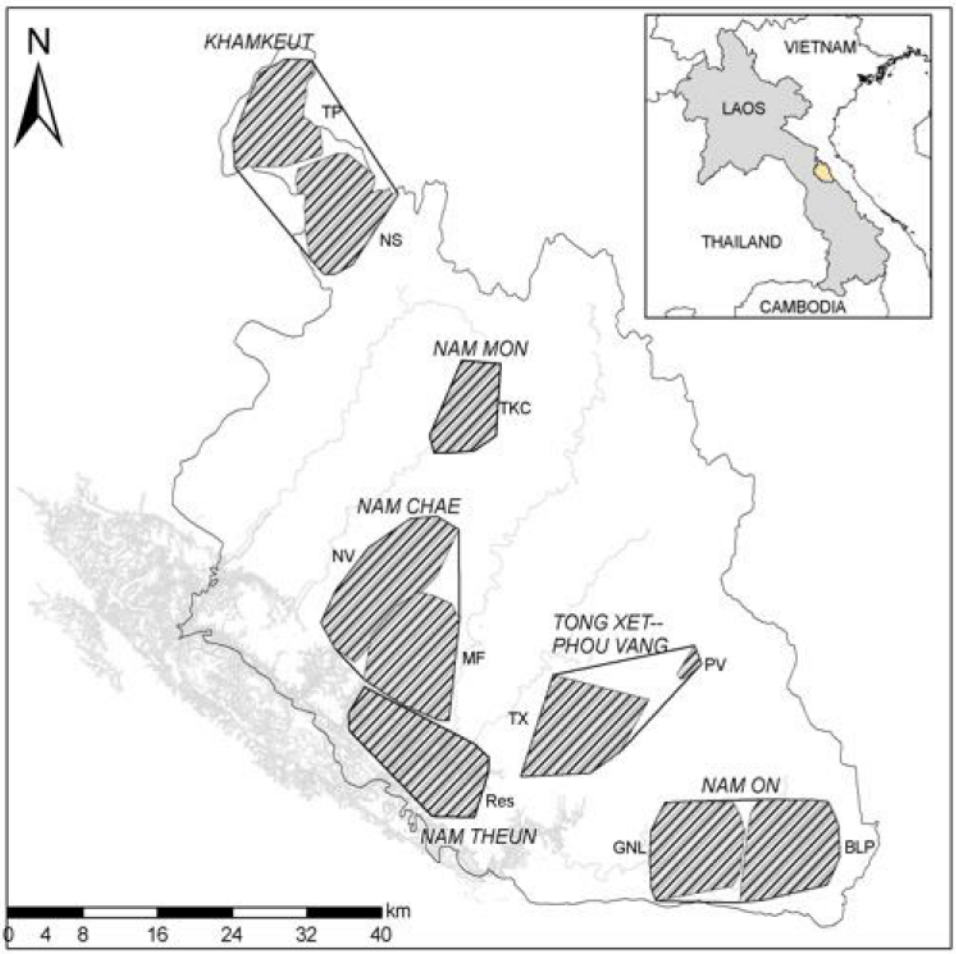


Figure 7.1: Camera-trap sampling effort within Nakai–Nam Theun NPA in 2006-2011 (c.f. Table 7.1) at ten sites in six general areas: KHAMKEUT: Thong Pae (TP) and Nam San (NS); NAM MON: Thongkacheng (TKC); NAM CHAE: Navang (NV) and Makfuang (MF); NAM THEUN: reservoir (Res); THONG XET-PHOUVANG: Thong Xet (TX) and Phou Vang (PV); NAM ON: Gnomalath (GML) and Boualapha (BLP). Note: areas and sites are delimited in ArcGIS 9.3 with a minimum convex polygon around the all camera-trap localities.

Of all photos taken (N=9265) during the survey period, all the small carnivore (excluding Felidae) photo records were selected and identified with the assistance of J.W. Duckworth. The number of records for each species is of independent photos, here considered as consecutive photographs of individuals/social units of the same species taken more than 30 minutes apart (except when the same individual/social unit can be identified and is photographed consecutively for >30 minutes, in this case photos are still considered as one independent photo) and

non-consecutive photos (i.e. hours to days apart or separated by photograph[s] of other species) of individuals/social units of the same species. The GPS coordinate localities (used with UTM Indian Thailand datum) where each species was recorded within NNT NPA is represented on Figure 7.2, and all record details are presented in Appendix 7.1.

I compare the relative abundance of all carnivore species between the six general areas sampled with a relative encounter rate index (RERI) where RERI = (total number of independent images)/(number of camera-trap days)*100 (see Jenks et al., 2011). The difference in relative encounter rate is investigated in terms of ecological (mean annual temperature, mean annual precipitation, elevation, slope, distance to river) and anthropogenic (distance to villages) variables, averaged for all camera-trap-localities within each of the six areas. Variables were obtained remotely and processed in ArcGIS 9.3.

In addition, I tabulate opportunistic data on small-carnivores that I collected during foot surveys from 2011-2012 over 10 different sites in NNT NPA.

Results

Six general areas (ten different sites) were sampled (Figure 7.1) with differing environmental and topographic conditions (Table 7.4), totalling 20216 camera-trap days (Table 7.2). Of the latters, 58% occurred during the dry season (Oct-Feb), 34% during the end of the dry season (Mar-May) and 8% during the wet season (Jun-Sept). Ten small carnivore species ('species' sensu lato – ferret badger species are not identifiable from images and therefore considered as *Melogale* sp(p).) were recorded on camera-traps (Table 7.3). The most frequently recorded were the common palm civet, ferret badger sp(p)., large Indian civet and hog badger (70-100 independent images), followed by the Owston's civet, masked palm civet and crab-eating mongoose (40-60 independent images), and yellow-throated marten, spotted linsang and binturong (1-20 independent images).

Table 7.2: Details of camera-trapping survey effort in Nakai-Nam Theun NPA from 2006 to 2011.

Area - site	time period	Total cameras[a]	CTD	Total photos taken[b]
Khamkeut - Nam San (NS)	Mar-May 06	49	2181	1109
Nam On - Boualapha (BLP)	Oct-Nov 06	49	1638	357
Nam On - Gnomalath (GML)	Dec 06-Feb 07	49	1705	344
Khamkeut - Thong Pae (TP)	Mar-May 07	48	2134	721
Nam Chae - Makfuang (MF)	Nov 07-Jan 08	50	2308	624
Nam Chae - Navang (NV)	Jan-Mar 08	47	1846	601
Phou Vang - Houay Nam Heuy (PV)	Apr-Aug 08	32	1687	1013
Thong Xet (TX)	Nov 08-Jan 09	22	1174	307
Nam Mon - Thongkacheng (TKC)	Mar-May 09	3	183	1222
Nam Theun - reservoir (Res)	Nov-Dec 09	40	1636	585
Nam Mon - Thongkacheng (TKC)	Mar-May 10	45	2405	2219
Khamkeut - Nam San (NS)	Dec 10-Jan 11	33	1319	126
TOTAL	**Mar 06-Jan 11**	**467**	**20216**	**9228**

[a] faulty cameras are excluded
[b] Includes test, unidentified and photos with no objects
CTD=camera trap day

Table 7.3: Number (nb) of independent images taken for each species over the 20259 camera-trap days period, elevation and percentage of them taken at dusk (17h00-19h00), night (19h00 to 05h00), dawn (05h00-07h00) and in day time (07h00 to 17h00).

Species	nb. ind. pho.	nb. cam-localities[a]	nb. Sites[b]	Elev. range	% dusk (17:00-19:00)	% night (19:00-05:00)	% dawn (05:00-07:00)	% day (07:00-17:00)
Large Indian civet	79	39	6	531-1707	6	87	7	0
common palm civet	100	54	10	549-1792	5	89	6	0
masked palm civet	55	36	6	629-1792	2	94	2	2
Owston's civet	60	15	5	1033-1675	2	98	0	0
binturong	1	1	1	828	0	100	0	0
spotted linsang	5	4	3	839-1594	0	60	40	0
yellow-throated marten	18	15	8	562-1792	6	0	11	83
ferret badger sp(p).	101	34	6	583-1675	1	94	5	0
hog badger	80	42	9	547-1622	8	60	22	10
crab-eating mongoose	40	27	8	531-1792	8	3	15	75

[a] number of camera-trap-locality (a single camera-trap per locality) where recorded, out of the 469 camera-trap-sites set.
[b] number of sampling sites where recorded, out of the ten sampling sites (c.f. Table 7.1).

The elevation range at which each species was recorded (Table 7.3) fell into the general known range across the country (Duckworth et al., 1999; Johnson et al., 2009; Sivilay et al., 2011).

The 24-hour activity cycle varied between species. Yellow-throated marten, and crab-eating mongoose were largely recorded from dawn through day time (05h00 to 17h00); whereas the other eight species were predominantly recorded from dusk through night time (17h00 to 05h00). Spotted linsang, yellow-throated marten, hog badger and crab-eating mongoose were the most regularly recorded at dawn (05h00-07h00; >10% of images) (Table 7.3).

Relative encounter rates for all ten species combined were highest in Khamkeut and Nam Mon areas (249 independent small carnivore images over 5634 camera-trap-days and 109 images over 2588 camera-trap-days, respectively) and the lowest in Nam Chae area (40 images over 4154 camera-trap-days) (Figure 7.2).

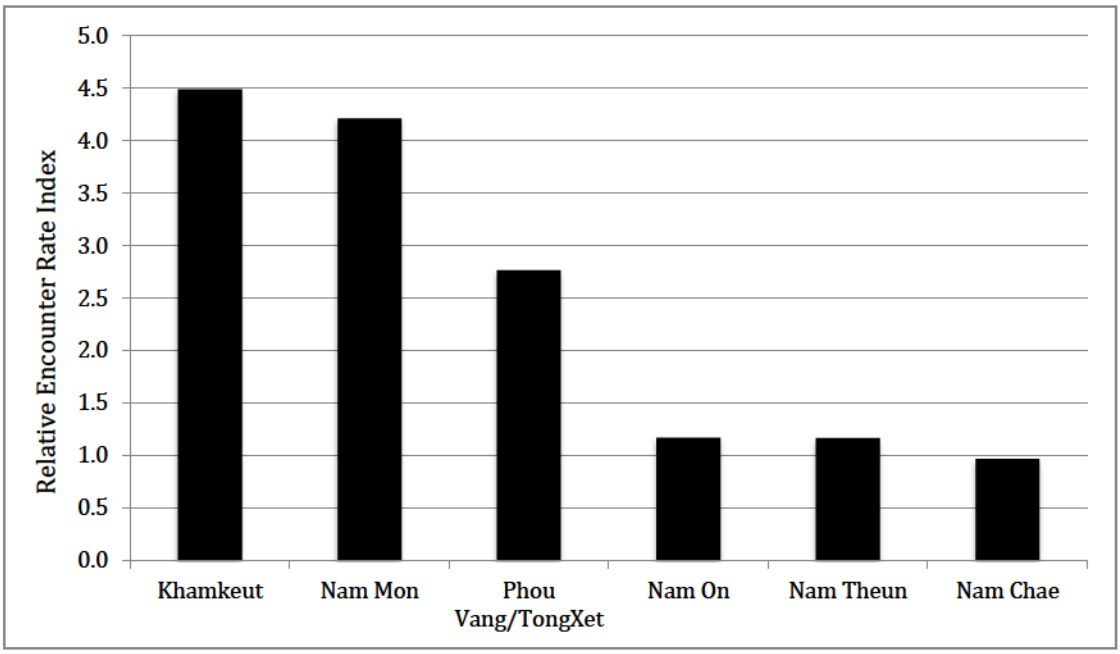


Figure 7.2: Comparison of encounter rate (i.e. number of independent images/camera-trap days*100) of all ten small carnivore species between the six general areas sampled (c.f. Figure 7.1).

Table 7.4: Averages of different variables, obtained remotely using GIS, for all camera-trap localities at each of the six general areas sampled within Nakai-Nam Theun NPA.

Area	distance water (m)	distance village (m)	Slope	Elevation	Mean annual temperature	Mean annual precipitation
Khamkeut	501.75	12123.78	15.66	1119.53	19.52	1994.40
Nam Chae	353.51	6213.61	11.26	788.44	21.62	2281.40
Nam Mon	287.28	12034.30	15.84	1247.39	18.89	2126.57
Nam On	260.78	7687.26	9.67	766.74	21.79	2333.85
Nam Theun	361.01	3664.45	2.61	568.10	22.89	2434.95
Thong Xet-Phou Vang	343.94	5464.64	16.07	877.86	21.13	2277.13

Distribution of records was not uniform across the areas sampled between the different species (Figure 7.3; Figure 7.4). Common palm civet was the only species recorded at all ten different sites sampled and was recorded from the highest number of camera-trap-localities (n=52). Encounter rate and localities were the fewest for spotted linsang and binturong, though this does not necessarily indicate that they are the rarest and localised of the species (c.f. Discussion).

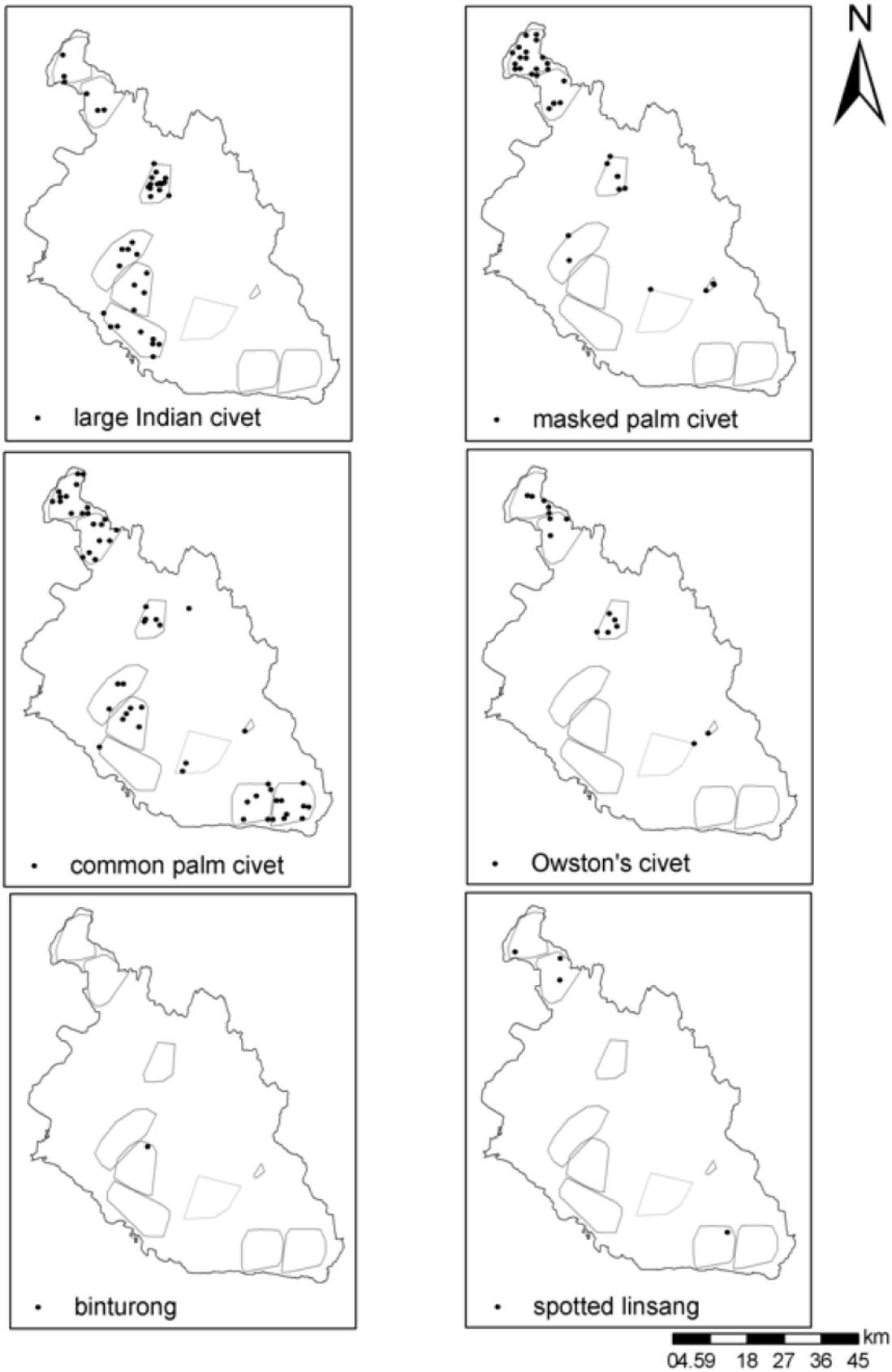


Figure 7.3: Distribution of the camera-trap records for Viverrid and linsang in Nakai-Nam Theun NPA during 2006-2011 survey period.

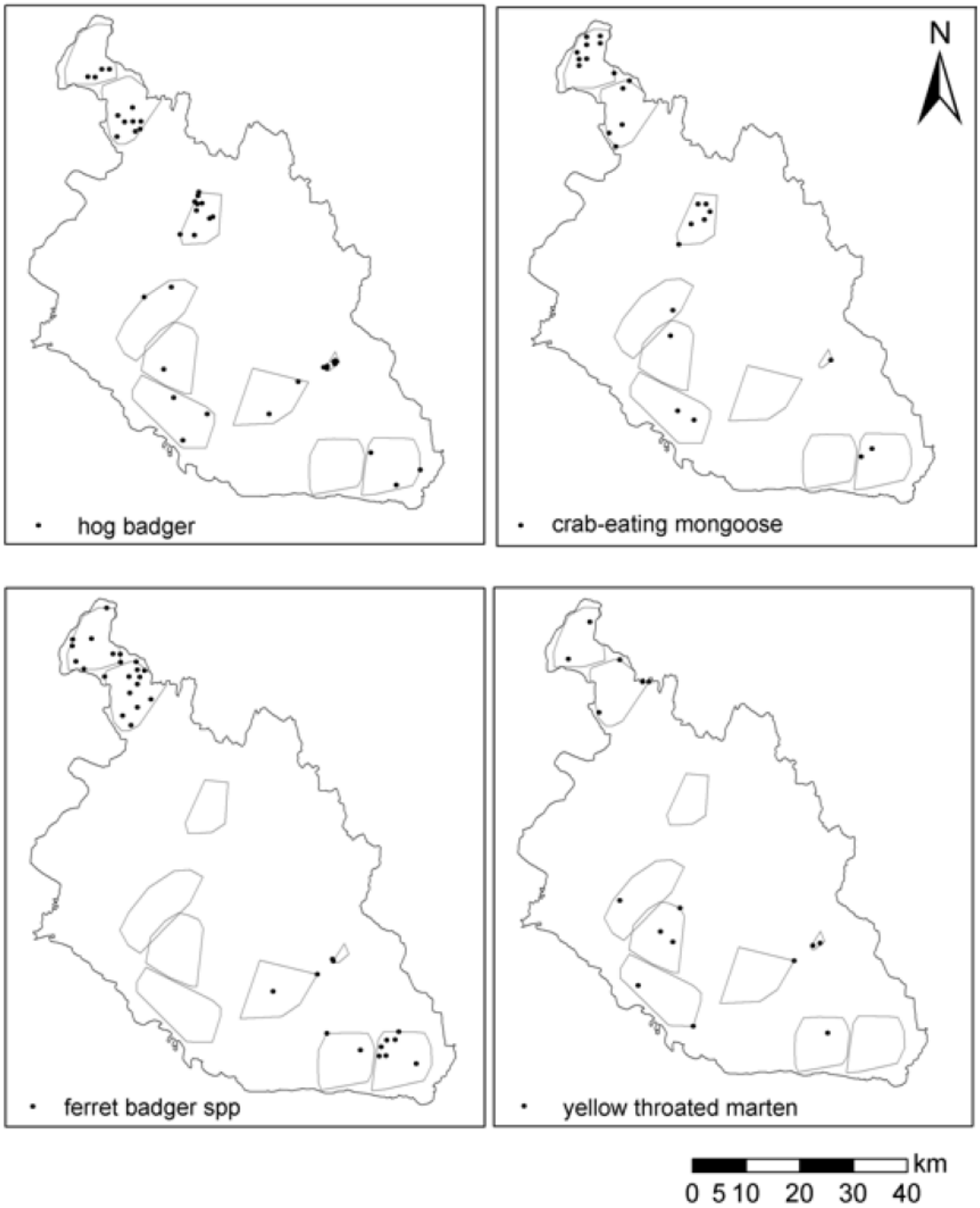


Figure 7.4: Distribution of the camera-trap records for Mustelid and Herpestid in Nakai-Nam Theun NPA during 2006-2011 survey period.

Masked palm civet, large Indian civet, Owston's civet, crab-eating mongoose and yellow-throated marten were occasionally recorded with conspecifics on some images (Table 7.5).

Table 7.5: Details of photographs that captured groups (≥2 individuals) of animals.

Species and Area of record	nb of inds	inds size	general behaviour	date	time
Large Indian civet					
Nam Mon (Thongkacheng)	2	adults size	2 individuals sniffing each other's perineal region	01 Apr 10	22h00
Masked palm civet					
Khamkeut (Nam San)	2	adults size	travelling side by side, looking down	27 Apr 06	00h42
Khamkeut (Thong Pae)	2	adults size	travelling side by side (3 consecutive photos)	04 Apr 07	05h43
Nam Mon (Thongkacheng)	2	adults size	travelling side by side	09 Mar 10	19h59
Owston's civet					
Khamkeut (Thong Pae)	2	adults size	travelling side by side, looking down	06 Apr 07	01h54
Khamkeut (Thong Pae)	2	adults size	travelling side by side, looking down	03 May 07	21h46
crab-eating mongoose					
Khamkeut (Nam San)	2	adults size	travelling side by side, looking down	16 Apr 06	11h46
Nam On (Boualapha)	2	adults size	travelling side by side, looking down	10 Nov 06	06h47
Nam On (Boualapha)	3	adults size	travelling side by side, 2 sniffing the air, 1 looking down	17 Nov 06	10h08
Nam Theun reservoir	3	adults size	travelling side by side, 2 sniffing the ground, 1 looking up	03 Dec 09	15h04
yellow-throated marten					
Khamkeut (Nam San)	2	adults size	travelling side by side, looking down	27 Mar 06	15h52
Phou Vang	2	adults size	standing side by side, looking up	13 Mar 08	10h00

Other relevant records during 2011-2012 surveys in NNT NPA are presented in Table 7.6.

Table 7.6: Additional opportunistic data collected during foot surveys over 10 different sites visited in NNT NPA in 2011-2012

Species	Details	Date	Area	Geographic coordinates	Elevation (m a.s.l.)
hog badger	remains in snares: skull	Mar-11	Maka	17° 58' N 105° 30' E	~700
hog badger	remains in snares: skull	Jul-11	Thong Xet	17° 46' 21.630" N 105° 30' 47.876" E	973
masked-palm civet	captive at Vietnamese camp; released	Jul-11	Thong Xet	17° 46' 17.559" N 105° 31' 18.574" E	n/a
spotted linsang	remains: tail in poacher camp c.f. App. 1	Jan-12	Nam Chae	17° 48' 2.099" N 105° 17' 5.075" E	n/a
smooth-coated otter	tracks along large river (Nam Theun) c.f. App. 1	Jan-12	upper Nam Theun	18° 0' 52.971" N 105° 27' 28.249" E	675
crab-eating mongoose	sighting	Jan 12, 07h54 am	upper Nam Theun	18° 5' 40.596" N 105° 30' 17.827" E	1006
binturong	remains: spine and hair	Mar-12	Nam Mon	18° 1' 2.323" N 105° 20' 14.896" E	1255

Discussion

Ten species of small carnivores were recorded from camera-traps in NNT NPA from 2006 to 2011. This falls in the upper range (5 - 12) of small carnivore species richness (excluding cats and otters) recorded from camera-trap surveys (>1000 camera-trap days) at single sites in other Southeast Asian countries (e.g. Grassman, 2003; Kawanishi and Sunquist, 2004; Holden and Neang, 2006; Chen et al., 2009; Cheyne et al., 2010; Wilting et al., 2010; Jenks et al., 2011; Than Zaw et al., 2008). In Northern Laos, ten species were also recorded during a long-term camera-trap survey (8499 camera-trap days) although species recorded slightly differ (Johnson et al., 2009). In 1994 and 1996, during a direct observation survey, ten small carnivore species were directly observed within one part of NNT NPA (Duckworth, 1998), of which three were not recorded from this

camera-trap survey (Siberian weasel, stripe-backed weasel, small-toothed palm civet; see below *Other species not recorded*). This highlights the differing adequacy of methodologies for recording some species. The species targeted by camera-trap surveys are in general larger, ground-dwelling mammals, with an associated positioning of cameras not adequate to many other species. When deploying camera-traps, taking into consideration the respective behaviour of small carnivore species to place cameras accordingly can improve the completeness of species inventory (e.g. Samejima and Semiadi, 2012). Placing additional cameras in trees or other microhabitats, for instance, may record these species that are semi- or mainly arboreal or strongly associated with specific microhabitat features.

Viverridae

Five civet species were photographed in NNT NPA. Of the latter, all but Owston's civet had previously been recorded from spot-lighting foot surveys within NNT NPA (Duckworth, 1997). Civets were relatively frequently and widely recorded over the area and altitudes surveyed.

The common palm civet and large Indian civet were the most widely recorded species and found at the largest altitudinal ranges, which concurs with sighting records of the two species across Laos (Duckworth, 1997) and another camera-trap survey in northern Laos (Johnson et al., 2009).

The distribution of records for the other three civet species was more restricted, which may reflect their affinity to higher elevations within NNT NPA. Masked palm civet is indeed considered to range only above 500 m a.s.l. in Laos (Duckworth, 1997; Duckworth et al., 1999). There were fewer to no masked palm civet records at all from sampling areas at lower elevations (e.g. Nam Chae, Nam On, Nam Theun). However, the species' semi-arboreality may render its camera-capture under-represented. In Myanmar, in some areas where captive or dead

specimens of masked palm civets were often recorded, relatively high camera-trap efforts (~300-2000 camera-trap-days) failed to record images of this species (Than Zaw et al., 2008).

Little is known of the distribution and status of Owston's civet across its range (Roberton et al., 2008). In Laos, other records for the species come from elevations >1000 m a.s.l. (Johnson et al., 2009; Sivilay et al. 2011). Given the terrestriality of this species (as deduced from frequent camera-trap captures in its habitat), the elevation range at which it is recorded via camera-trapping across its range, is likely well representative of the elevation range of the species In NNT NPA, where Owston's civet seems to be found only above 1000 m a.s.l. Records from the Vietnamese side of the Annamites go down below the lowest altitude of NNT NPA, e.g. in nearby Pu Mat Nature Reserve, Vietnam, it was camera-trapped down to 400 m (Grieser-Johns, 2000). However, habitat is significantly different between the two slopes, notably in terms of dry-season: it is longer and harsher in most of the west (Timmins and Trinh, 2001), and this may explain the differing altitudinal distribution between the two sides.

The single record of binturong during this survey may in principle be due to any or all of the following (i) arboreality (ii) rarity (iii) the location of cameras that excludes its microhabitats. Binturong is mainly arboreal but regularly comes to the ground where it cannot move between trees in the canopy (Widmann et al., 2008). Camera-trap surveys in Asia at sites where binturongs are known to occur, generally captured only few photographs or none at all (e.g. Holden and Neang, 2006; Datta et al., 2008; Than Zaw et al., 2008; Cheyne et al., 2010; Wilting et al., 2010; Jenks et al., 2011; Samejima and Semiadi, 2012).

Camera-trap records for civets confirm all four frequently photographed species as primarily nocturnal. Sociality of these species is poorly known; they are all classified as solitary but occasionally are found with conspecifics as shown on a few photographs in this study with duos of adult-size individuals of masked palm

civet, large Indian civet and Owston's civet, all taken during March–May. This is the end of the dry season in Laos, and the concentration of the photographs suggests it possibly coincides with the mating season, although it is unclear from the images of what age and sex the individuals were. In Laos, groups (two to five individuals) were occasionally sighted of masked palm civet and common palm civet (Duckworth, 1997; Johnson et al., 2009) and two to five common palm civets were regularly photographed gathering at a salt lick in Cambodia (Edwards, 2012). Our single image of a pair of large Indian civets where the individuals are sniffing each other's perineal region, may indicate they are engaging in mating behaviour. In Cambodia, a pair of *Viverra/Viverricula* (species unconfirmed) was observed possibly involved in a reproductive behaviour in trees in May 2011 (Iseborn et al., 2012). The species has been said to breed throughout the year (Lekagul and McNeely, 1988), although this has never been studied in wild populations. Similarly, little is known of the breeding seasons of masked palm civet and Owston's civet in the wild.

Prionodontidae

Four photos were taken of the spotted linsang. This low frequency of photo-capture of linsangs (*Prionodon*) is common during camera-trap surveys across their range, when the species is not targeted (e.g. Holden and Neang, 2006; Datta et al., 2008; Than Zaw et al., 2008; Cheyne et al., 2010; Wilting et al., 2010; Jenks et al., 2011). Camera-traps generally exclude micro-habitats of the species; as an ambush hunter, it may spend most of its ground-level time hidden in thicker understorey (Duckworth, pers. comm.) where camera-traps are rarely set. Linsangs are semi-arboreal species, possibly primarily ranging in dense understorey 1 m above ground (Van Rompaey, 1995). When this was taken in consideration, camera-traps have recorded the species at higher frequency (e.g. Samejima and Semiadi, 2012). The species remains poorly known but it has been found in various forest types and wide altitudinal range where it occurs and seems resilient to degraded habitat (Roberton et al., 2008). The species seems

mainly active at dusk and night with occasional activity during daytime (Borah, 2010).

Mustelidae

Four Mustelid taxa were recorded in NNT NPA, which had previously been confirmed in the area (Duckworth, 1997; Robichaud and Stuart, 1999; Robichaud, 2010; Duckworth et al., 1999). Ferret badgers were the most frequently camera-trapped taxa, although not evenly recorded throughout the sampled areas. The distribution of *Melogale* spp. in Laos and neighbouring countries remain uncertain. Two species of ferret badgers have been recorded in Laos: large-toothed (*M. personata*) and small-toothed (*M. moschata*) ferret badgers (Duckworth et al., 1999), and a third, *M. cucphuongensis*, has recently been named from neighbouring Vietnam; Nadler et al., 2011) and could plausibly inhabit Laos (if valid taxonomically). Despite intensive camera-trap survey in Nam Et-Phou Louey NPA, north-eastern Laos, no images were taken of the genus (Johnson et al., 2009), suggesting the possibility of their absence from that area, given the comparatively frequency at which it was recorded in NNT NPA. However, other factors such as differences in camera positioning might also contribute to this pattern. On current knowledge, species identification requires observation of the skull and dentition (Schank et al., 2009; Robichaud, 2010), therefore few records across Laos have been identified to species. A skull of *M. moschata* recently found in NNT NPA confirms that at least the latter species occurs there (Robichaud, 2010). How many species are found in the NPA remains unclear. Photographs of the genus in NNT NPA shows variation in the individuals' fur coloration, from light brown to grey (Appendix 7.2). This variation may be found within single species (e.g. Schank et al., 2009; Nadler et al., 2011) as is also observed in other small carnivore species (Veron et al., 2004). Photographs confirm the genus as exclusively nocturnal in NNT NPA.

Hog badger was recorded widely in terms of altitude, geography and photo-capture frequency. Records suggest the species can be active during day and night time, as has previously been found in Myanmar (Than Zaw et al., 2008). A few photographs showed partial-albino/leucistic forms, which has rarely been documented on other badger species (e.g. Roest, 1961; and see McCardle, 2012).

Activity cycle, altitudinal range and sociality of yellow-throated marten recorded from this survey is consistent with previous studies, in which the species has been recorded primarily by day and often travelling in small groups (e.g. Duckworth, 1997; Holden and Neang, 2009; Datta et al., 2008; Parr and Duckworth, 2007).

Herpestidae

The photos of crab-eating mongoose in duos or groups of 3-4 individuals are consistent with previous observations that this species regularly travels with conspecifics (Duckworth, 1997; Than Zaw et al., 2008; Johnson et al., 2009). The species was primarily recorded from 5h00 to 17h00, consistent with previous records across its range (e.g. Duckworth, 1997; Edwards, 2012; Holden and Neang, 2009; Chen et al., 2009; Than Zaw et al. 2008), although occasional activity was recorded from dusk to night time.

Species not recorded

Previously confirmed species in NNT NPA were not recorded during this camera-trap survey. Both the stripe-backed weasel (*Mustela strigidorsa*) and the Siberian weasel (*M. sibirica*) have been sighted at least once in NNT NPA (Duckworth, 1997; Duckworth, 1998; Abramov et al., 2008; Streicher et al., 2010). Little is known of their ecology and habitat use. Both species have been recorded in various habitat types across their range; however, stripe-backed weasel probably occurs mainly in hills and mountain evergreen forests for which NNT NPA is

typical; but the regional habitat use of Siberian weasel remain poorly understood (Lekagul and McNeely, 1988; Duckworth et al., 1999; Abramov et al., 2008).

The small-toothed palm civet (*Arctogalidia trivirgata*) is at least locally common in NNT NPA (Duckworth, 1997), but is a strictly arboreal species (Duckworth and Nettelbeck, 2007), which explains its absence from image records from ground-level camera-trapping.

Of the other small carnivore species inhabiting the area, are at least two otter species: Oriental small-clawed otter (*Aonyx cinereus*) and smooth-coated otter (*Lutrogale perspicillata*) (see Duckworth, 1997; Coudrat, 2012a). The latter species has never officially been confirmed in NNT NPA, though recent (Jan 2012) photographs of tracks along the Nam (=river) Theun (18° 0' 52.971" N 105° 27' 28.249" E) were attributed to that species (N. Duplaix, pers. comm.). Otters were unsurprisingly not recorded from this camera-trap survey due to the location of cameras at unsuitable otter-habitat. Otter tracks were commonly observed along large rivers in the area in 1996 (Timmins and Evans, 1996) and several tracks were observed along the Nam Theun in 2012 (Coudrat, 2012a).

Various small carnivores known from Laos remain unrecorded from NNT NPA except from its lowland western part (the Nakai plateau), which is not here covered. Two of these species are tied in Laos to highly deciduous and/or degraded habitats: small Indian civet (*Viverricula indica*) and small Asian mongoose (*Herpestes javanicus*) (see Duckworth et al., 1999; Duckworth et al., 2010). For these, there is presently little if any suitable habitat in the NPA off the Nakai plateau. Large-spotted civet (*Viverra magaspila*) probably occurs, or used to, on the Nakai Plateau (Khounboline, 2005), but this seems to be about its upper altitudinal limit in Laos (Duckworth et al., 2010) and it is likely to be extremely local, if present at all, in the NPA off the plateau. The final species known to inhabit Laos but not recorded from the NPA is yellow-bellied weasel *Mustela kathiah*. This is known from highlands (over 1000 m) in both North and

South Laos (Tizard, 2002; Duckworth and Robichaud, 2005) and presumably occurs along the intervening Annamite spine, although there are as yet no records. Like other weasels in South-east Asia it seems only poorly recorded by camera-traps (Supparatvikorn et al., 2012), so it may well inhabit NNT NPA. Two other species have not been recorded in the NPA but are so difficult to identify that they may have been detected but not identified: Eurasian otter (*Lutra lutra*) and large-toothed ferret badger (*M. personata*).

Threats

Of all small carnivore species discussed here, civets are the most commonly used in Laos: they have been recorded sold as food in markets, as processed products for traditional medicine, kept as trophies and as pets and are also traded with Vietnamese (Duckworth et al., 1999; Nooren and Claridge, 2001; Sivilay et al., 2011). In NNT NPA, the extent of small carnivore hunting -- whether for local consumption or trade with Vietnamese -- is unknown; however the extremely large scale of ground snare traps set-up across the area by Lao and Vietnamese poachers (Coudrat, 2012a; Robichaud et al., 2009) undoubtedly catch large number of these animals, targeted or not. The opportunistic findings of live or remains of small carnivores at a poacher camps or in snares in 2011-2012, suggests at least that such traps often catch these species. Wild meat, including several small carnivore species, traditionally formed a large part of upland Lao people's diet, but unsustainable harvest has led to a decrease in these species' wild populations (Krahn, 2005; Krahn and Johnson, 2007). Annual kill rate of Viverrid species have dramatically decreased in some villages in Laos (Krahn, 2005) and there has been a switch to smaller-bodied animals (such as squirrels and rats) now more commonly hunted (Krahn and Johnson, 2007).

The difference in the relative encounter rates of small carnivores between the six areas sampled in this study is surely at least in part driven by methodological factors as well as differences in environmental and topographical characteristics

between these areas, notably influencing behaviour of the species (c.f. Sollmann et al., 2013). Nonetheless, it is likely that also unsustainable hunting is reducing populations of some species of small carnivores in some parts of the NPA. The areas with the highest relative encounter rates in small carnivores, are also found the farthest away from villages as well as at the highest mean elevation and most rugged terrain, therefore are the most difficult accessible areas to humans. This trend was also suggested in Cambodia for large mammals recorded on camera-traps (Gray and Phan, 2011). Much fewer species were recorded from the southern sampling area (Nam On), with some species not recorded even once. This is likely demonstrating their relatively higher sensitivity to hunting pressure. Surveys in 2011 in this area found evidence of hunting including Vietnamese poacher camps, snare traps, and gunshots (Coudrat, 2012a).

Overall, 15 species of the 21 small carnivore species confirmed to occur in Laos are found in NNT NPA. As small carnivore species remain very poorly known, a wide variety of new techniques for placement of cameras should be considered. NNT NPA is one of the largest remaining forest blocks in Indochina, where species would be assumed to be more resilient to anthropogenic activity than in smaller and more fragmented landscapes. However, the intensity of snare hunting in the area puts the wildlife at high risk of local extinction, especially ground dwelling mammals such as small carnivores, and cat records from this survey are now so few as to suggest strongly that they are already severely reduced (c.f. CHAPTER 6). The area nonetheless may still be one of the most important for the conservation of Owston's civet (Schreiber et al., 1989) and its two species of otters.

Appendix 7.1: (a) smooth-coated otter tracks (identified to species by N. Duplaix, pers. comm.) along the Nam (=river) Theun; (b) spotted linsang tail found at a poacher camp in Nam Chae (Houay Thong) area (c.f. Table 7.5).

a

b

Appendix 7.2: Two main coat colorations observed of *Melogale* sp(p). photo-captured in NNT NPA: (a) grey; (b) light brown-orange; Photos credit © WMPA

a

b

Appendix 7.3: camera-trap records (only first photograph taken for each camera is presented small carnivores in Nakai-Nam Theun National Protected Area from 2006 to 2011.

Species	Area	site	Longitude	Latitude	date	time	Elev.
Large Indian civet	Khamkeut	Nam San	105.192299	18.253809	15/04/2006	19h43	770
	Khamkeut	Nam San	105.232228	18.217421	12/04/2006	02h23	629
	Khamkeut	Nam San	105.217444	18.216697	21/04/2006	05h34	716
	Khamkeut	Thong Pae	105.141786	18.279287	18/05/2007	02h34	1191
	Khamkeut	Thong Pae	105.140471	18.292113	14/04/2007	20h24	1199
	Khamkeut	Thong Pae	105.137566	18.338744	03/04/2007	01h55	661
	Nam Chae	Makfueng	105.300027	17.779554	20/12/2007	21h47	585
	Nam Chae	Makfueng	105.322785	17.817571	27/11/2007	00h56	964
	Nam Chae	Makfueng	105.328931	17.860341	16/12/2007	03h00	855
	Nam Chae	Makfueng	105.301233	17.834671	21/12/2007	19h47	757
	Nam Chae	Navang	105.296622	17.927920	20/03/2008	19h12	822
	Nam Chae	Navang	105.267037	17.876018	04/02/2008	02h04	819
	Nam Chae	Navang	105.272984	17.913195	11/02/2008	18h49	867
	Nam Chae	Navang	105.286012	17.912525	03/03/2008	18h45	839
	Nam Chae	Navang	105.306614	17.901792	18/02/2008	00h41	856
	Nam Mon	Thongkacheng	105.333891	18.048615	14/03/2009	03h47	-
	Nam Mon	Thongkacheng	105.335000	18.050556	28/04/2009	02h10	-
	Nam Mon	Thongkacheng	105.337400	18.045825	14/03/2010	04h24	784
	Nam Mon	Thongkacheng	105.338199	18.028497	05/03/2010	23h43	1097
	Nam Mon	Thongkacheng	105.370035	18.059305	27/03/2010	05h40	1622
	Nam Mon	Thongkacheng	105.351493	18.081637	18/03/2010	20h28	1352
	Nam Mon	Thongkacheng	105.346142	18.099742	29/03/2010	21h47	1175
	Nam Mon	Thongkacheng	105.341613	18.069426	29/03/2010	22h18	1033
	Nam Mon	Thongkacheng	105.338099	18.055675	30/03/2010	04h35	957
	Nam Mon	Thongkacheng	105.380337	18.029774	09/03/2010	22h56	1421
	Nam Mon	Thongkacheng	105.358850	18.041999	07/03/2010	23h01	1243
	Nam Mon	Thongkacheng	105.364321	18.056107	09/03/2010		1424
	Nam Mon	Thongkacheng	105.360222	18.057018	14/03/2010	19h31	1282
	Nam Mon	Thongkacheng	105.372549	18.068664	07/04/2010	01h16	1707
	Nam Mon	Thongkacheng	105.362525	18.055469	18/03/2010	20h51	1369
	Nam Mon	Thongkacheng	105.354021	18.055719	13/03/2010	04h12	1379
	Nam Theun	reservoir	105.314897	17.731553	18/12/2009	22h19	541
	Nam Theun	reservoir	105.343833	17.716193	21/11/2009	21h34	531
	Nam Theun	reservoir	105.342671	17.705385	15/12/2009	22h55	548
	Nam Theun	reservoir	105.261983	17.744385	23/11/2009	18h07	573
	Nam Theun	reservoir	105.246512	17.742959	20/11/2009	23h11	539
	Nam Theun	reservoir	105.343006	17.677870	22/11/2009	23h45	565
	Nam Theun	reservoir	105.357231	17.704726	08/12/2009	05h00	551
	Nam Theun	reservoir	105.230468	17.772969	04/12/2009	01h14	549
masked palm civet	Khamkeut	Nam San	105.207102	18.204064	24/03/2006	01h47	901
	Khamkeut	Nam San	105.232228	18.217421	21/03/2006	01h33	629
	Khamkeut	Nam San	105.217444	18.216697	05/04/2006	02h05	716
	Khamkeut	Nam San	105.218171	18.215522	23/12/2010	19h07	824
	Khamkeut	Nam San	105.178777	18.277665	24/01/2011	20h37	652
	Khamkeut	Nam San	105.241563	18.265259	31/12/2010	00h21	1609

	Khamkeut	Thong Pae	105.128729	18.291489	05/04/2007	21h00	1242
	Khamkeut	Thong Pae	105.140471	18.292113	04/04/2007	05h43	1199
	Khamkeut	Thong Pae	105.128708	18.302434	07/04/2007	21h16	1247
	Khamkeut	Thong Pae	105.178159	18.366602	03/03/2007	01h58	891
	Khamkeut	Thong Pae	105.154780	18.315728	23/04/2007	04h29	1332
	Khamkeut	Thong Pae	105.203416	18.303499	14/04/2007	03h04	1189
	Khamkeut	Thong Pae	105.178355	18.290916	28/04/2007	20h17	826
	Khamkeut	Thong Pae	105.192624	18.316715	23/03/2007	18h39	1621
	Khamkeut	Thong Pae	105.204318	18.290221	19/04/2007	02h11	1245
	Khamkeut	Thong Pae	105.140974	18.316498	17/05/2007	19h40	1069
	Khamkeut	Thong Pae	105.178260	18.354310	04/05/2007	21h03	1792
	Khamkeut	Thong Pae	105.122925	18.327049	24/04/2007	22h15	761
	Khamkeut	Thong Pae	105.154583	18.328500	02/04/2007	21h04	1344
	Khamkeut	Thong Pae	105.137566	18.338744	09/04/2007	02h09	661
	Khamkeut	Thong Pae	105.154379	18.365141	02/05/2007	01h00	796
	Khamkeut	Thong Pae	105.250711	17.926277	11/05/2007	02h58	769
	Nam Chae	Navang	105.252826	17.872593	06/03/2008	02h03	1063
	Nam Chae	Navang	105.364321	18.056107	21/02/2008	19h35	651
	Nam Mon	Thongkacheng	105.346142	18.099742	11/03/2010	23h06	1424
	Nam Mon	Thongkacheng	105.339183	18.083864	23/03/2010	03h32	1175
	Nam Mon	Thongkacheng	105.380337	18.029774	20/03/2010	23h13	1221
	Nam Mon	Thongkacheng	105.366351	18.028012	09/03/2010	19h59	1421
	Nam Mon	Thongkacheng	105.364321	18.056107	14/03/2010	00h27	1380
	Nam Mon	Thongkacheng	105.362525	18.055469	01/04/2010	*night*	1424
	Nam Mon	Thongkacheng	105.581386	17.820001	11/03/2010	01h21	1369
	Phou Vang	Nam Heuy	105.565148	17.805903	15/03/2008	02h09	-
	Phou Vang	Nam Heuy	105.583900	17.818620	30/03/2008	02h54	-
	Phou Vang	Nam Heuy	105.583334	17.818368	09/03/2008	03h23	-
	Phou Vang	Nam Heuy	105.438904	18.079560	06/03/2008	22h53	-
	Thong Xet		105.438236	17.808407	28/12/2008	22h26	686
common palm civet	Khamkeut	Nam Sane	105.207102	18.204064	20/03/2006	05h28	901
	Khamkeut	Nam Sane	105.255323	18.230018	28/04/2006	01h40	1634
	Khamkeut	Nam Sane	105.244531	18.277068	11/05/2006	02h27	1675
	Khamkeut	Nam Sane	105.192299	18.193559	29/03/2006	18h56	1278
	Khamkeut	Nam Sane	105.236266	18.266268	06/04/2006	02h03	1649
	Khamkeut	Nam Sane	105.221656	18.188737	06/04/2006	23h34	981
	Khamkeut	Nam Sane	105.217971	18.267149	17/04/2006	22h54	1425
	Khamkeut	Nam Sane	105.270446	18.253759	10/04/2006	22h36	1437
	Khamkeut	Nam Sane	105.231243	18.230474	08/04/2006	00h05	1359
	Khamkeut	Thong Pae	105.180812	18.378323	15/04/2007	01h54	929
	Khamkeut	Thong Pae	105.193524	18.377171	01/04/2007	03h40	906
	Khamkeut	Thong Pae	105.166632	18.290537	02/05/2007	23h23	1015
	Khamkeut	Thong Pae	105.203416	18.303499	08/05/2007	20h27	1189
	Khamkeut	Thong Pae	105.204318	18.290221	29/03/2007	03h45	1245
	Khamkeut	Thong Pae	105.178260	18.354310	30/03/2007	02h28	1792
	Khamkeut	Thong Pae	105.140974	18.316498	20/04/2007	19h25	1069
	Khamkeut	Thong Pae	105.154583	18.328500	05/04/2007	23h33	1344
	Khamkeut	Thong Pae	105.191838	18.290758	03/04/2007	22h43	974

	Khamkeut	Thong Pae	105.137566	18.338744	17/04/2007	19h47	661
	Khamkeut	Thong Pae	105.141011	18.327209	11/05/2007	20h11	845
	Khamkeut	Thong Pae	105.122776	18.316556	24/03/2007	20h40	1152
	Nam Chae	Makfueng	105.302453	17.858892	17/11/2007	03h04	799
	Nam Chae	Makfueng	105.322785	17.817571	21/12/2007	22h16	964
	Nam Chae	Makfueng	105.328931	17.860341	06/12/2007	19h25	855
	Nam Chae	Makfueng	105.284886	17.834135	17/11/2007	19h04	864
	Nam Chae	Makfueng	105.293004	17.846244	17/11/2007	02h16	957
	Nam Chae	Navang	105.253049	17.856983	12/03/2008	21h32	742
	Nam Chae	Navang	105.272984	17.913195	08/02/2008	01h09	867
	Nam Chae	Navang	105.286012	17.912525	25/02/2008	22h25	839
	Nam Mon	Thongkacheng	105.339183	18.083864	21/03/2010	04h52	1221
	Nam Mon	Thongkacheng	105.338099	18.055675	12/03/2010	03h04	957
	Nam Mon	Thongkacheng	105.371513	18.042951	04/03/2010	19h23	1398
	Nam Mon	Thongkacheng	105.362525	18.055469	03/04/2010	02h09	1369
	Nam On	Boualapha	105.701894	17.640339	13/10/2006	02h44	831
	Nam On	Boualapha	105.698811	17.613280	01/11/2006	00h56	823
	Nam On	Boualapha	105.663114	17.622695	16/11/2006	01h36	778
	Nam On	Boualapha	105.714056	17.638379	31/10/2006	02h08	924
	Nam On	Boualapha	105.656698	17.613135	23/11/2006	04h20	757
	Nam On	Boualapha	105.650763	17.653394	18/10/2006	01h04	791
	Nam On	Boualapha	105.701225	17.691544	13/10/2006	19h34	914
	Nam On	Boualapha	105.630784	17.612054	09/11/2006	17h31	742
	Nam On	Boualapha	105.639034	17.653080	13/11/2006	21h47	787
	Nam On	Gnomalath	105.593309	17.664196	08/01/2007	21h33	702
	Nam On	Gnomalath	105.562920	17.611726	06/01/2007	19h40	623
	Nam On	Gnomalath	105.619181	17.612136	26/12/2006	20h01	657
	Nam On	Gnomalath	105.572712	17.650446	09/01/2007	22h33	692
	Nam On	Gnomalath	105.626903	17.678111	15/01/2007	18h47	850
	Nam On	Gnomalath	105.620257	17.689638	20/01/2007	02h40	839
	Nam Theun	reservoir	105.230468	17.772969	19/11/2009	22h48	549
	Phou Vang	Nam Heuy	105.566945	17.807227	11/03/2008	21h09	-
	Phou Vang	Nam Heuy	105.335000	18.050556	28/03/2008	02h22	-
	ThongXet		105.438904	18.079560	25/12/2008	19h54	686
	ThongXet		105.422513	17.718733	03/12/2008	22h12	626
	ThongXet		105.430394	17.737092	18/01/2009	19h01	688
Owston's civet	Khamkeut	Nam San	105.566945	17.807227	24/03/2006	01h53	1155
	Khamkeut	Nam San	105.338199	18.028497	13/04/2006	18h49	1675
	Khamkeut	Nam San	105.341613	18.069426	02/05/2006	21h49	1370
	Khamkeut	Thong Pae	105.358850	18.041999	11/04/2007	00h43	1189
	Khamkeut	Thong Pae	105.354021	18.055719	24/03/2007	00h20	1527
	Khamkeut	Thong Pae	105.313005	18.030130	24/03/2007	02h55	1621
	Khamkeut	Thong Pae	105.207069	18.240751	03/04/2007	21h11	1245
	Khamkeut	Thong Pae	105.244531	18.277068	19/04/2007	20h37	1344
	Phou vang	Houay Nam Heuy	105.206195	18.277556	07/03/2008	19h54	-
	Nam Mon	Thongkacheng	105.203416	18.303499	27/03/2010	21h12	1097
	Nam Mon	Thongkacheng	105.165739	18.326719	25/03/2010	01h47	1033

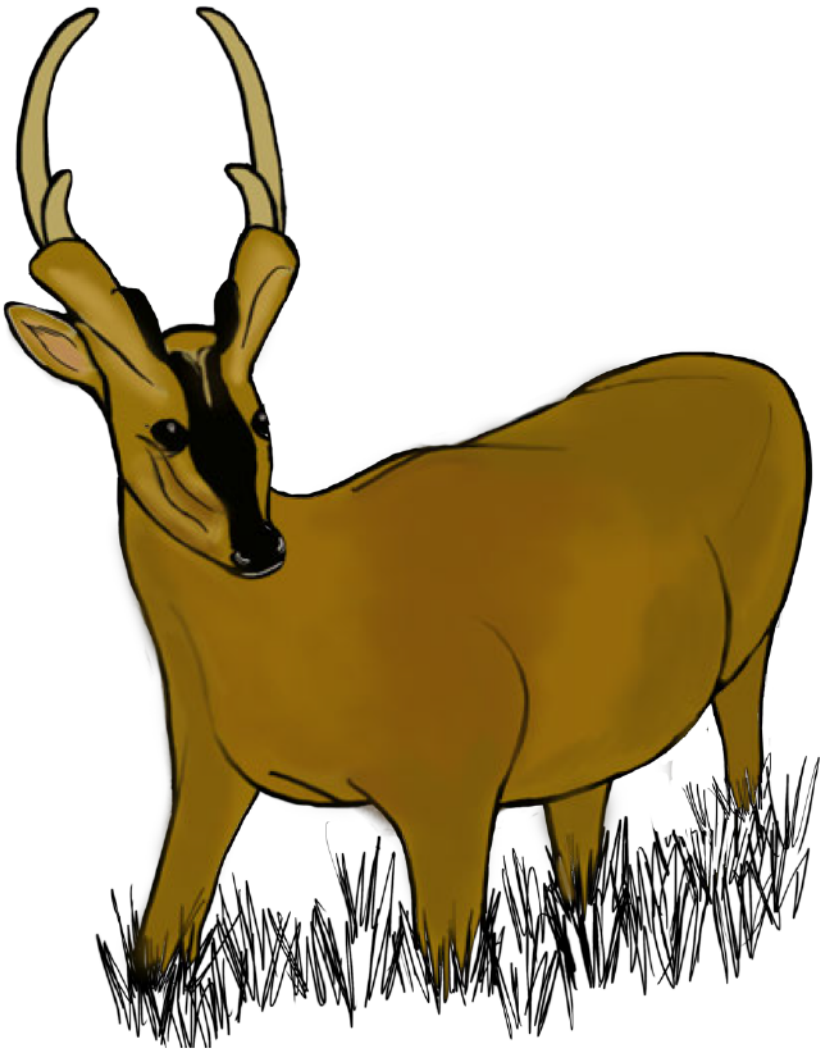
	Nam Mon	Thongkacheng	105.192624	18.316715	16/03/2010	20h46	1243
	Nam Mon	Thongkacheng	105.204318	18.290221	15/03/2010	03h04	1379
	Nam Mon	Thongkacheng	105.154583	18.328500	13/03/2010	21h22	1034
	Thong Xet	Thong Xet	105.535110	17.785326	16/12/2008	23h39	904
spotted linsang	Khamkeut	Nam San	105.232195	18.277933	18/04/2006	05h29	1594
	Khamkeut	Nam San	105.231243	18.230474	03/04/2006	04h59	1359
	Khamkeut	Thong Pae	105.128729	18.291489	18/04/2007	02h58	1242
	Nam On	Gnomalath	105.613360	17.677340	02/01/2007	04h11	839
yellow throated marten	Khamkeut	Thong Pae	105.357872	17.676470	07/04/2007	12h57	1792
	Khamkeut	Thong Pae	105.261983	17.744385	12/04/2007	15h19	1199
	Khamkeut	Nam San	105.593309	17.664196	27/03/2006	15h52	1437
	Khamkeut	Nam San	105.178260	18.354310	27/04/2006	18h06	1358
	Khamkeut	Nam San	105.140471	18.292113	18/04/2006	05h53	1305
	Khamkeut	Nam San	105.270446	18.253759	17/05/2006	06h43	1548
	Nam Chae	Navang	105.281637	18.253553	11/02/2008	08h59	758
	Nam Chae	Makfueng	105.193954	18.202433	26/12/2007	16h38	964
	Nam Chae	Makfueng	105.230272	18.290878	08/12/2007	08h36	1036
	Nam On	Gnomalath	105.567779	17.811111	21/01/2007	09h18	702
	Nam Theun	reservoir	105.230152	17.887499	12/11/2009	07h15	562
	Nam Theun	reservoir	105.322785	17.817571	23/11/2009	09h48	573
	Phou Vang	Nam Heuy	105.335498	17.874069	13/03/2008	10h00	-
	Phou Vang	Nam Heuy	105.301233	17.834671	18/03/2008	16h14	-
	Thong Xet		105.535110	17.785326	09/12/2008	10h42	904
ferret badger	Khamkeut	Nam San	105.232183	18.254822	05/04/2006	02h33	1377
	Khamkeut	Nam San	105.207102	18.204064	21/03/2006	23h18	901
	Khamkeut	Nam San	105.255323	18.230018	24/04/2006	04h14	1634
	Khamkeut	Nam San	105.244531	18.277068	29/04/2006	21h42	1675
	Khamkeut	Nam San	105.236266	18.266268	02/04/2006	20h21	1649
	Khamkeut	Nam San	105.232195	18.277933	02/04/2006	01h58	1594
	Khamkeut	Nam San	105.221656	18.188737	26/03/2006	21h12	981
	Khamkeut	Nam San	105.232228	18.217421	22/03/2006	23h25	629
	Khamkeut	Nam San	105.217971	18.267149	04/04/2006	01h10	1425
	Khamkeut	Nam San	105.230272	18.290878	01/04/2006	20h39	1548
	Khamkeut	Nam San	105.177319	18.266893	08/04/2006	03h17	583
	Khamkeut	Nam San	105.219300	18.240855	24/12/2010	19h01	1271
	Khamkeut	Thong Pae	105.128729	18.291489	24/04/2007	00h57	1242
	Khamkeut	Thong Pae	105.141786	18.279287	02/05/2007	01h21	1191
	Khamkeut	Thong Pae	105.180812	18.378323	11/05/2007	01h18	929
	Khamkeut	Thong Pae	105.203416	18.303499	04/04/2007	04h47	1189
	Khamkeut	Thong Pae	105.191503	18.303773	04/04/2007	19h47	1108
	Khamkeut	Thong Pae	105.204318	18.290221	08/04/2007	05h01	1245
	Khamkeut	Thong Pae	105.122925	18.327049	01/04/2007	18h56	761
	Khamkeut	Thong Pae	105.154583	18.328500	25/04/2007	00h33	1344
	Khamkeut	Thong Pae	105.122776	18.316556	06/05/2007	21h04	1152
	Nam On	Boualapha	105.701894	17.640339	21/10/2006	03h53	831
	Nam On	Boualapha	105.642574	17.667666	12/11/2006	05h16	827
	Nam On	Boualapha	105.666271	17.679093	17/10/2006	22h09	728

	Nam On	Boualapha	105.650763	17.653394	19/10/2006	02h52	791
	Nam On	Boualapha	105.651854	17.679015	28/10/2006	02h31	882
	Nam On	Boualapha	105.672071	17.692016	30/10/2006	03h08	933
	Nam On	Boualapha	105.639034	17.653080	20/11/2006	01h05	787
	Nam On	Gnomalath	105.551027	17.689898	24/01/2007	22h31	780
	Nam On	Gnomalath	105.607616	17.662760	19/02/2007	00h07	708
	Phou Vang	Nam Heuy	105.561112	17.809720	04/03/2008	22h27	-
	Phou Vang	Nam Heuy	105.562500	17.806941	05/03/2008	04h30	-
	Thong Xet		105.460385	17.758138	29/11/2008	20h19	846
	Thong Xet		105.535110	17.785326	06/12/2008	03h28	904
Hog badger	Khamkeut	Nam San	105.205559	18.227014	16/04/2006	01h59	1050
	Khamkeut	Nam San	105.204279	18.191802	24/04/2006	02h26	820
	Khamkeut	Nam San	105.244306	18.204291	15/04/2006	00h55	1481
	Khamkeut	Nam San	105.217444	18.216697	19/03/2006	09h54	716
	Khamkeut	Nam San	105.236423	18.200578	22/03/2006	02h59	1001
	Khamkeut	Nam San	105.245904	18.217278	30/03/2006	05h15	1356
	Khamkeut	Nam San	105.232228	18.217421	18/04/2006	05h08	629
	Khamkeut	Nam San	105.231728	18.240045	15/04/2006	20h20	1383
	Khamkeut	Thong Pae	105.191503	18.303773	04/04/2007	04h40	1108
	Khamkeut	Thong Pae	105.166632	18.290537	07/05/2007	23h42	1015
	Khamkeut	Thong Pae	105.153784	18.291533	14/05/2007	05h54	911
	Khamkeut	Thong Pae	105.178321	18.303678	01/05/2007	00h47	897
	Nam Chae	Makfueng	105.284597	17.806377	23/11/2007	00h39	612
	Nam Chae	Navang	105.250711	17.926277	12/03/2008	04h49	1063
	Nam Chae	Navang	105.297883	17.942742	10/03/2008	03h20	1052
	Nam Mon	Thongkacheng	105.338199	18.028497	02/04/2010	05h56	1097
	Nam Mon	Thongkacheng	105.370035	18.059305	09/03/2010	07h11	1622
	Nam Mon	Thongkacheng	105.351493	18.081637	21/04/2010	06h24	1352
	Nam Mon	Thongkacheng	105.344760	18.094131	17/04/2010	20h12	1152
	Nam Mon	Thongkacheng	105.346142	18.099742	22/03/2010	01h34	1175
	Nam Mon	Thongkacheng	105.339183	18.083864	27/03/2010	04h04	1221
	Nam Mon	Thongkacheng	105.343221	18.079926	17/04/2010	00h00	1065
	Nam Mon	Thongkacheng	105.341613	18.069426	11/03/2010	06h26	1033
	Nam Mon	Thongkacheng	105.364321	18.056107	11/03/2010	*night*	1424
	Nam Mon	Thongkacheng	105.313005	18.030130	17/03/2010	18h36	1034
	Nam On	Boualapha	105.686033	17.614192	07/11/2006	04h30	885
	Nam On	Boualapha	105.642574	17.667666	29/10/2006	19h13	827
	Nam On	Boualapha	105.727737	17.639305	19/10/2006	19h18	954
	Nam Theun	resevoir	105.317868	17.688786	14/11/2010	04h31	577
	Nam Theun	resevoir	105.359577	17.732498	21/11/2009	17h24	547
	Nam Theun	resevoir	105.301730	17.759621	25/11/2009	17h55	550
	Phou Vang	Nam Heuy	105.581490	17.820326	31/03/2008	*day*	-
	Phou Vang	Nam Heuy	105.583334	17.818368	21/03/2008	05h05	-
	Phou Vang	Nam Heuy	105.580567	17.814797	16/03/2008	19h22	-
	Phou Vang	Nam Heuy	105.579725	17.817222	-	-	-
	Phou Vang	Nam Heuy	105.581670	17.820552	20/03/2008	04h09	-
	Phou Vang	Nam Heuy	105.578332	17.818338	12/03/2008	04h01	-
	Phou Vang	Nam Heuy	105.566945	17.807227	06/03/2008	11h06	-

	Phou Vang	Nam Heuy	105.561112	17.809720	19/03/2008	22h58	-
	Phou Vang	Nam Heuy	105.567779	17.811111	26/03/2008	12h44	730
	Thong Xet		105.466893	17.732209	12/12/2008	09h54	725
	Thong Xet		105.516940	17.785709	19/12/2008	17h24	725
crab-eating mongoose	Khamkeut	Nam San	105.206023	18.179463	02/05/2006	10h16	630
	Khamkeut	Nam San	105.218817	18.277759	04/04/2006	16h40	1430
	Khamkeut	Nam San	105.193954	18.202433	10/04/2006	17h46	1305
	Khamkeut	Nam San	105.230272	18.290878	16/04/2006	11h46	1548
	Khamkeut	Nam San	105.217444	18.216697	27/03/2006	15h42	716
	Khamkeut	Thong Pae	105.178159	18.366602	01/05/2006	09h31	891
	Khamkeut	Thong Pae	105.154651	18.352117	28/04/2006	11h48	1031
	Khamkeut	Thong Pae	105.203416	18.303499	24/04/2007	07h48	1189
	Khamkeut	Thong Pae	105.178260	18.354310	27/04/2007	10h37	1792
	Khamkeut	Thong Pae	105.140974	18.316498	23/04/2007	05h48	1069
	Khamkeut	Thong Pae	105.154583	18.328500	02/05/2007	15h47	1344
	Khamkeut	Thong Pae	105.137566	18.338744	02/04/2007	08h04	661
	Khamkeut	Thong Pae	105.141011	18.327209	11/05/2007	05h00	845
	Khamkeut	Thong Pae	105.154379	18.365141	04/05/2007	09h57	796
	Nam Chae	Makfueng	105.302453	17.858892	15/12/2007	15h46	799
	Nam Chae	Navang	105.306614	17.901792	18/02/2008	14h40	856
	Nam Mon	Thongkacheng	105.351493	18.081637	23/03/2010	11h46	1352
	Nam Mon	Thongkacheng	105.317444	18.013727	01/04/2010	16h28	798
	Nam Mon	Thongkacheng	105.372549	18.068664	13/04/2010	09h25	1707
	Nam Mon	Thongkacheng	105.365480	18.081674	27/03/2010	08h20	1494
	Nam Mon	Thongkacheng	105.362525	18.055469	13/03/2010	06h45	1369
	Nam Mon	Thongkacheng	105.339484	18.048316	05/03/2010	10h30	934
	Nam On	Boualapha	105.658080	17.666693	10/11/2006	06h47	719
	Nam On	Boualapha	105.639034	17.653080	17/11/2006	10h08	787
	Nam Theun	reservoir	105.314897	17.731553	15/12/2009	11h36	541
	Nam Theun	reservoir	105.343833	17.716193	03/12/2009	15h04	531
	Phou Vang	Nam Heuy	105.585698	17.817024	11/03/2008	15h56	-
Binturong	Nam Chae	Makfueng	105.322402	17.871840		01h18	828

CHAPTER 8

ASSESSING THE NICHE OF THE ENDANGERED LARGE-ANTLERED MUNTJAC (*M. VUQUANGENSIS*) AND OTHER MUNTJAC SPP. IN NAKAI-NAM THEUN NATIONAL PROTECTED AREA, LAOS



Introduction

The Cervidae and Bovidae in Southeast Asia are diverse families but have been poorly studied and indeed much confusion remains on their taxonomy, distribution and ecology. The world's latest new discoveries of large mammals, belong to these two families and were only found two decades ago in the Annamite mountain range along the Lao-Vietnamese border. These include the saola (*Pseudoryx nghetinhensis*) (Vu Van Dzung et al., 1993; Schaller and Rabinowitz, 1995), the large-antlered muntjac (*Muntiacus vuquangensis*) (Tuoc et al., 1994; Duckworth et al., 1994; Evans and Timmins, 1995; Schaller and Vrba, 1996) and the Annamite muntjac (*M. truongsonensis*) (Giao et al., 1998). The saola has still never been observed directly in the wild by a biologist but has been camera-trapped from a few locations in Vietnam and Laos (Robichaud and Stuart, 1999; Hardcastle et al., 2004). The large-antlered muntjac has been more widely recorded since its discovery, mainly via camera-traps. The Annamite muntjac was described from a single skull holotype from central Vietnam (Giao et al., 1998), its taxonomic position remains debated given that morphological characteristics for this taxon are not objectively defined (Timmins et al., 2008a) (c.f. Table 8.1).

Table 8.1: note on taxonomic status of muntjac species referred to in the text

Taxon	Consensus on species validated?	Clear morphological characteristics to differentiate from other muntjac species?	Species complex (i.e. *sensu lato*, *s.l.*) to which taxon belongs	references
M. vaginalis Northern red muntjac	no	no	*M. muntjac s.l.*	Groves, 2003; Timmins et al., 2008b
M. truongsonensis Annamite muntjac	no	no	*M. rooseveltorum s.l.*	Giao et al., 1998; Timmins et al., 2008a
M. vuquangensis Large-antlered muntjac	yes	yes	-	Tuoc et al., 1994

Since their discovery, little information has been collected on these species. Indeed, direct sighting by biologists is too rare and tell-tale signs (i.e. tracks, droppings, and muntjacs calls) are unidentifiable to species level; this, coupled

with the difficulty of access of the habitats where they occur, make their study challenging. More recently, however, the use of camera-traps allowed wide records of images of these species with clear observation of species-specific morphology to confirm identification of at least some species.

Several of these species are found sympatrically in areas of the Annamite Mountains but their respective niche is poorly understood. Using the confirmed localities where they are photographed is very informative for the study of their ecology. Nakai-Nam Theun National Protected Area (NNT NPA), central eastern Laos is one of these areas and represents an ideal model to investigate the niche differentiation of sympatric species owing to its habitat heterogeneity. The area holds at least nine different species of ungulates, including three muntjacs: the Northern red muntjac *M. vaginalis,* the large-antlered muntjac *M. vuquangensis*, and a third species assumed to be the Annamite muntjac *M. truongsonensis.* In 2006, systematic camera-trap surveys were initialized in the area, deployed in various habitat types. I use the confirmed identifications of photographs of the large-antlered muntjac and other muntjac species as occurrence localities and model their respective habitat suitability to investigate a potential niche differentiation between the large-antlered muntjac and the two other muntjac species. I use two methods: maximum entropy (MAXENT) and ecological niche factor analysis (ENFA), that have recently been widely used to model habitat suitability, potential distribution and/or niche of various species worldwide (e.g. MAXENT: Chunco et al., 2012; Clements et al., 2012; Jenks et al., 2012; Junker et al., 2012; ENFA: Galparsoro et al., 2009; Jones et al., 2010; Rebelo and Jones, 2010; Rood et al., 2010). I discuss the implication of my results for the conservation of muntjac species in NNT NPA.

Methods

Study area

Nakai-Nam Theun National Protected Area (NNT NPA), ~3550 km^2, is located in the central-east of Laos within the Annamite mountain range (Figure 8.1). The area remains largely forested (Robichaud et al., 2009) with mixed semi-evergreen/coniferous, upper montane, dry-evergreen and wet evergreen forests (Timmins and Evans, 1996). Elevation throughout the NPA ranges mainly from ~500 m to c. 2300 m a.s.l. Annual precipitation ranges from 1865 mm to 2620 mm and annual mean temperatures from 14°C to 24° C, with extremes of 4°C to 32°C (Hijmans et al., 2005).

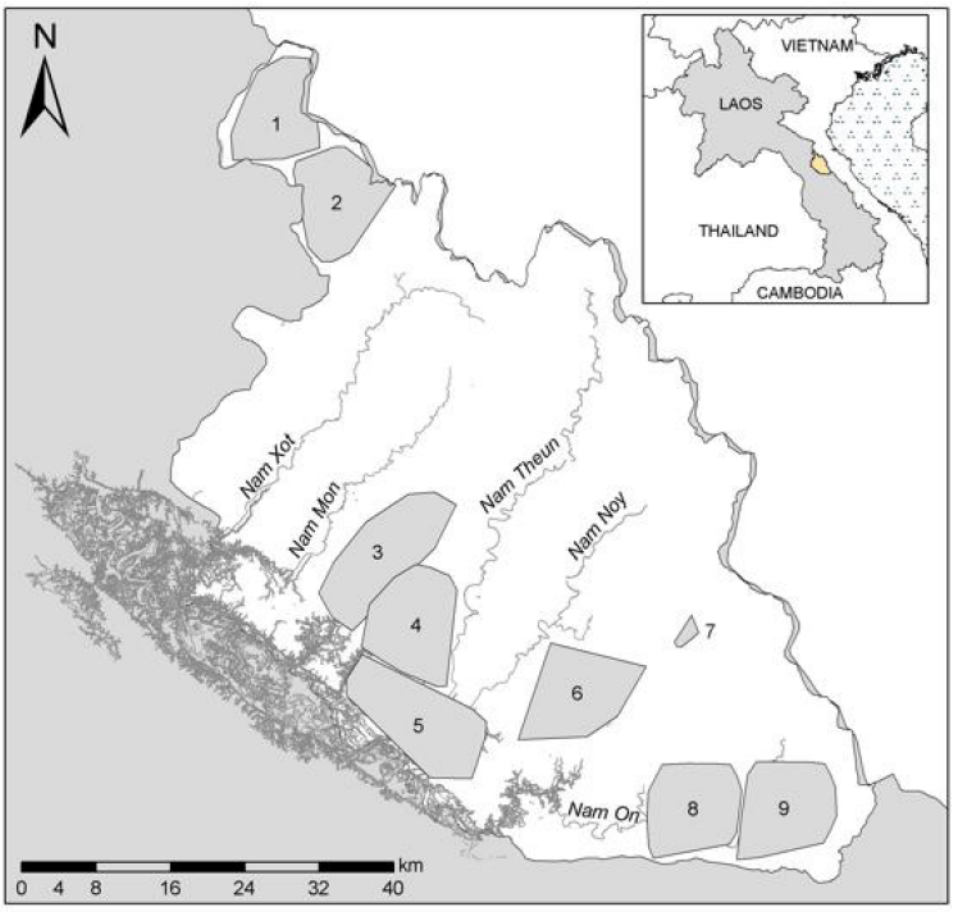


Figure 8.1: Nakai-Nam Theun National Protected Area with the ten camera-trap sampling sites visited in 2006-2011. Note: sampling sites delimitation was obtained from minimum convex polygon method around all camera-traps set at each site.

Biological data and Eco-geographical variables

I retrieved presence of muntjac species in NNT NPA from camera-trap data. From 2006 to 2011 systematic camera-trapping was carried out in the area by the Nam Theun 2-Watershed Management and Protection Authority (WMPA unpubl. data; Johnson and Johnston, 2007). The analysed data are from ten different sites sampled over the 2006-2011 period (Figure 8.1), totalling 20216 camera-trapping-days.

Images of muntjac species (Figure 8.2) were identified by experts (R.J. Timmins and W.G. Robichaud). Given the unclear morphological differentiation between *M. vaginalis* and *M. truongsonensis* of some individuals, the latter two taxa are modelled as a single group (and referred to as *M. vaginalis + M. truongsonensis* hereafter). Localities for *M. vuquangensis* and for *M. vaginalis + M. truongsonensis* were first mapped (projected to UTM WGS 84 zone 48N) in ArcGIS 9.3. To avoid autocorrelation and model over-fitting (Veloz, 2009; Merckx et al., 2011; Dormann et al., 2012), the data were pruned as to keep only one locality per 1km^2-grid cell. This resulted in a total of 48 locality points for *M. vuquangensis* and 35 for *M. vaginalis + M. truongsonensis* (Figure 8.3).

a

b

Figure 8.2: Photos taken by camera-traps in Nakai-Nam Theun NPA of a large-antlered muntjac (a) and a red muntjac (b) © WMPA

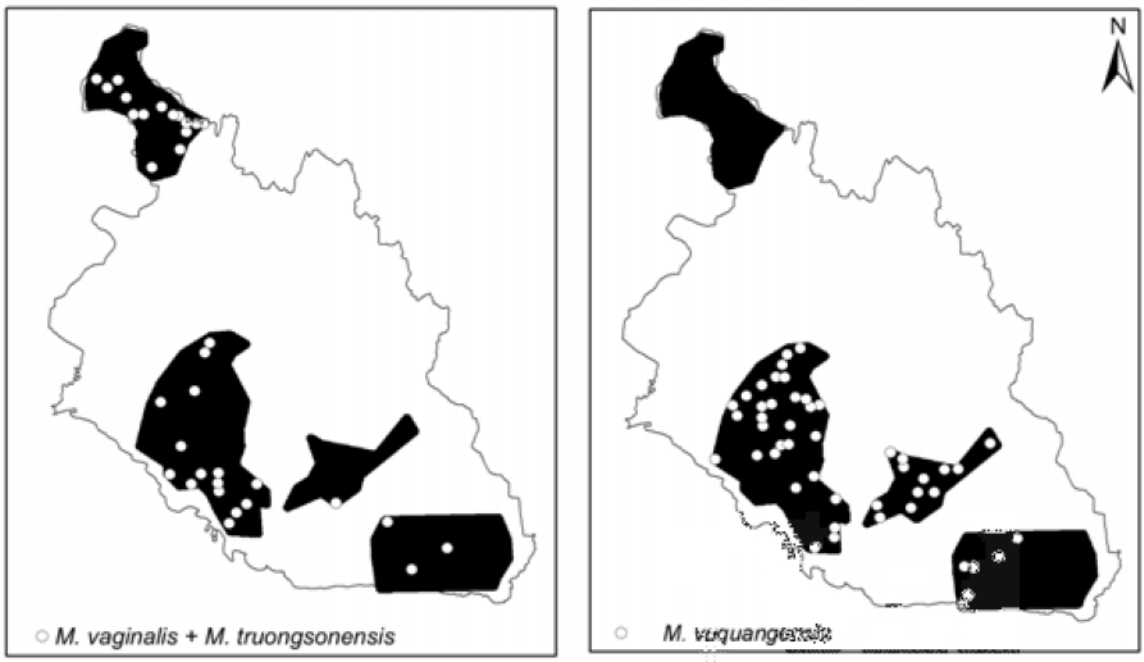


Figure 8.3: locality points within sampling areas (black) of *M. vaginalis + M. truongsonensis* and *M. vuquangensis* used in the models within Nakai-Nam Theun NPA.

Model over-complexity (i.e. number of variables > number of locality points) can decrease model predictions due notably to highly correlated variables (Warren and Steifert, 2011). To select variables, I built a correlation trees (Pearson' r) of between all initial 25 variables available (Appendix 8.1). For each group of variables highly correlated (r>0.95), I kept one (the most general; e.g. averaged over a larger period of time) and discarded the other(s). A final 13 variables (Table 8.2) are used for the models (however, due to too large eigenvalues when running the factor analysis for *M. vaginalis + M. truongsonensis,* I discarded one more variable from its ENFA model).

Table 8.2: Eco-geographical variables used in the models for *M. vuquangensis* and *M. vaginalis + M. truongsonensis* (13 variables).

	Eco-geographical variables	Source
	Climate	
1	bio2	WorldClim
2	bio3	(http://www.worldclim.org/)
3	bio4	
4	bio7	
5	bio12	
6	bio18	
7	bio19**	
	Topography/vegetation	
8	Elevation	(http://edc.usgs.gov/products/elevation/gtpo30/hydro/index.html)
9	Slope	derived from elevation layer in ArcGIS 9.3
10	distance to water	derived from river features in ArcGIS 9.3 (Euclidean distance)
11	percentage forest cover	MODIS vegetation field (http://modis.gsfc.nasa.gov/data)
	human impact	
12	categorical land use (in MAXENT) OR distance to forest (in ENFA)	Lao Department of Geography, 2002 derived from reclassified land use in IDRISI Selva v.17
13	distance to villages	derived from village features in ArcGIS 9.3 (Eucledean distance)

bio2=mean diurnal range (mean of monthly [max temp - min temp]); **bio3**=Isothermality [bio2/bio7]*100 ; **bio4**=temperature seasonality (standard deviation*100) ; **bio7**= temperature annual range (bio5-bio6); **bio12**=annual precipitation; **bio18**=precipitation of warmest quarter ; **bio19**=precipitation of coldest quarter
**bio19 was discarded for the ENFA of *M. vaginalis + M. truongsonensis* due to high correlation with bio12 which created too large factors' eigenvalues

MAXENT Models

The maximum entropy general purpose machine learning method has been adapted and developed as a software (MAXENT v.3.3.3k) for species distribution modelling (Phillips et al., 2004; 2006) and identified as one of the best methods for species niche modelling (Elith et al., 2006). The method combines biological data of species occurrence (presence-only data) with environmental characteristics (e.g. GIS layers with a grid of values for the geographic area considered) to estimate the probability distribution of maximum entropy (i.e. closest to uniform), subject to the set of constraints provided (i.e. environmental characteristics where the species occurs) (Phillips et al. 2006). The same projected coordinate system

(UTM WGS84 Zone 48N), cell size (90 m), and extent (NNT NPA) were selected for each variable layer.

I set a 10-fold cross-validation replication run type where a sample of the occurrence localities is randomly allocated for test data (to compute the model evaluation's AUC value, see below) at each of the ten replications. I chose to present the outputs with the cumulative format (i.e. continuous 0 to 100) for compatibility with the ENFA model outputs. I set all other settings as default (Phillips and Dudik, 2008).

I use the jackknife test option incorporated in MAXENT to assess variable importance for the prediction. The test consists in running models with each variable in isolation, and with each variable excluded at each run. This provides information on the variables that encompasses the most information to create the prediction (both the variables that increase the training gain the most when used in isolation and that decrease the training gain the most when it is omitted from the model).

ENFA Models

The Ecological Niche Factor Analysis (ENFA) computes suitability functions by comparing the eco-geographical variables of the localities where the species is known to occur to that of the whole study area (NNT NPA) (Hirzel et al., 2002). The method is based on the ecological niche theory defined as 'the hyper-volume in the multidimensional space of ecological variables within which a species can maintain a viable population' (Hutchinson, 1957). It identifies the principal factors that explain the *marginality* (i.e. how the species niche differs from the average habitat of the study area) and the *specialization* (i.e. how restricted is the niche of the species) within the area considered (Hirzel et al., 2002). This is achieved by transforming the *n* eco-geographical variables into *n* uncorrelated factors, which are then combined and extracted as different factors. The first factors account for the marginality of the species while the n remaining factors maximize the specialisation of the species. The first few factors that explain the highest

percentage information are retained to build the habitat suitability map over the study area.

The model was performed with the software BioMapper v.4 (Hirzel et al., 2004). All variables were converted from ESRI raster format (Grid format from ArcGIS) to IDRISI raster format (*.rst) using IDRISI Selva v.17 (Eastman, 2012) and all set to the same extent (NNT NPA), cell size (90 m), format (Integer) and background value (-9999 = *no data*). All variables used for the respective species-model were first transformed for normality with the Box-Cox (Box and Cox, 1964) function of the software. The number of factors retained for the habitat suitability map is chosen according to the MacArthur's Brocken stick rule (MacArthur, 1957).

I used the *harmonic-mean algorithm* to build the map as this puts more weight to any single locality than to the overall density of presences over the eco-geographical space (Hirzel, 2004). Mean algorithms have also showed better predictive performance than median algorithm (Hirzel and Arlettaz, 2003). The outputs of the ENFA models are interpreted in terms of the marginality and specialization scores and compared for the modelled taxa.

Ensemble Models

An ensemble model is built upon the resulting two methods by averaging the MAXENT and ENFA final outputs. The ensemble models are reclassified as binary maps (i.e. suitable vs. non-suitable) using the minimum presence threshold provided by MAXENT. I quantify an average of some general variables within the resulting predicted distributions.

Model evaluation

I evaluate the predictive performance of the models with the Boyce Index (Boyce et al., 2002). In addition, I present the area under the curve (AUC) of the receiver-operating characteristic (ROC), computed within MAXENT.

To compute a Boyce index from the MAXENT outputs, the continuous habitat suitability scores obtained (0 to 100) are reclassified into 100 bins (classes) of equal interval. For each class, two frequencies of pixels are calculated: the Predicted Frequency and the Expected Frequency. The Predicted Frequency is the number of occurrence points predicted by the model falling into in the class *i* divided by the total number of occurrence points. The Expected Frequency is the number of grid cells included in class *i*, divided by the total number of grid cells in the whole geographic area considered. A Predicted-to-Expected ratio is calculated for each class and a Spearman rank correlation coefficient *rho* (1-tailed test) evaluates if the ratio significantly increases as suitability increases ($p<0.05$) (Hirzel et al., 2006). Statistical tests are performed with SPSS.v.17. For the ENFA models, the continuous Boyce Index is computed within BioMapper software.

Results

Model performance

Validation tests indicate MAXENT models as predicting significantly better than random as opposed to the ENFA models (Table 8.3). Nonetheless, the habitat suitability maps from both methods (Figure 8.4) show a general similar distribution pattern for both species, mostly differing in the suitability score of each grid cell.

Table 8.3: Validation tests for the two modelling methods. The continuous Boyce Index and test AUC are computed in Biomapper and MAXENT, respectively; Boyce Index 100 is calculated as described in the method section.

Modelling Method	**ENFA**		**MAXENT**	
test / **species**	Boyce Index 100 pValue	continuous Boyce Index	Boyce Index 100 pValue	test AUC
M. vuquangensis	p=0.06	0.088	p<0.01**	0.826
M. vaginalis + M. truongsonensis	p=0.42	0.137	p<0.01**	0.783

** models has a significant predictive power (Spearman rho test)

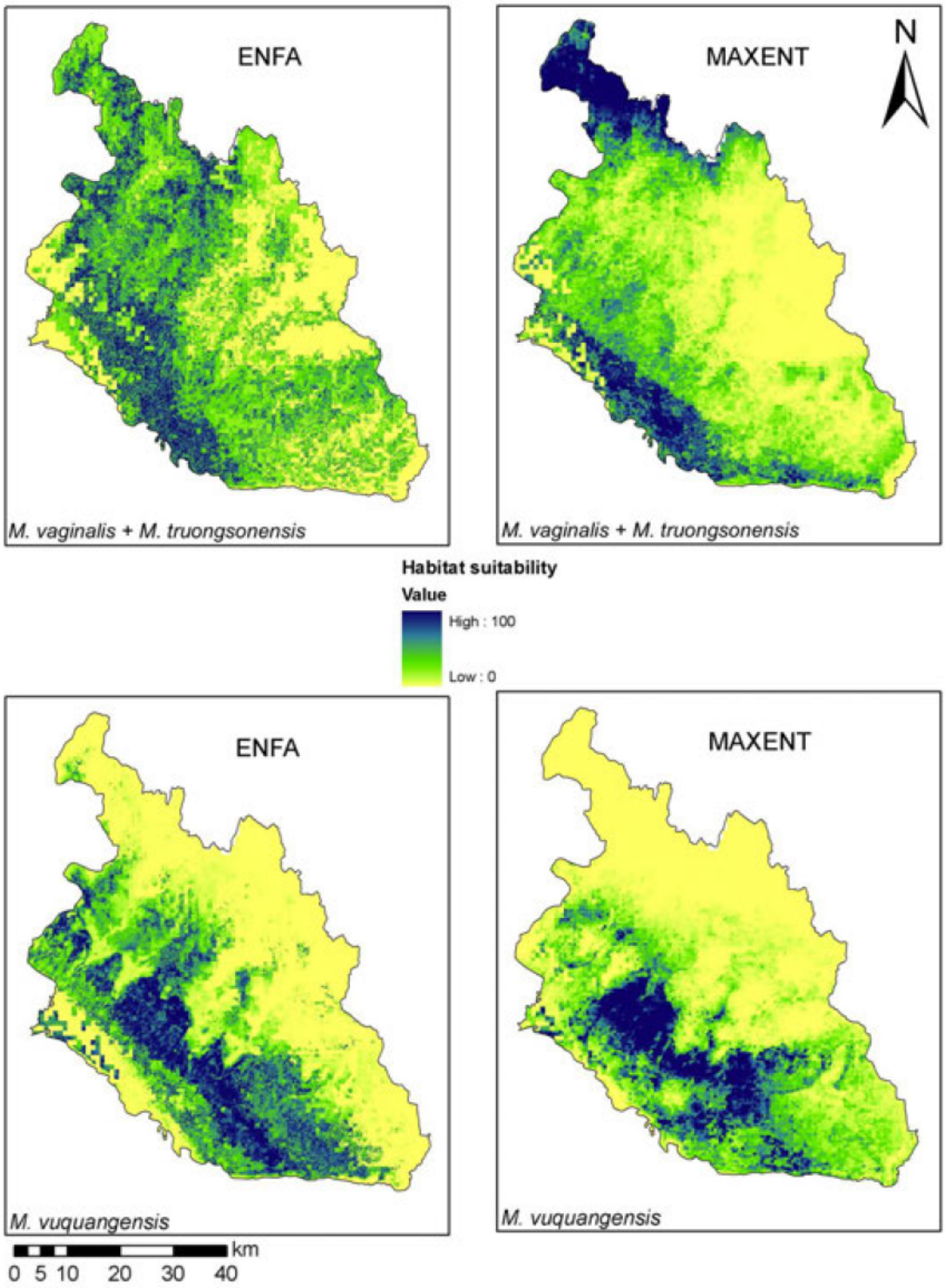
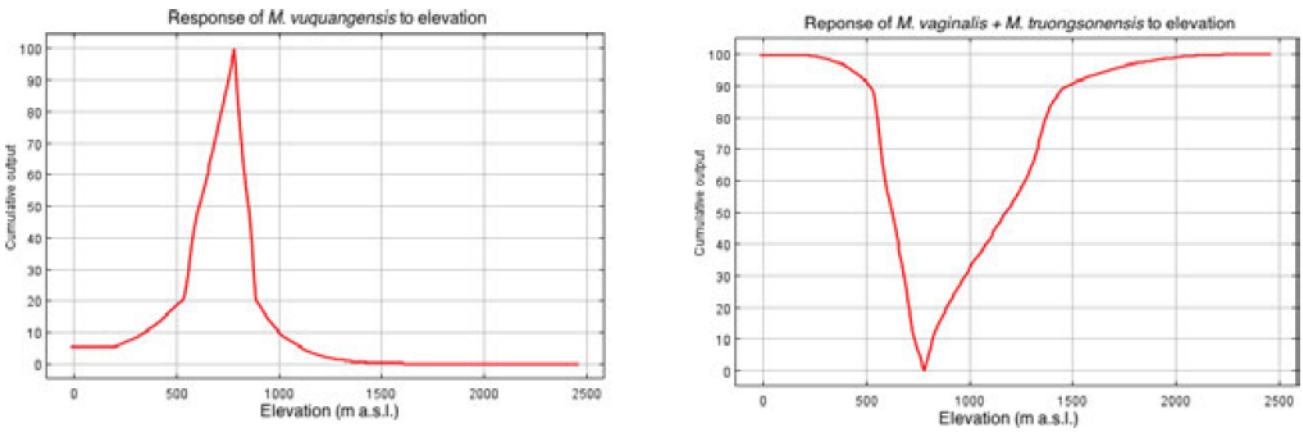


Figure 8.4: ENFA and MAXENT models of *M. vaginalis + M. truongsonensis* (top) and *M. vuquangensis* (bottom).

MAXENT models

The jackknife test shows that mean annual precipitation gives the highest gain to the model when used in isolation and distance to villages decreases the gain the most when omitted from the model for *M. vaginalis + M. truongsonensis,* while it is precipitation of warmest quarter and mean annual precipitation, respectively, for *M. vuquangensis*.

The response curve of species to elevation (when all other variables are excluded), reveals that suitable habitat for *M. vuquangensis* mostly ranges from 500 to 1000 m a.s.l. with a peak at ~800 m, whereas suitable habitat for *M. vaginalis + M. truongsonensis* ranges up to ~500 m a.s.l. and from 1500 to 2500 m a.s.l.



a b

Figure 8.5: Mean of the ten replications of response curves produced by MAXENT of the response of elevation on predicted suitability score, when all other variables are disregarded for (a) *M. vuquangensis* and (b) *M. vaginalis + M. truongsonensis.*

ENFA models

Two factors were retained for *M. vaginalis + M. truongsonensis* and three for *M. vuquangensis*, explaining a total of 85% and 71% of the variance, respectively (Table 8.5). Both *M. vaginalis + M. truongsonensis* and *M. vuquangensis* tend to occupy a niche that differs from the average conditions of the study area (c.f. Appendix 8.2), indicated by a high marginality value (Table 8.4). *M. vuquangensis* seems slightly more tolerant of the area's conditions than *M. vaginalis + M.*

truongsonensis. The habitat suitability map from ENFA indeed shows more grid cells with higher suitability for *M. vuquangensis* than for *M. vaginalis + M. truongsonensis* (Figure 8.3). Both are predicted to occupy a niche associated with higher precipitation and temperature than the area's average. While *M. vaginalis + M. truongsonensis* seems relatively specialized to higher elevations, *M. vuquangensis* is predicted associated with lower elevations within the area, confirming the response curve to elevation obtained from MAXENT modelling (Figure 8.5).

Table 8.4: Global Marginality, Specialization and Tolerance within Nakai-Nam Theun NPA, obtained from the Ecological Niche Factor Analysis for *M. vaginalis + M. truongsonensis* and *M. vuquangensis.*

species	Marginality	Specialization (S)	Tolerance (1/S)
M. vaginalis + M. truongsonensis	0.528	3.159	0.317
M. vuquangensis	0.596	1.974	0.507

Marginality: closer to 1 = species' niche differs from available average conditions of the study area
Tolerance = 1/Specialization: closer to 0 = occupying a narrower range of conditions over the study area

Table 8.5: Contribution of each of the variables to the retained niche factors for *M. vaginalis + M. truongsonensis* (**a**) and *M. vuquangensis* (**b**).

Note: The Factor 1 (Marginality) explains 100% of the marginality and the most part of the Specialization (% indicated in bracket) while the other factors (Specialization) explains the remaining parts of the specialization retained.
+: the species uses a niche with higher average than the average condition of the study area.
-: the species uses a niche with lower average than the average condition of the study area.
*: Narrowness of species' niche on the specialization factor
0: weak specialization
Number of symbols indicates the relative intensity of marginality or specialisation of the species within the study area.

a – *M. vaginalis + M. truongsonensis*

ecogeographical variables	**Marginality (53%)**	**Specialization (32%)**
mean temperature diurnal range (bio02)	+++++	**
Isothermality (bio03)	+++++	**
temperature seasonality (bio04)	----	***
precipitation of warmest quarter (bio18)	+++	********
temperature annual range (bio07)	+++	*
slope	--	0
vegetation cover	-	0
mean annual precipitation (bio12)	-	****
distance to villages	+	*
distance to forests	-	0
distance to water source	+	0
elevation	+	***

b – *M. vuquangensis*

ecogeographical variables	**Marginality (35%)**	**Specialization 1 (24 %)**	**Specialization 2 (12 %)**
precipitation of warmest quarter (bio18)	+++++	0	*
mean annual precipitation (bio 12)	+++++	****	*
mean temperature diurnal range (bio02)	+++	****	*******
temperature annual range (bio07)	+++	*	****
distance to forests	---	*	***
elevation	--	***	***
temperature seasonality (bio04)	--	**	0
distance to villages	--	*	0
Isothermality (bio03)	++	0	*
slope	--	0	0
precipitation of coldest quarter (bio19)	-	*******	***
vegetation cover	+	0	**
distance to water source	+	0	*

bio02=mean of monthly (max temp-min temp)

bio03=bio02/bio07*100

bio07=max temperature of warmest month-min temperature of coldest month

Ensemble Models

When ecogeographical variables are averaged within the predicted distribution of modelled taxa and compared to the average conditions of the study area, elevation differs the most with lower elevation for *M. vuquangensis* compared to available conditions (Table 8.6). The final habitat suitability maps (Figure 8.7) show a wider distribution of *M. vaginalis + M. truongsonensis* while *M. vuquangensis* is more restricted.

Table 8.6: Mean (with standard deviation, SD, and range) of general eco-geographical variables within the ensemble model (i.e. MAXENT and ENFA averaged) predicted distribution (under the minimum training presence threshold) of the two modelled taxa and over the study area.

	M. vuquangensis			*M. vaginalis + M. truongsonensis*			Nakai-Nam Theun NPA	
	Mean	SD	range	Mean	SD	range	Mean	range
annual temp.	22	1	15.5 - 24.8	21	2	14.4 - 24.8	21	14.4 - 24.8
annual precip.	2291	100	1970 - 2616	2237	133	1865 - 2617	2236	1865 - 2617
elevation	784	218	191 - 1942	891	306	248 - 2261	873	189 - 2272
slope	11	8	0 - 69	12	8	0 - 69	12	0 - 69
Dist. water (m)	392	397	0 - 2850	398	380	0 - 2896	393	0 - 2896
% vegetation	74	7	15 - 81	73	9	6 - 81	73	6 - 81
top 3 habitat types*	DEV; MBC; MDE	-	-	DEV; MBC; MDE	-	-	DEV; MBC; MDE	-
Dist. villages (km)	6	3	0 - 24	9	6	0 - 28	8	0 - 28

* DEV = Dry Evergreen forest; MBC = Mixed Broad-leaved/Coniferous; MDE = Mixed Deciduous/Evergreen

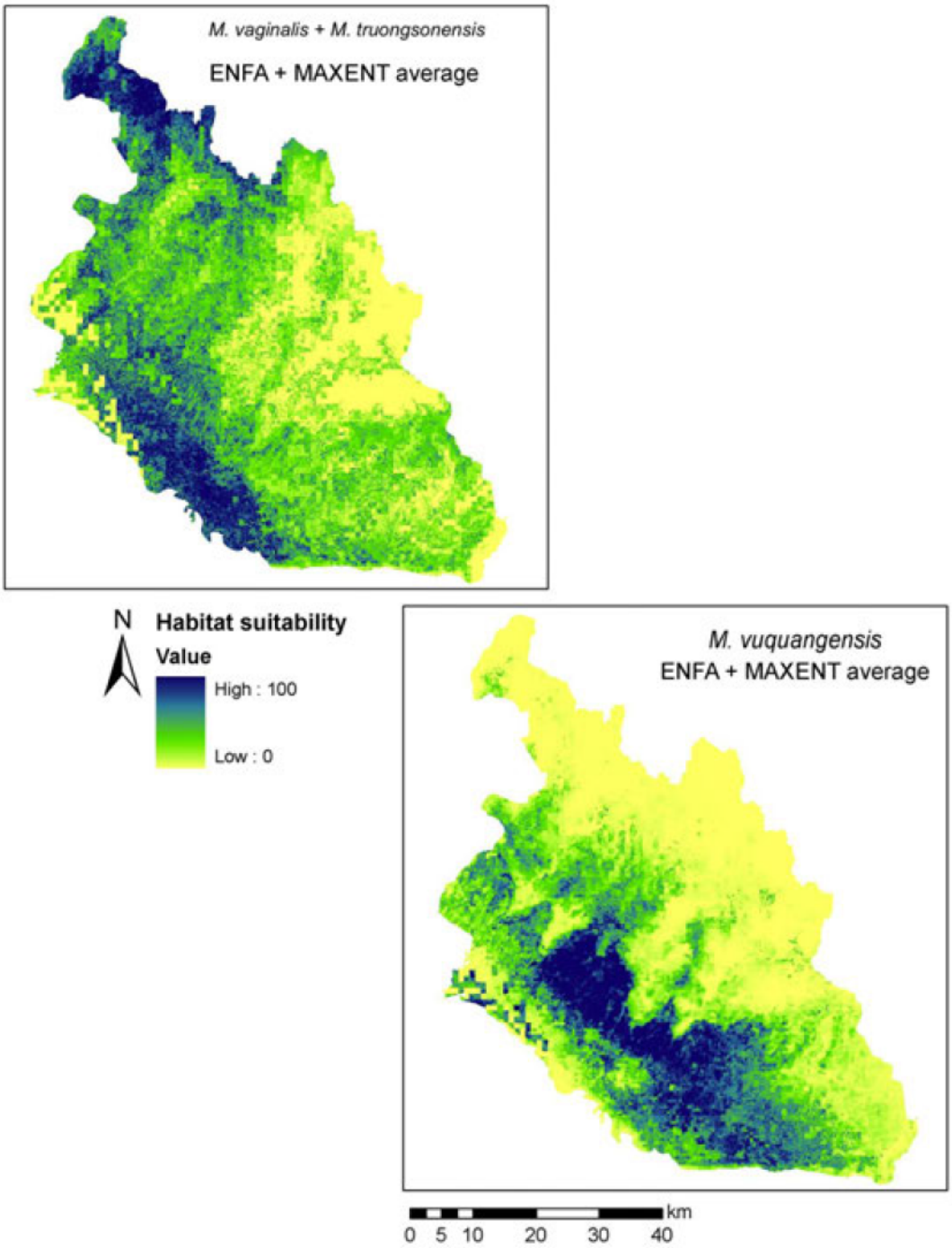


Figure 8.6: Average of ENFA and MAXENT models for *M. vaginalis + M. truongsonensis* (top) and *M. vuquangensis* (bottom).

Discussion

Models' performance

Performance tests revealed the ENFA as less powerful than MAXENT and may be due to the greater sensitivity of ENFA to small sample size compared to MAXENT, the latter being known for outperform other methods on low sample size training (Hernandez et al., 2006). Performance of the model for *M. vaginalis + M. truongsonensis* may also be altered when combining more than one species which may actually differ in their respective niches. The fact that occurrence points used in both methods are restricted to areas where sampling occurred (sampling bias), also likely influenced the outputs (Phillips et al., 2009). The choice of not including a sampling bias in the model setting within MAXENT allowed comparison with ENFA outputs which does not have the possibility to deal with sampling bias. Overall, the two methods gave comparative visual maps with similar areas that are predicted as unsuitable for the same species (-group). Given uncertainty of such models, it is useful to combine several methods for comparison and create averaged ensemble models used for final interpretation.

Muntjacs' niches in Nakai-Nam Theun NPA

Both methods indicated, to some extent, a niche differentiation of *M. vuquangensis* and *M. vaginalis + M. truongsonensis* within NNT NPA. The ENFA shows that *M. vuquangensis* occupies a slightly wider range of conditions (as opposed to geographical range) within NNT NPA than does *M. vaginalis + M. truongsonensis,* which indicates that the conditions found within the area are more optimal to the former species. Indeed, *M. vuquangensis* seems more tolerant of the overall conditions of NNT NPA. The ensemble model's output shows a wider distribution of *M. vaginalis + M. truongsonensis* over the area, but the suitability score remains relatively low throughout. This suggests the adaptability of *M. vaginalis + M. truongsonensis* to a habitat that does not encompass its optimal conditions. The wider geographical distribution of *M. vaginalis + M. truongsonensis* in NNT NPA is also likely due to the modelling two

species as one group, thus including a wider niche. The results make evident the importance of NNT NPA's habitat for *M. vuquangensis*.

Climate – Climate factors play an important role in the predictive niche of both modelled species (-group), although the arbitrary selection of particular variables over others due to auto-correlation does not allow the identification of the exact variables that influence their distribution. Nonetheless, the models indicated a marginality and specialisation of *M. vuquangensis* in habitats with higher annual precipitation, while *M. vaginalis + M. truongsonensis* is predicted in habitats where annual precipitation is lower than the area's average conditions. The latter was also predicted in habitats where mean annual temperature is slightly higher than for *M. vuquangensis*. The model however does not allow to test if these variables are actually environmental determinants for the species.

Topography – Similarly, both species differ in their predicted association with a range of elevation and slope. The niche of *M. vuquangensis* being predicted at lower average elevations than for *M. vaginalis + M. truongsonensis*. Indeed, the ENFA shows the marginality of *M. vuquangensis* at lower elevation than the averaged elevations in NNT NPA and its speciality to these lower elevations. In contrast, *M. vaginalis + M. truongsonensis* is predicted at and specialized to higher elevations than the averaged area's conditions. MAXENT's response curve similarly shows a clear differentiation in the suitability of habitats when the elevation variable is isolated. The optimal suitability score for *M. vuquangensis* is at an elevation of 800 m a.s.l. (suitability score of 50 from ~700 to 900 m), while for *M. vaginalis + M. truongsonensis* is at the two extremes of the elevation range of NNT NPA: up to 200 m a.s.l. and 2000 to 2500 m a.s.l. (suitability score of 50 up to 600 m and 1200 to 2500). This large variability in elevation suitability for *M. vaginalis + M. truongsonensis* confirms what has been speculated of the ecology of *M. vaginalis* and *M. truongsonensis*: in Indochina, the former is believed to range up to 1500 m a.s.l., while the latter above this (Timmins et al., 2008a; 2008b). The average slope profile where *M. vaginalis + M. truongsonensis* is predicted is lower than for *M. vuquangensis*, and for both lower than the averaged area's condition.

Anthropogenic – The niche of *M. vuquangensis* is predicted at greater distance from agricultural areas (closer to forest areas) compared to *M. vaginalis + M. truongsonensis.* This is also suggested by the fact that the latter is predicted to be associated with habitats with lower vegetation cover than is *M. vuquangensis.* The ensemble model map confirms this pattern where village clusters are predicted as unsuitable for *M. vuquangensis*.

Although there are undoubtedly regions of sympatry between *M. vuquangensis* and *M. vaginalis + M. truongsonensis, M. vuquangensis* seems limited to some areas with optimal ecogeographical variables. Where they occur in sympatry, more local, micro-habitat variables may play a role in their niche use. However, the vegetation layer used in this analysis not being detailed at the micro-habitat level, it was not possible to assess a particular tendency to use a forest type over the other by the species; this may be considered in the future with refined vegetation data. The preferential use of different forest types within the same area has been observed in sympatric deer species elsewhere in the world (e.g. Hemami et al., 2004). The activity peak of related and competitive deer species that co-exist may also differ (e.g. Forde, 1989; Chapman et al., 1993), and/or they may choose different sleeping sites with particular characteristics (Teng et al., 2004; Brodie and Brockelman, 2009), these behaviours ultimately reducing inter-species competition. The overall difference in niche use of *M. vuquangensis* and *M. vaginalis + M. truongsonensis* in NNT NPA likely results in difference in main diet.

Implications for conservation

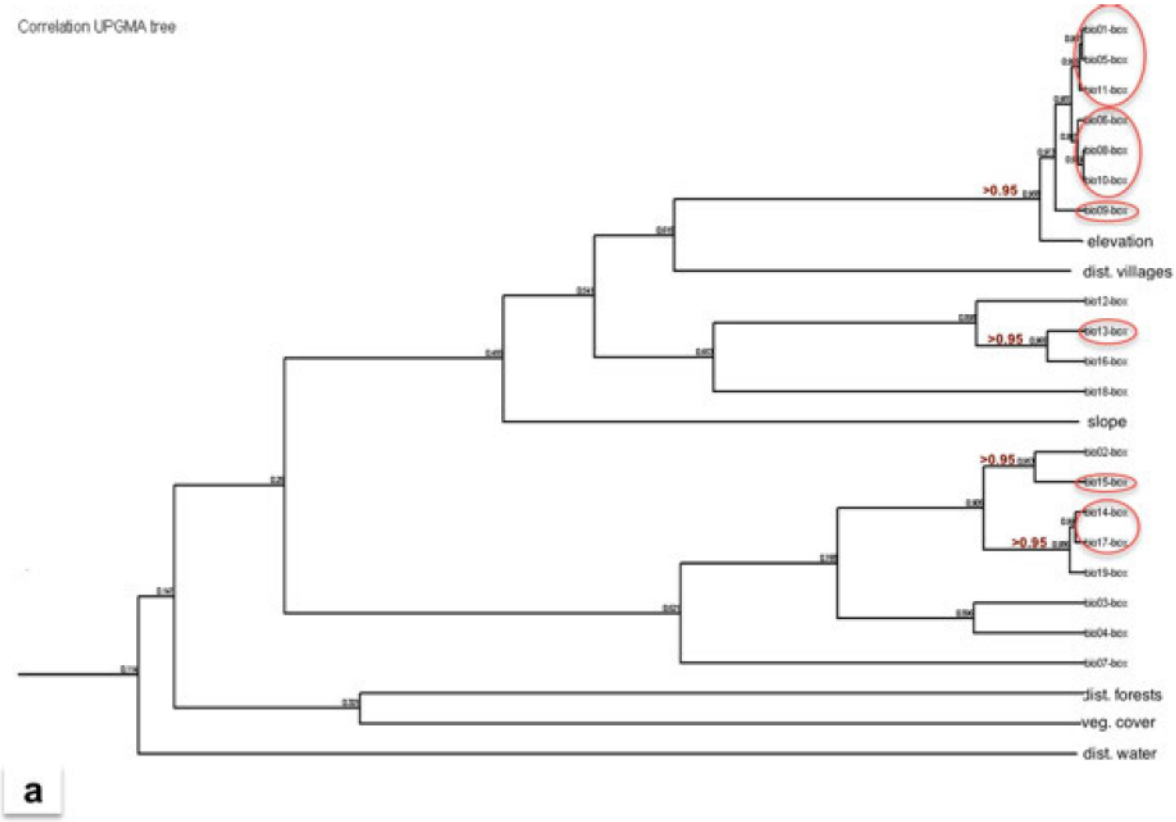
In Laos, the Endangered large-antlered muntjac *M. vuquangensis* is classified under the *Prohibition* category of the Lao hunting regulation, which groups species "rare, near extinct, high value and are of special importance in the development of social-economic, environmental, educational, scientific research" (National Assembly Laos, 2007: Article 11: 4). Species in this category should be "managed, inspected, preserved" (National Assembly Laos, 2007: Article 11: 4); their hunting is not permitted at anytime or anywhere. The Annamite muntjac *M.*

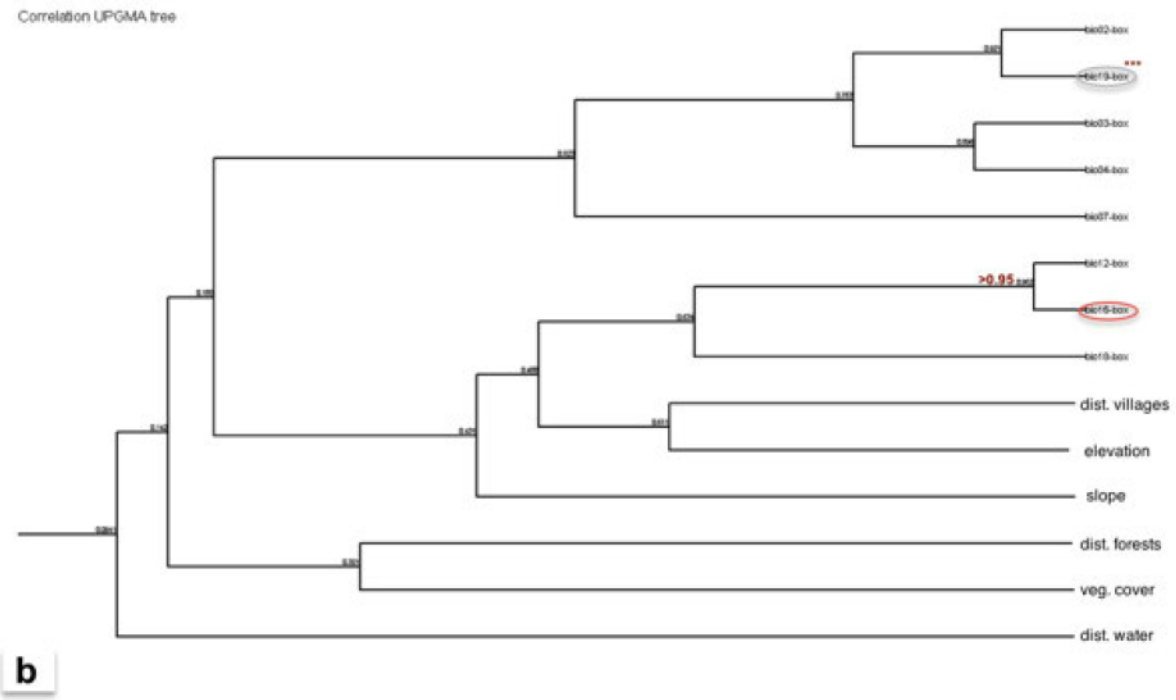
truongsonensis is not listed in the regulation and the red muntjac *M. vaginalis* is under the *Management* category, which includes "wildlife and aquatic that are able to reproduce widely in nature, and are very important for social - economic development, and educational scientific research" (National Assembly Laos, 2007: Article 11: 5); species in this category may be hunted in zones delimited and during certain seasons only (National Assembly Laos, 2007). This classification, however, does not ensure the protection and sustainable use of either species for several reasons. (1) In NNT NPA, the main and widely used hunting technique is ground snares. These are non-selective and can catch any ground-dwelling animal from the small bird or civet to any of the deer species, and totally indiscriminative of age and sex. If *M. vuquangensis* is limited by elevation and mainly occurs around village clusters, as indicated by the models, this means that hunting by Lao villagers may catch a greater number of this species. In the late 1990s in NNT NPA, the number of antlers *M. vuquangensis* kept as trophies in village houses was twice as numerous as the ones from the red muntjac (Timmins et al., 1998). (2) Hunting pressure is dramatically increased from the Vietnamese poachers illegally crossing the border to set a large amount of snares in the area (c.f. CHAPTER 9). This is encouraged by the – mainly Vietnamese and Chinese – trade demand for wildlife used in traditional medicine (Nooren and Claridge, 2001). Although muntjac species are unlikely targeted for the trade, this has no influence on the numbers being caught by snares. (3) Hunting regulation is often not well-communicated to Lao villagers and/or enforced resulting in over-harvesting outside the permitted zones; this is also intensified by the growing human population in NNT NPA's villages and by the trade demand that leads to increasingly hunting for the trade rather than for local consumption.

This has considerable implications for the conservation of the Endangered large-antlered muntjac, which remains poorly known even after its discovery over a decade ago. The models reveal that NNT NPA encompasses optimal habitats for the species and confirms what had been speculated following its discovery that "The Nakai-Nam Theun National Biodiversity Conservation Area (NBCA) may be both a centre of the giant muntjac's Lao distribution and its population's core area" (Timmins et al., 1998: 61). Management of the species in NNT NPA should

therefore be considered as a priority given its restricted global distribution and the potential that NNT NPA still holds for its conservation. The apparent restriction in elevation range of *M. vuquangensis* in NNT NPA means that special protection zones targeted for the protection of the Critically Endangered saola (*Pseudoryx nghetinensis*), may not serve as an 'umbrella' for *M. vuquangensis*. Focussing on the conservation of both species however may benefit all key species occurring in NNT NPA.

Appendix 8.1: correlation trees for stepwise variables selection.(a) first tree from which 11 variables were discarded for their high correlation (r>0.95) with other variables; (b) second tree from which one more variable was discarded (r>0.95). ***Bio19 was later discarded for ENFA model of *M. vaginalis + M. truongsonensis* because of too high correlation with bio02, creating too large eigenvalues.





Introduction

Over two decades ago, part of the Indochinese region (namely, 'Northern Vietnam [including adjacent areas in China, Laos and Thailand]'; Schreiber et al., 1989: 75) was listed as one of the most important areas for the global conservation of small carnivores (Mustelids and Viverrids). The authors notably recommended increasing research on the distribution, status and taxonomy of these species, which has generally remained lacking in the region until now. Within Laos, small carnivores' diversity, distribution and status (here defined as Viverrids, Prionodontids, Mustelids, and Herpestids) remain little known. Countrywide wildlife surveys conducted in the 1990s provided preliminary information on the group (Duckworth, 1997; Duckworth et al., 1999), although survey intensity and methodology were unlikely to record all species possibly present at any given site visited (Duckworth, 1997). At least 21 species occur in the country (Table 7.1) including five Globally Threatened and three Near Threatened (IUCN, 2012a). In the past decade, systematic and intensive camera-trap surveys in a few National protected areas have collected extensive data on ground-dwelling species (Johnson and Johnston 2007; DERSU, 2008; Johnson et al., 2009; Duckworth et al., 2010; WCS Lao Programme unpublished data). Although camera-traps are unlikely to record the total small carnivore species community of an area, the technique has proven effective for some ground species and long-term surveys might be suitable for monitoring population status. For instance, the Owston's civet (*Hemigalus owstoni*) that had only ever been recorded in Laos from market animals, captives and reported from villagers, and never seen directly in the field (Sivilay et al., 2011) was for the first time recorded in the wild in Laos with camera-traps in Nam Et-Phou Louey National Protected Area (NPA), north-eastern Laos, (Johnson et al., 2009), Nakai-Nam Theun NPA, central-eastern Laos (Johnson and Johnston, 2007) and Phou Chomvoy Provincial Protected Area (Sivilay et al., 2011).

Data collected from camera-trap surveys often remain unpublished and not readily available, although they offer invaluable information. When combined,

countrywide data from such surveys can depict the geographical and ecological national distribution of these species and provide insight into their general behaviour and morphological characteristics. A long-term wildlife monitoring program using camera-traps was initiated in 2006 in Nakai-Nam Theun NPA (NNT NPA) (Johnson et al., 2005; Johnson and Johnston, 2007). I present records of small carnivores (excluding small cats) from the period 2006-2011. The characteristics of the camera-trapping methodology (without using bait) focussing on ground-dwelling animals means that results will not present the comprehensive species diversity occurring in NNT NPA.

Table 7.1: Confirmed small carnivore (excluding Felidae) species in Laos.

Species	General National distribution	Global status (IUCN, 2012a)	National status (1999)*	Lao hunting regulation category (NA, 2008)**
Mustelidae				
yellow-bellied weasel (*Mustela kathiah*)	N, S	Least Concern	Little Known	*not listed*
Siberian weasel (*Mustela sibirica*)	C	Least Concern	Little Known	*not listed*
stripe-backed weasel (*Mustela strigidorsa*)	N, C	Least Concern	Little Known	Prohibited
yellow-throated marten (*Martes flavigula*)	N, C, S	Least Concern		*not listed*
hog badger (*Arctonyx collaris*)	N, C, S	Near Threatened	Little Known	Managed
large-toothed ferret badger (*Melogale personata*)	C, S	Data Deficient	Little Known	Managed
small-toothed ferret badger (*Melogale moschata*)	N, C	Least Concern	Little Known	Managed
Eurasian otter (*Lutra lutra*)	N	Near Threatened	At Risk	Prohibited
smooth-coated otter (*Lutrogale perspicillata*)	N, S	Vulnerable	At Risk	Prohibited
Oriental small-clawed otter (*Aonyx cinereus*)	N, C, S	Vulnerable	At Risk	Prohibited
Viverridae				
large Indian civet (*Viverra zibetha*)	N, C, S	Near Threatened		Managed
large spotted civet (*Viverra megaspila*)	C, S	Vulnerable	At Risk	Prohibited
small Indian civet (*Viverricula indica*)	N, C, S	Least Concern		Managed
common palm civet (*Paradoxurus hermaphroditus*)	N, C, S	Least Concern		Managed
masked palm civet	N, C, S	Least Concern		Managed

(*Paguma larvata*)				
binturong (*Arctictis binturong*)	N, C	Vulnerable	At Risk	Managed
small-toothed palm civet (*Arctogalidia trivirgata*)	N, C, S	Least Concern		Managed
Owston's civet (*Chrotogale owstoni*)	N, C	Vulnerable	Little Known	Prohibited
Prionodontidae				
spotted linsang (*Prionodon pardicolor*)	N, C, S	Least Concern	Little Known	Prohibited
Herpestidae				
small Asian mongoose (*Herpestes javanicus*)	N, C, S	Least Concern		Managed
crab-eating mongoose (*Herpestes urva*)	N, C, S	Least Concern		Managed

N= north, C= center, S= south
References used: Duckworth et al., 1999 (includes historical records – i.e. pre-1990s); Tizard, 2002; Robichaud, 2010; Sivilay et al., 2011.
* National status not indicated means that the species is considered secure in the medium-long term (Duckworth et al., 1999)
** Prohibited: hunting of the species is not allowed at any time and place; Managed: hunting is permitted in specified zones and seasonally only

Methods

Study area

Nakai-Nam Theun National Protected Area (NNT NPA) (Figure 7.1) is ~3550 km^2 with altitudes ranging from ~500 to >2200 m a.s.l.. Around 90% of the area remains covered in forest (Robichaud et al., 2009). It is dominated by old growth mainly undisturbed dry-evergreen forest, with other localised habitat including pine/semi-evergreen, upper-mountain and wet-evergreen forest (Timmins and Evans, 1996). Thirty-one villages are located within the NPA; each village is allocated subsistence-use forest areas, where they are allowed to collect non-timber forest products, including some common wildlife species according the Wildlife and Aquatic Law and Forestry Law (National Assembly Laos, 2007a; 2007b).

Camera-trap data

Camera-trap data were obtained from systematic survey during 2006 to 2011 conducted in NNT NPA by NT2 WMPA staff. The sampling technique was designed and training provided by the Wildlife Conservation Society-Lao Program (Johnson et al., 2005; Johnson and Johnston, 2007). From March 2006 to January 2011, camera-traps were set in 10 different survey blocks within NNT NPA's boundaries (Table 7.1; Figure 7.1). Three to 50 passive infrared cameras were set in a survey site (a single camera set per locality), each camera being in general ~1 km apart. Each was positioned on trees at a height of ~45 cm (initially targeted for large mammals), beside animal trails or small streams and/or at other open understorey locations arbitrarily chosen, without the use of lure or bait. Each camera was programmed to operate 24 hours per day and take photos at least 20-seconds apart. Most of the cameras (96.8%) had a maximum capacity of 36 photos, therefore the survey effort ceased once 36 photos had already been taken. The remaining cameras had a large capacity of >600 photos which was never reached before removal of the camera. Thus, survey effort for each camera is calculated from the day of the first photo taken to the day of the last photo taken. Total survey effort (camera-trap days, CTD) is the sum of all cameras' survey effort. Data from faulty cameras (i.e. cameras for which only the first test-photo was taken and thus no possibility to calculate camera-trap days) were removed from the analysis. For each camera, available data include GPS coordinates of location, elevation (m a.s.l. taken with GPS unit), date and time of each photo taken.

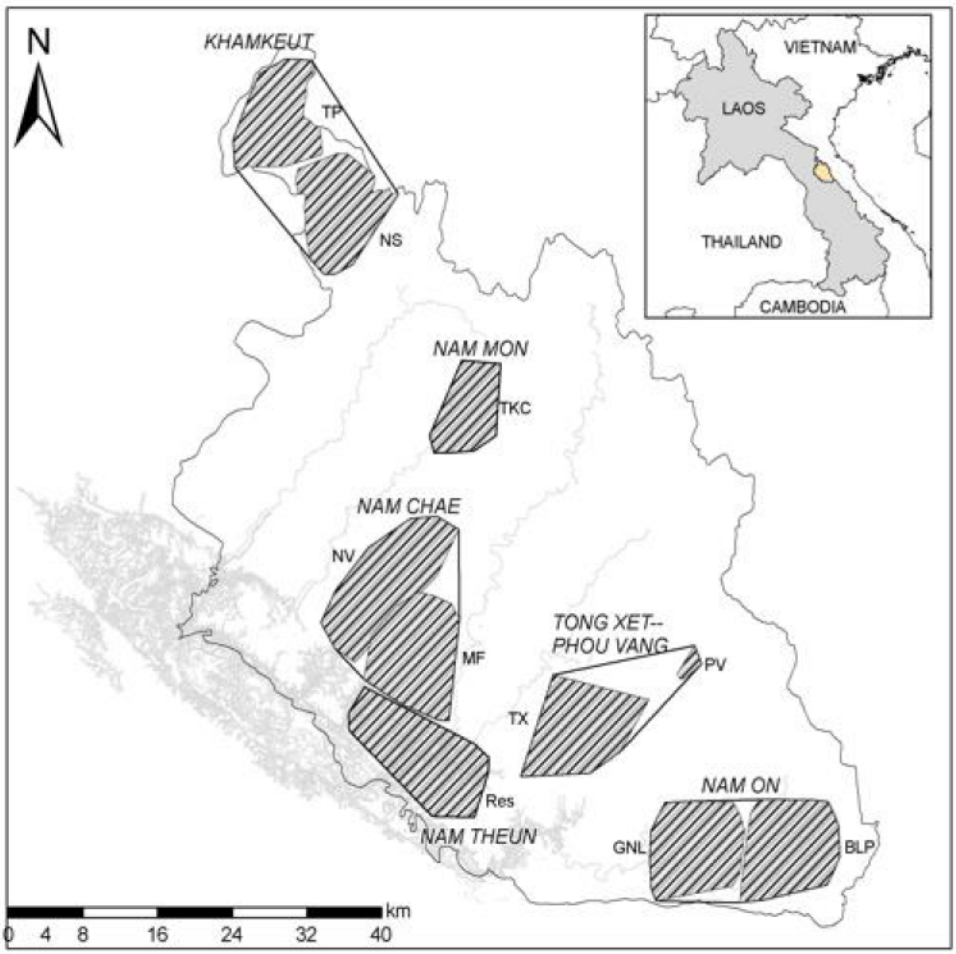


Figure 7.1: Camera-trap sampling effort within Nakai–Nam Theun NPA in 2006-2011 (c.f. Table 7.1) at ten sites in six general areas: KHAMKEUT: Thong Pae (TP) and Nam San (NS); NAM MON: Thongkacheng (TKC); NAM CHAE: Navang (NV) and Makfuang (MF); NAM THEUN: reservoir (Res); THONG XET-PHOUVANG: Thong Xet (TX) and Phou Vang (PV); NAM ON: Gnomalath (GML) and Boualapha (BLP). Note: areas and sites are delimited in ArcGIS 9.3 with a minimum convex polygon around the all camera-trap localities.

Of all photos taken (N=9265) during the survey period, all the small carnivore (excluding Felidae) photo records were selected and identified with the assistance of J.W. Duckworth. The number of records for each species is of independent photos, here considered as consecutive photographs of individuals/social units of the same species taken more than 30 minutes apart (except when the same individual/social unit can be identified and is photographed consecutively for >30 minutes, in this case photos are still considered as one independent photo) and

non-consecutive photos (i.e. hours to days apart or separated by photograph[s] of other species) of individuals/social units of the same species. The GPS coordinate localities (used with UTM Indian Thailand datum) where each species was recorded within NNT NPA is represented on Figure 7.2, and all record details are presented in Appendix 7.1.

I compare the relative abundance of all carnivore species between the six general areas sampled with a relative encounter rate index (RERI) where RERI = (total number of independent images)/(number of camera-trap days)*100 (see Jenks et al., 2011). The difference in relative encounter rate is investigated in terms of ecological (mean annual temperature, mean annual precipitation, elevation, slope, distance to river) and anthropogenic (distance to villages) variables, averaged for all camera-trap-localities within each of the six areas. Variables were obtained remotely and processed in ArcGIS 9.3.

In addition, I tabulate opportunistic data on small-carnivores that I collected during foot surveys from 2011-2012 over 10 different sites in NNT NPA.

Results

Six general areas (ten different sites) were sampled (Figure 7.1) with differing environmental and topographic conditions (Table 7.4), totalling 20216 camera-trap days (Table 7.2). Of the latters, 58% occurred during the dry season (Oct-Feb), 34% during the end of the dry season (Mar-May) and 8% during the wet season (Jun-Sept). Ten small carnivore species ('species' sensu lato – ferret badger species are not identifiable from images and therefore considered as *Melogale* sp(p).) were recorded on camera-traps (Table 7.3). The most frequently recorded were the common palm civet, ferret badger sp(p)., large Indian civet and hog badger (70-100 independent images), followed by the Owston's civet, masked palm civet and crab-eating mongoose (40-60 independent images), and yellow-throated marten, spotted linsang and binturong (1-20 independent images).

Table 7.2: Details of camera-trapping survey effort in Nakai-Nam Theun NPA from 2006 to 2011.

Area - site	time period	Total cameras[a]	CTD	Total photos taken[b]
Khamkeut - Nam San (NS)	Mar-May 06	49	2181	1109
Nam On - Boualapha (BLP)	Oct-Nov 06	49	1638	357
Nam On - Gnomalath (GML)	Dec 06-Feb 07	49	1705	344
Khamkeut - Thong Pae (TP)	Mar-May 07	48	2134	721
Nam Chae - Makfuang (MF)	Nov 07-Jan 08	50	2308	624
Nam Chae - Navang (NV)	Jan-Mar 08	47	1846	601
Phou Vang - Houay Nam Heuy (PV)	Apr-Aug 08	32	1687	1013
Thong Xet (TX)	Nov 08-Jan 09	22	1174	307
Nam Mon - Thongkacheng (TKC)	Mar-May 09	3	183	1222
Nam Theun - reservoir (Res)	Nov-Dec 09	40	1636	585
Nam Mon - Thongkacheng (TKC)	Mar-May 10	45	2405	2219
Khamkeut - Nam San (NS)	Dec 10-Jan 11	33	1319	126
TOTAL	**Mar 06-Jan 11**	**467**	**20216**	**9228**

[a] faulty cameras are excluded
[b] Includes test, unidentified and photos with no objects
CTD=camera trap day

Table 7.3: Number (nb) of independent images taken for each species over the 20259 camera-trap days period, elevation and percentage of them taken at dusk (17h00-19h00), night (19h00 to 05h00), dawn (05h00-07h00) and in day time (07h00 to 17h00).

Species	nb. ind. pho.	nb. cam-localities[a]	nb. Sites[b]	Elev. range	% dusk (17:00-19:00)	% night (19:00-05:00)	% dawn (05:00-07:00)	% day (07:00-17:00)
Large Indian civet	79	39	6	531-1707	6	87	7	0
common palm civet	100	54	10	549-1792	5	89	6	0
masked palm civet	55	36	6	629-1792	2	94	2	2
Owston's civet	60	15	5	1033-1675	2	98	0	0
binturong	1	1	1	828	0	100	0	0
spotted linsang	5	4	3	839-1594	0	60	40	0
yellow-throated marten	18	15	8	562-1792	6	0	11	83
ferret badger sp(p).	101	34	6	583-1675	1	94	5	0
hog badger	80	42	9	547-1622	8	60	22	10
crab-eating mongoose	40	27	8	531-1792	8	3	15	75

[a] number of camera-trap-locality (a single camera-trap per locality) where recorded, out of the 469 camera-trap-sites set.
[b] number of sampling sites where recorded, out of the ten sampling sites (c.f. Table 7.1).

The elevation range at which each species was recorded (Table 7.3) fell into the general known range across the country (Duckworth et al., 1999; Johnson et al., 2009; Sivilay et al., 2011).

The 24-hour activity cycle varied between species. Yellow-throated marten, and crab-eating mongoose were largely recorded from dawn through day time (05h00 to 17h00); whereas the other eight species were predominantly recorded from dusk through night time (17h00 to 05h00). Spotted linsang, yellow-throated marten, hog badger and crab-eating mongoose were the most regularly recorded at dawn (05h00-07h00; >10% of images) (Table 7.3).

Relative encounter rates for all ten species combined were highest in Khamkeut and Nam Mon areas (249 independent small carnivore images over 5634 camera-trap-days and 109 images over 2588 camera-trap-days, respectively) and the lowest in Nam Chae area (40 images over 4154 camera-trap-days) (Figure 7.2).

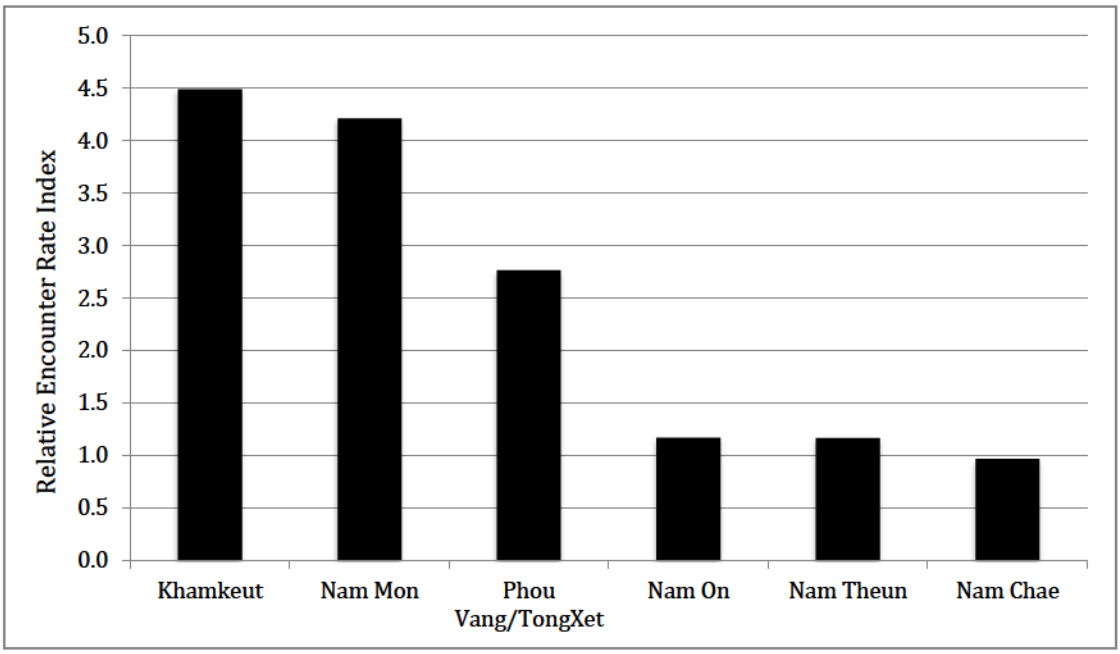


Figure 7.2: Comparison of encounter rate (i.e. number of independent images/camera-trap days*100) of all ten small carnivore species between the six general areas sampled (c.f. Figure 7.1).

Table 7.4: Averages of different variables, obtained remotely using GIS, for all camera-trap localities at each of the six general areas sampled within Nakai-Nam Theun NPA.

Area	distance water (m)	distance village (m)	Slope	Elevation	Mean annual temperature	Mean annual precipitation
Khamkeut	501.75	12123.78	15.66	1119.53	19.52	1994.40
Nam Chae	353.51	6213.61	11.26	788.44	21.62	2281.40
Nam Mon	287.28	12034.30	15.84	1247.39	18.89	2126.57
Nam On	260.78	7687.26	9.67	766.74	21.79	2333.85
Nam Theun	361.01	3664.45	2.61	568.10	22.89	2434.95
Thong Xet-Phou Vang	343.94	5464.64	16.07	877.86	21.13	2277.13

Distribution of records was not uniform across the areas sampled between the different species (Figure 7.3; Figure 7.4). Common palm civet was the only species recorded at all ten different sites sampled and was recorded from the highest number of camera-trap-localities (n=52). Encounter rate and localities were the fewest for spotted linsang and binturong, though this does not necessarily indicate that they are the rarest and localised of the species (c.f. Discussion).

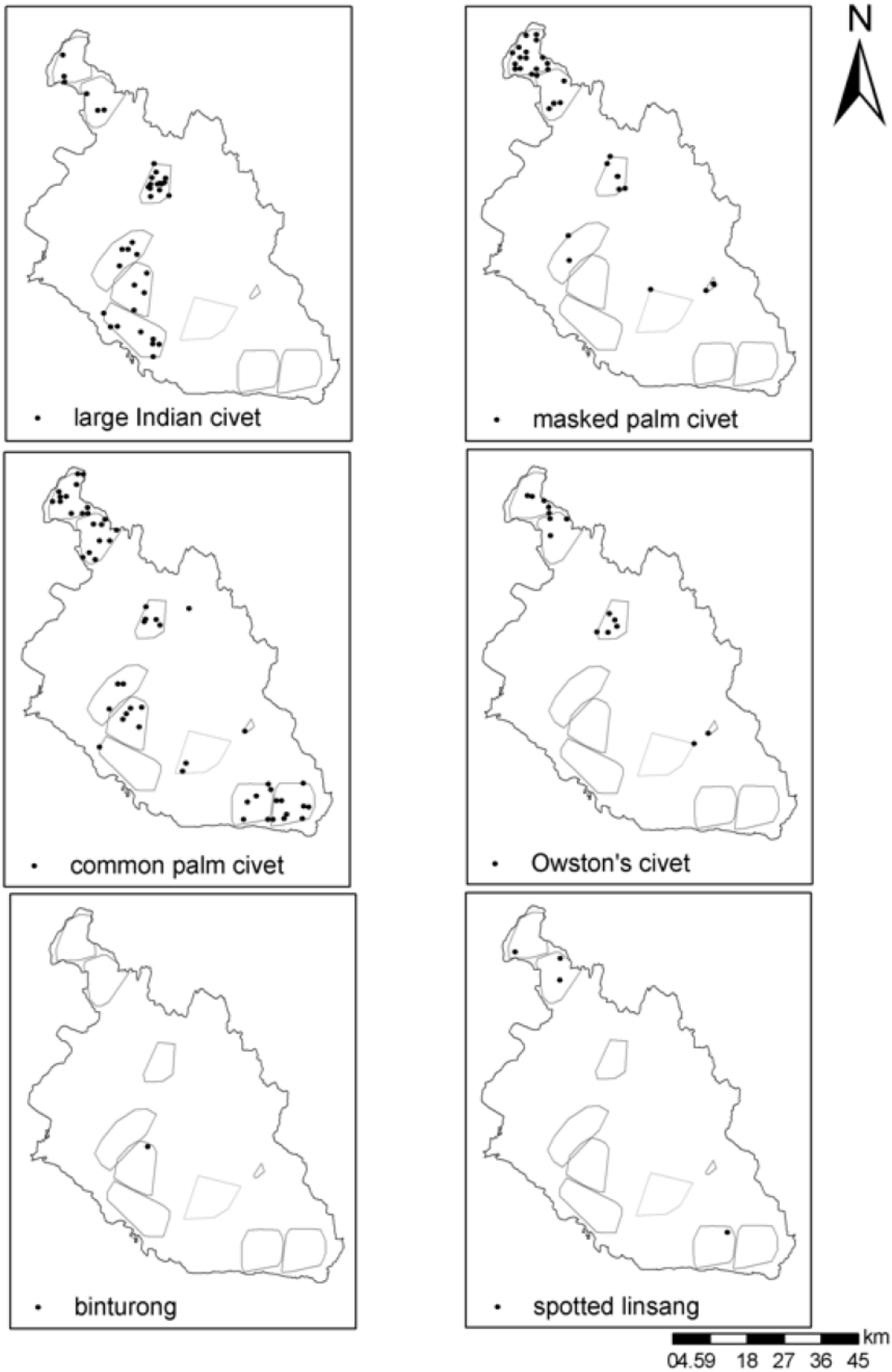


Figure 7.3: Distribution of the camera-trap records for Viverrid and linsang in Nakai-Nam Theun NPA during 2006-2011 survey period.

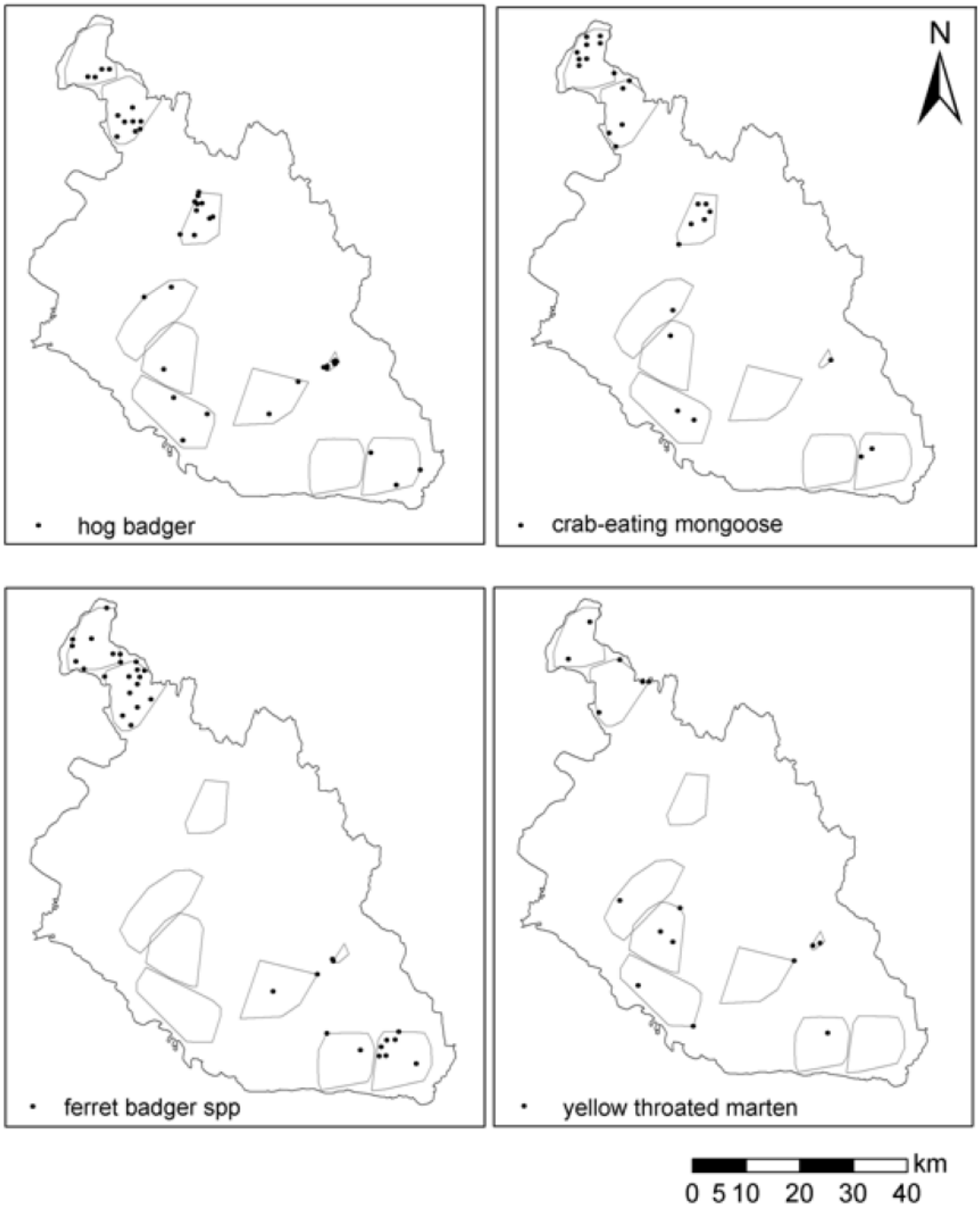


Figure 7.4: Distribution of the camera-trap records for Mustelid and Herpestid in Nakai-Nam Theun NPA during 2006-2011 survey period.

Masked palm civet, large Indian civet, Owston's civet, crab-eating mongoose and yellow-throated marten were occasionally recorded with conspecifics on some images (Table 7.5).

Table 7.5: Details of photographs that captured groups (≥2 individuals) of animals.

Species and Area of record	nb of inds	inds size	general behaviour	date	time
Large Indian civet					
Nam Mon (Thongkacheng)	2	adults size	2 individuals sniffing each other's perineal region	01 Apr 10	22h00
Masked palm civet					
Khamkeut (Nam San)	2	adults size	travelling side by side, looking down	27 Apr 06	00h42
Khamkeut (Thong Pae)	2	adults size	travelling side by side (3 consecutive photos)	04 Apr 07	05h43
Nam Mon (Thongkacheng)	2	adults size	travelling side by side	09 Mar 10	19h59
Owston's civet					
Khamkeut (Thong Pae)	2	adults size	travelling side by side, looking down	06 Apr 07	01h54
Khamkeut (Thong Pae)	2	adults size	travelling side by side, looking down	03 May 07	21h46
crab-eating mongoose					
Khamkeut (Nam San)	2	adults size	travelling side by side, looking down	16 Apr 06	11h46
Nam On (Boualapha)	2	adults size	travelling side by side, looking down	10 Nov 06	06h47
Nam On (Boualapha)	3	adults size	travelling side by side, 2 sniffing the air, 1 looking down	17 Nov 06	10h08
Nam Theun reservoir	3	adults size	travelling side by side, 2 sniffing the ground, 1 looking up	03 Dec 09	15h04
yellow-throated marten					
Khamkeut (Nam San)	2	adults size	travelling side by side, looking down	27 Mar 06	15h52
Phou Vang	2	adults size	standing side by side, looking up	13 Mar 08	10h00

Other relevant records during 2011-2012 surveys in NNT NPA are presented in Table 7.6.

Table 7.6: Additional opportunistic data collected during foot surveys over 10 different sites visited in NNT NPA in 2011-2012

Species	Details	Date	Area	Geographic coordinates	Elevation (m a.s.l.)
hog badger	remains in snares: skull	Mar-11	Maka	17° 58' N 105° 30' E	~700
hog badger	remains in snares: skull	Jul-11	Thong Xet	17° 46' 21.630" N 105° 30' 47.876" E	973
masked-palm civet	captive at Vietnamese camp; released	Jul-11	Thong Xet	17° 46' 17.559" N 105° 31' 18.574" E	n/a
spotted linsang	remains: tail in poacher camp c.f. App. 1	Jan-12	Nam Chae	17° 48' 2.099" N 105° 17' 5.075" E	n/a
smooth-coated otter	tracks along large river (Nam Theun) c.f. App. 1	Jan-12	upper Nam Theun	18° 0' 52.971" N 105° 27' 28.249" E	675
crab-eating mongoose	sighting	Jan 12, 07h54 am	upper Nam Theun	18° 5' 40.596" N 105° 30' 17.827" E	1006
binturong	remains: spine and hair	Mar-12	Nam Mon	18° 1' 2.323" N 105° 20' 14.896" E	1255

Discussion

Ten species of small carnivores were recorded from camera-traps in NNT NPA from 2006 to 2011. This falls in the upper range (5 - 12) of small carnivore species richness (excluding cats and otters) recorded from camera-trap surveys (>1000 camera-trap days) at single sites in other Southeast Asian countries (e.g. Grassman, 2003; Kawanishi and Sunquist, 2004; Holden and Neang, 2006; Chen et al., 2009; Cheyne et al., 2010; Wilting et al., 2010; Jenks et al., 2011; Than Zaw et al., 2008). In Northern Laos, ten species were also recorded during a long-term camera-trap survey (8499 camera-trap days) although species recorded slightly differ (Johnson et al., 2009). In 1994 and 1996, during a direct observation survey, ten small carnivore species were directly observed within one part of NNT NPA (Duckworth, 1998), of which three were not recorded from this

camera-trap survey (Siberian weasel, stripe-backed weasel, small-toothed palm civet; see below *Other species not recorded*). This highlights the differing adequacy of methodologies for recording some species. The species targeted by camera-trap surveys are in general larger, ground-dwelling mammals, with an associated positioning of cameras not adequate to many other species. When deploying camera-traps, taking into consideration the respective behaviour of small carnivore species to place cameras accordingly can improve the completeness of species inventory (e.g. Samejima and Semiadi, 2012). Placing additional cameras in trees or other microhabitats, for instance, may record these species that are semi- or mainly arboreal or strongly associated with specific microhabitat features.

Viverridae

Five civet species were photographed in NNT NPA. Of the latter, all but Owston's civet had previously been recorded from spot-lighting foot surveys within NNT NPA (Duckworth, 1997). Civets were relatively frequently and widely recorded over the area and altitudes surveyed.

The common palm civet and large Indian civet were the most widely recorded species and found at the largest altitudinal ranges, which concurs with sighting records of the two species across Laos (Duckworth, 1997) and another camera-trap survey in northern Laos (Johnson et al., 2009).

The distribution of records for the other three civet species was more restricted, which may reflect their affinity to higher elevations within NNT NPA. Masked palm civet is indeed considered to range only above 500 m a.s.l. in Laos (Duckworth, 1997; Duckworth et al., 1999). There were fewer to no masked palm civet records at all from sampling areas at lower elevations (e.g. Nam Chae, Nam On, Nam Theun). However, the species' semi-arboreality may render its camera-capture under-represented. In Myanmar, in some areas where captive or dead

specimens of masked palm civets were often recorded, relatively high camera-trap efforts (~300-2000 camera-trap-days) failed to record images of this species (Than Zaw et al., 2008).

Little is known of the distribution and status of Owston's civet across its range (Roberton et al., 2008). In Laos, other records for the species come from elevations >1000 m a.s.l. (Johnson et al., 2009; Sivilay et al. 2011). Given the terrestriality of this species (as deduced from frequent camera-trap captures in its habitat), the elevation range at which it is recorded via camera-trapping across its range, is likely well representative of the elevation range of the species In NNT NPA, where Owston's civet seems to be found only above 1000 m a.s.l. Records from the Vietnamese side of the Annamites go down below the lowest altitude of NNT NPA, e.g. in nearby Pu Mat Nature Reserve, Vietnam, it was camera-trapped down to 400 m (Grieser-Johns, 2000). However, habitat is significantly different between the two slopes, notably in terms of dry-season: it is longer and harsher in most of the west (Timmins and Trinh, 2001), and this may explain the differing altitudinal distribution between the two sides.

The single record of binturong during this survey may in principle be due to any or all of the following (i) arboreality (ii) rarity (iii) the location of cameras that excludes its microhabitats. Binturong is mainly arboreal but regularly comes to the ground where it cannot move between trees in the canopy (Widmann et al., 2008). Camera-trap surveys in Asia at sites where binturongs are known to occur, generally captured only few photographs or none at all (e.g. Holden and Neang, 2006; Datta et al., 2008; Than Zaw et al., 2008; Cheyne et al., 2010; Wilting et al., 2010; Jenks et al., 2011; Samejima and Semiadi, 2012).

Camera-trap records for civets confirm all four frequently photographed species as primarily nocturnal. Sociality of these species is poorly known; they are all classified as solitary but occasionally are found with conspecifics as shown on a few photographs in this study with duos of adult-size individuals of masked palm

civet, large Indian civet and Owston's civet, all taken during March–May. This is the end of the dry season in Laos, and the concentration of the photographs suggests it possibly coincides with the mating season, although it is unclear from the images of what age and sex the individuals were. In Laos, groups (two to five individuals) were occasionally sighted of masked palm civet and common palm civet (Duckworth, 1997; Johnson et al., 2009) and two to five common palm civets were regularly photographed gathering at a salt lick in Cambodia (Edwards, 2012). Our single image of a pair of large Indian civets where the individuals are sniffing each other's perineal region, may indicate they are engaging in mating behaviour. In Cambodia, a pair of *Viverra/Viverricula* (species unconfirmed) was observed possibly involved in a reproductive behaviour in trees in May 2011 (Iseborn et al., 2012). The species has been said to breed throughout the year (Lekagul and McNeely, 1988), although this has never been studied in wild populations. Similarly, little is known of the breeding seasons of masked palm civet and Owston's civet in the wild.

Prionodontidae

Four photos were taken of the spotted linsang. This low frequency of photo-capture of linsangs (*Prionodon*) is common during camera-trap surveys across their range, when the species is not targeted (e.g. Holden and Neang, 2006; Datta et al., 2008; Than Zaw et al., 2008; Cheyne et al., 2010; Wilting et al., 2010; Jenks et al., 2011). Camera-traps generally exclude micro-habitats of the species; as an ambush hunter, it may spend most of its ground-level time hidden in thicker understorey (Duckworth, pers. comm.) where camera-traps are rarely set. Linsangs are semi-arboreal species, possibly primarily ranging in dense understorey 1 m above ground (Van Rompaey, 1995). When this was taken in consideration, camera-traps have recorded the species at higher frequency (e.g. Samejima and Semiadi, 2012). The species remains poorly known but it has been found in various forest types and wide altitudinal range where it occurs and seems resilient to degraded habitat (Roberton et al., 2008). The species seems

mainly active at dusk and night with occasional activity during daytime (Borah, 2010).

Mustelidae

Four Mustelid taxa were recorded in NNT NPA, which had previously been confirmed in the area (Duckworth, 1997; Robichaud and Stuart, 1999; Robichaud, 2010; Duckworth et al., 1999). Ferret badgers were the most frequently camera-trapped taxa, although not evenly recorded throughout the sampled areas. The distribution of *Melogale* spp. in Laos and neighbouring countries remain uncertain. Two species of ferret badgers have been recorded in Laos: large-toothed (*M. personata*) and small-toothed (*M. moschata*) ferret badgers (Duckworth et al., 1999), and a third, *M. cucphuongensis*, has recently been named from neighbouring Vietnam; Nadler et al., 2011) and could plausibly inhabit Laos (if valid taxonomically). Despite intensive camera-trap survey in Nam Et-Phou Louey NPA, north-eastern Laos, no images were taken of the genus (Johnson et al., 2009), suggesting the possibility of their absence from that area, given the comparatively frequency at which it was recorded in NNT NPA. However, other factors such as differences in camera positioning might also contribute to this pattern. On current knowledge, species identification requires observation of the skull and dentition (Schank et al., 2009; Robichaud, 2010), therefore few records across Laos have been identified to species. A skull of *M. moschata* recently found in NNT NPA confirms that at least the latter species occurs there (Robichaud, 2010). How many species are found in the NPA remains unclear. Photographs of the genus in NNT NPA shows variation in the individuals' fur coloration, from light brown to grey (Appendix 7.2). This variation may be found within single species (e.g. Schank et al., 2009; Nadler et al., 2011) as is also observed in other small carnivore species (Veron et al., 2004). Photographs confirm the genus as exclusively nocturnal in NNT NPA.

Hog badger was recorded widely in terms of altitude, geography and photo-capture frequency. Records suggest the species can be active during day and night time, as has previously been found in Myanmar (Than Zaw et al., 2008). A few photographs showed partial-albino/leucistic forms, which has rarely been documented on other badger species (e.g. Roest, 1961; and see McCardle, 2012).

Activity cycle, altitudinal range and sociality of yellow-throated marten recorded from this survey is consistent with previous studies, in which the species has been recorded primarily by day and often travelling in small groups (e.g. Duckworth, 1997; Holden and Neang, 2009; Datta et al., 2008; Parr and Duckworth, 2007).

Herpestidae

The photos of crab-eating mongoose in duos or groups of 3-4 individuals are consistent with previous observations that this species regularly travels with conspecifics (Duckworth, 1997; Than Zaw et al., 2008; Johnson et al., 2009). The species was primarily recorded from 5h00 to 17h00, consistent with previous records across its range (e.g. Duckworth, 1997; Edwards, 2012; Holden and Neang, 2009; Chen et al., 2009; Than Zaw et al. 2008), although occasional activity was recorded from dusk to night time.

Species not recorded

Previously confirmed species in NNT NPA were not recorded during this camera-trap survey. Both the stripe-backed weasel (*Mustela strigidorsa*) and the Siberian weasel (*M. sibirica*) have been sighted at least once in NNT NPA (Duckworth, 1997; Duckworth, 1998; Abramov et al., 2008; Streicher et al., 2010). Little is known of their ecology and habitat use. Both species have been recorded in various habitat types across their range; however, stripe-backed weasel probably occurs mainly in hills and mountain evergreen forests for which NNT NPA is

typical; but the regional habitat use of Siberian weasel remain poorly understood (Lekagul and McNeely, 1988; Duckworth et al., 1999; Abramov et al., 2008).

The small-toothed palm civet (*Arctogalidia trivirgata*) is at least locally common in NNT NPA (Duckworth, 1997), but is a strictly arboreal species (Duckworth and Nettelbeck, 2007), which explains its absence from image records from ground-level camera-trapping.

Of the other small carnivore species inhabiting the area, are at least two otter species: Oriental small-clawed otter (*Aonyx cinereus*) and smooth-coated otter (*Lutrogale perspicillata*) (see Duckworth, 1997; Coudrat, 2012a). The latter species has never officially been confirmed in NNT NPA, though recent (Jan 2012) photographs of tracks along the Nam (=river) Theun (18° 0' 52.971" N 105° 27' 28.249" E) were attributed to that species (N. Duplaix, pers. comm.). Otters were unsurprisingly not recorded from this camera-trap survey due to the location of cameras at unsuitable otter-habitat. Otter tracks were commonly observed along large rivers in the area in 1996 (Timmins and Evans, 1996) and several tracks were observed along the Nam Theun in 2012 (Coudrat, 2012a).

Various small carnivores known from Laos remain unrecorded from NNT NPA except from its lowland western part (the Nakai plateau), which is not here covered. Two of these species are tied in Laos to highly deciduous and/or degraded habitats: small Indian civet (*Viverricula indica*) and small Asian mongoose (*Herpestes javanicus*) (see Duckworth et al., 1999; Duckworth et al., 2010). For these, there is presently little if any suitable habitat in the NPA off the Nakai plateau. Large-spotted civet (*Viverra magaspila*) probably occurs, or used to, on the Nakai Plateau (Khounboline, 2005), but this seems to be about its upper altitudinal limit in Laos (Duckworth et al., 2010) and it is likely to be extremely local, if present at all, in the NPA off the plateau. The final species known to inhabit Laos but not recorded from the NPA is yellow-bellied weasel *Mustela kathiah*. This is known from highlands (over 1000 m) in both North and

South Laos (Tizard, 2002; Duckworth and Robichaud, 2005) and presumably occurs along the intervening Annamite spine, although there are as yet no records. Like other weasels in South-east Asia it seems only poorly recorded by camera-traps (Supparatvikorn et al., 2012), so it may well inhabit NNT NPA. Two other species have not been recorded in the NPA but are so difficult to identify that they may have been detected but not identified: Eurasian otter (*Lutra lutra*) and large-toothed ferret badger (*M. personata*).

Threats

Of all small carnivore species discussed here, civets are the most commonly used in Laos: they have been recorded sold as food in markets, as processed products for traditional medicine, kept as trophies and as pets and are also traded with Vietnamese (Duckworth et al., 1999; Nooren and Claridge, 2001; Sivilay et al., 2011). In NNT NPA, the extent of small carnivore hunting -- whether for local consumption or trade with Vietnamese -- is unknown; however the extremely large scale of ground snare traps set-up across the area by Lao and Vietnamese poachers (Coudrat, 2012a; Robichaud et al., 2009) undoubtedly catch large number of these animals, targeted or not. The opportunistic findings of live or remains of small carnivores at a poacher camps or in snares in 2011-2012, suggests at least that such traps often catch these species. Wild meat, including several small carnivore species, traditionally formed a large part of upland Lao people's diet, but unsustainable harvest has led to a decrease in these species' wild populations (Krahn, 2005; Krahn and Johnson, 2007). Annual kill rate of Viverrid species have dramatically decreased in some villages in Laos (Krahn, 2005) and there has been a switch to smaller-bodied animals (such as squirrels and rats) now more commonly hunted (Krahn and Johnson, 2007).

The difference in the relative encounter rates of small carnivores between the six areas sampled in this study is surely at least in part driven by methodological factors as well as differences in environmental and topographical characteristics

between these areas, notably influencing behaviour of the species (c.f. Sollmann et al., 2013). Nonetheless, it is likely that also unsustainable hunting is reducing populations of some species of small carnivores in some parts of the NPA. The areas with the highest relative encounter rates in small carnivores, are also found the farthest away from villages as well as at the highest mean elevation and most rugged terrain, therefore are the most difficult accessible areas to humans. This trend was also suggested in Cambodia for large mammals recorded on camera-traps (Gray and Phan, 2011). Much fewer species were recorded from the southern sampling area (Nam On), with some species not recorded even once. This is likely demonstrating their relatively higher sensitivity to hunting pressure. Surveys in 2011 in this area found evidence of hunting including Vietnamese poacher camps, snare traps, and gunshots (Coudrat, 2012a).

Overall, 15 species of the 21 small carnivore species confirmed to occur in Laos are found in NNT NPA. As small carnivore species remain very poorly known, a wide variety of new techniques for placement of cameras should be considered. NNT NPA is one of the largest remaining forest blocks in Indochina, where species would be assumed to be more resilient to anthropogenic activity than in smaller and more fragmented landscapes. However, the intensity of snare hunting in the area puts the wildlife at high risk of local extinction, especially ground dwelling mammals such as small carnivores, and cat records from this survey are now so few as to suggest strongly that they are already severely reduced (c.f. CHAPTER 6). The area nonetheless may still be one of the most important for the conservation of Owston's civet (Schreiber et al., 1989) and its two species of otters.

Appendix 7.1: (a) smooth-coated otter tracks (identified to species by N. Duplaix, pers. comm.) along the Nam (=river) Theun; (b) spotted linsang tail found at a poacher camp in Nam Chae (Houay Thong) area (c.f. Table 7.5).

a

b

Appendix 7.2: Two main coat colorations observed of *Melogale* sp(p). photo-captured in NNT NPA: (a) grey; (b) light brown-orange; Photos credit © WMPA

a

b

Appendix 7.3: camera-trap records (only first photograph taken for each camera is presented small carnivores in Nakai-Nam Theun National Protected Area from 2006 to 2011.

Species	Area	site	Longitude	Latitude	date	time	Elev.
Large Indian civet	Khamkeut	Nam San	105.192299	18.253809	15/04/2006	19h43	770
	Khamkeut	Nam San	105.232228	18.217421	12/04/2006	02h23	629
	Khamkeut	Nam San	105.217444	18.216697	21/04/2006	05h34	716
	Khamkeut	Thong Pae	105.141786	18.279287	18/05/2007	02h34	1191
	Khamkeut	Thong Pae	105.140471	18.292113	14/04/2007	20h24	1199
	Khamkeut	Thong Pae	105.137566	18.338744	03/04/2007	01h55	661
	Nam Chae	Makfueng	105.300027	17.779554	20/12/2007	21h47	585
	Nam Chae	Makfueng	105.322785	17.817571	27/11/2007	00h56	964
	Nam Chae	Makfueng	105.328931	17.860341	16/12/2007	03h00	855
	Nam Chae	Makfueng	105.301233	17.834671	21/12/2007	19h47	757
	Nam Chae	Navang	105.296622	17.927920	20/03/2008	19h12	822
	Nam Chae	Navang	105.267037	17.876018	04/02/2008	02h04	819
	Nam Chae	Navang	105.272984	17.913195	11/02/2008	18h49	867
	Nam Chae	Navang	105.286012	17.912525	03/03/2008	18h45	839
	Nam Chae	Navang	105.306614	17.901792	18/02/2008	00h41	856
	Nam Mon	Thongkacheng	105.333891	18.048615	14/03/2009	03h47	-
	Nam Mon	Thongkacheng	105.335000	18.050556	28/04/2009	02h10	-
	Nam Mon	Thongkacheng	105.337400	18.045825	14/03/2010	04h24	784
	Nam Mon	Thongkacheng	105.338199	18.028497	05/03/2010	23h43	1097
	Nam Mon	Thongkacheng	105.370035	18.059305	27/03/2010	05h40	1622
	Nam Mon	Thongkacheng	105.351493	18.081637	18/03/2010	20h28	1352
	Nam Mon	Thongkacheng	105.346142	18.099742	29/03/2010	21h47	1175
	Nam Mon	Thongkacheng	105.341613	18.069426	29/03/2010	22h18	1033
	Nam Mon	Thongkacheng	105.338099	18.055675	30/03/2010	04h35	957
	Nam Mon	Thongkacheng	105.380337	18.029774	09/03/2010	22h56	1421
	Nam Mon	Thongkacheng	105.358850	18.041999	07/03/2010	23h01	1243
	Nam Mon	Thongkacheng	105.364321	18.056107	09/03/2010		1424
	Nam Mon	Thongkacheng	105.360222	18.057018	14/03/2010	19h31	1282
	Nam Mon	Thongkacheng	105.372549	18.068664	07/04/2010	01h16	1707
	Nam Mon	Thongkacheng	105.362525	18.055469	18/03/2010	20h51	1369
	Nam Mon	Thongkacheng	105.354021	18.055719	13/03/2010	04h12	1379
	Nam Theun	reservoir	105.314897	17.731553	18/12/2009	22h19	541
	Nam Theun	reservoir	105.343833	17.716193	21/11/2009	21h34	531
	Nam Theun	reservoir	105.342671	17.705385	15/12/2009	22h55	548
	Nam Theun	reservoir	105.261983	17.744385	23/11/2009	18h07	573
	Nam Theun	reservoir	105.246512	17.742959	20/11/2009	23h11	539
	Nam Theun	reservoir	105.343006	17.677870	22/11/2009	23h45	565
	Nam Theun	reservoir	105.357231	17.704726	08/12/2009	05h00	551
	Nam Theun	reservoir	105.230468	17.772969	04/12/2009	01h14	549
masked palm civet	Khamkeut	Nam San	105.207102	18.204064	24/03/2006	01h47	901
	Khamkeut	Nam San	105.232228	18.217421	21/03/2006	01h33	629
	Khamkeut	Nam San	105.217444	18.216697	05/04/2006	02h05	716
	Khamkeut	Nam San	105.218171	18.215522	23/12/2010	19h07	824
	Khamkeut	Nam San	105.178777	18.277665	24/01/2011	20h37	652
	Khamkeut	Nam San	105.241563	18.265259	31/12/2010	00h21	1609

	Khamkeut	Thong Pae	105.128729	18.291489	05/04/2007	21h00	1242
	Khamkeut	Thong Pae	105.140471	18.292113	04/04/2007	05h43	1199
	Khamkeut	Thong Pae	105.128708	18.302434	07/04/2007	21h16	1247
	Khamkeut	Thong Pae	105.178159	18.366602	03/03/2007	01h58	891
	Khamkeut	Thong Pae	105.154780	18.315728	23/04/2007	04h29	1332
	Khamkeut	Thong Pae	105.203416	18.303499	14/04/2007	03h04	1189
	Khamkeut	Thong Pae	105.178355	18.290916	28/04/2007	20h17	826
	Khamkeut	Thong Pae	105.192624	18.316715	23/03/2007	18h39	1621
	Khamkeut	Thong Pae	105.204318	18.290221	19/04/2007	02h11	1245
	Khamkeut	Thong Pae	105.140974	18.316498	17/05/2007	19h40	1069
	Khamkeut	Thong Pae	105.178260	18.354310	04/05/2007	21h03	1792
	Khamkeut	Thong Pae	105.122925	18.327049	24/04/2007	22h15	761
	Khamkeut	Thong Pae	105.154583	18.328500	02/04/2007	21h04	1344
	Khamkeut	Thong Pae	105.137566	18.338744	09/04/2007	02h09	661
	Khamkeut	Thong Pae	105.154379	18.365141	02/05/2007	01h00	796
	Khamkeut	Thong Pae	105.250711	17.926277	11/05/2007	02h58	769
	Nam Chae	Navang	105.252826	17.872593	06/03/2008	02h03	1063
	Nam Chae	Navang	105.364321	18.056107	21/02/2008	19h35	651
	Nam Mon	Thongkacheng	105.346142	18.099742	11/03/2010	23h06	1424
	Nam Mon	Thongkacheng	105.339183	18.083864	23/03/2010	03h32	1175
	Nam Mon	Thongkacheng	105.380337	18.029774	20/03/2010	23h13	1221
	Nam Mon	Thongkacheng	105.366351	18.028012	09/03/2010	19h59	1421
	Nam Mon	Thongkacheng	105.364321	18.056107	14/03/2010	00h27	1380
	Nam Mon	Thongkacheng	105.362525	18.055469	01/04/2010	*night*	1424
	Nam Mon	Thongkacheng	105.581386	17.820001	11/03/2010	01h21	1369
	Phou Vang	Nam Heuy	105.565148	17.805903	15/03/2008	02h09	-
	Phou Vang	Nam Heuy	105.583900	17.818620	30/03/2008	02h54	-
	Phou Vang	Nam Heuy	105.583334	17.818368	09/03/2008	03h23	-
	Phou Vang	Nam Heuy	105.438904	18.079560	06/03/2008	22h53	-
	Thong Xet		105.438236	17.808407	28/12/2008	22h26	686
common palm civet	Khamkeut	Nam Sane	105.207102	18.204064	20/03/2006	05h28	901
	Khamkeut	Nam Sane	105.255323	18.230018	28/04/2006	01h40	1634
	Khamkeut	Nam Sane	105.244531	18.277068	11/05/2006	02h27	1675
	Khamkeut	Nam Sane	105.192299	18.193559	29/03/2006	18h56	1278
	Khamkeut	Nam Sane	105.236266	18.266268	06/04/2006	02h03	1649
	Khamkeut	Nam Sane	105.221656	18.188737	06/04/2006	23h34	981
	Khamkeut	Nam Sane	105.217971	18.267149	17/04/2006	22h54	1425
	Khamkeut	Nam Sane	105.270446	18.253759	10/04/2006	22h36	1437
	Khamkeut	Nam Sane	105.231243	18.230474	08/04/2006	00h05	1359
	Khamkeut	Thong Pae	105.180812	18.378323	15/04/2007	01h54	929
	Khamkeut	Thong Pae	105.193524	18.377171	01/04/2007	03h40	906
	Khamkeut	Thong Pae	105.166632	18.290537	02/05/2007	23h23	1015
	Khamkeut	Thong Pae	105.203416	18.303499	08/05/2007	20h27	1189
	Khamkeut	Thong Pae	105.204318	18.290221	29/03/2007	03h45	1245
	Khamkeut	Thong Pae	105.178260	18.354310	30/03/2007	02h28	1792
	Khamkeut	Thong Pae	105.140974	18.316498	20/04/2007	19h25	1069
	Khamkeut	Thong Pae	105.154583	18.328500	05/04/2007	23h33	1344
	Khamkeut	Thong Pae	105.191838	18.290758	03/04/2007	22h43	974

	Khamkeut	Thong Pae	105.137566	18.338744	17/04/2007	19h47	661
	Khamkeut	Thong Pae	105.141011	18.327209	11/05/2007	20h11	845
	Khamkeut	Thong Pae	105.122776	18.316556	24/03/2007	20h40	1152
	Nam Chae	Makfueng	105.302453	17.858892	17/11/2007	03h04	799
	Nam Chae	Makfueng	105.322785	17.817571	21/12/2007	22h16	964
	Nam Chae	Makfueng	105.328931	17.860341	06/12/2007	19h25	855
	Nam Chae	Makfueng	105.284886	17.834135	17/11/2007	19h04	864
	Nam Chae	Makfueng	105.293004	17.846244	17/11/2007	02h16	957
	Nam Chae	Navang	105.253049	17.856983	12/03/2008	21h32	742
	Nam Chae	Navang	105.272984	17.913195	08/02/2008	01h09	867
	Nam Chae	Navang	105.286012	17.912525	25/02/2008	22h25	839
	Nam Mon	Thongkacheng	105.339183	18.083864	21/03/2010	04h52	1221
	Nam Mon	Thongkacheng	105.338099	18.055675	12/03/2010	03h04	957
	Nam Mon	Thongkacheng	105.371513	18.042951	04/03/2010	19h23	1398
	Nam Mon	Thongkacheng	105.362525	18.055469	03/04/2010	02h09	1369
	Nam On	Boualapha	105.701894	17.640339	13/10/2006	02h44	831
	Nam On	Boualapha	105.698811	17.613280	01/11/2006	00h56	823
	Nam On	Boualapha	105.663114	17.622695	16/11/2006	01h36	778
	Nam On	Boualapha	105.714056	17.638379	31/10/2006	02h08	924
	Nam On	Boualapha	105.656698	17.613135	23/11/2006	04h20	757
	Nam On	Boualapha	105.650763	17.653394	18/10/2006	01h04	791
	Nam On	Boualapha	105.701225	17.691544	13/10/2006	19h34	914
	Nam On	Boualapha	105.630784	17.612054	09/11/2006	17h31	742
	Nam On	Boualapha	105.639034	17.653080	13/11/2006	21h47	787
	Nam On	Gnomalath	105.593309	17.664196	08/01/2007	21h33	702
	Nam On	Gnomalath	105.562920	17.611726	06/01/2007	19h40	623
	Nam On	Gnomalath	105.619181	17.612136	26/12/2006	20h01	657
	Nam On	Gnomalath	105.572712	17.650446	09/01/2007	22h33	692
	Nam On	Gnomalath	105.626903	17.678111	15/01/2007	18h47	850
	Nam On	Gnomalath	105.620257	17.689638	20/01/2007	02h40	839
	Nam Theun	reservoir	105.230468	17.772969	19/11/2009	22h48	549
	Phou Vang	Nam Heuy	105.566945	17.807227	11/03/2008	21h09	-
	Phou Vang	Nam Heuy	105.335000	18.050556	28/03/2008	02h22	-
	ThongXet		105.438904	18.079560	25/12/2008	19h54	686
	ThongXet		105.422513	17.718733	03/12/2008	22h12	626
	ThongXet		105.430394	17.737092	18/01/2009	19h01	688
Owston's civet	Khamkeut	Nam San	105.566945	17.807227	24/03/2006	01h53	1155
	Khamkeut	Nam San	105.338199	18.028497	13/04/2006	18h49	1675
	Khamkeut	Nam San	105.341613	18.069426	02/05/2006	21h49	1370
	Khamkeut	Thong Pae	105.358850	18.041999	11/04/2007	00h43	1189
	Khamkeut	Thong Pae	105.354021	18.055719	24/03/2007	00h20	1527
	Khamkeut	Thong Pae	105.313005	18.030130	24/03/2007	02h55	1621
	Khamkeut	Thong Pae	105.207069	18.240751	03/04/2007	21h11	1245
	Khamkeut	Thong Pae	105.244531	18.277068	19/04/2007	20h37	1344
	Phou vang	Houay Nam Heuy	105.206195	18.277556	07/03/2008	19h54	-
	Nam Mon	Thongkacheng	105.203416	18.303499	27/03/2010	21h12	1097
	Nam Mon	Thongkacheng	105.165739	18.326719	25/03/2010	01h47	1033

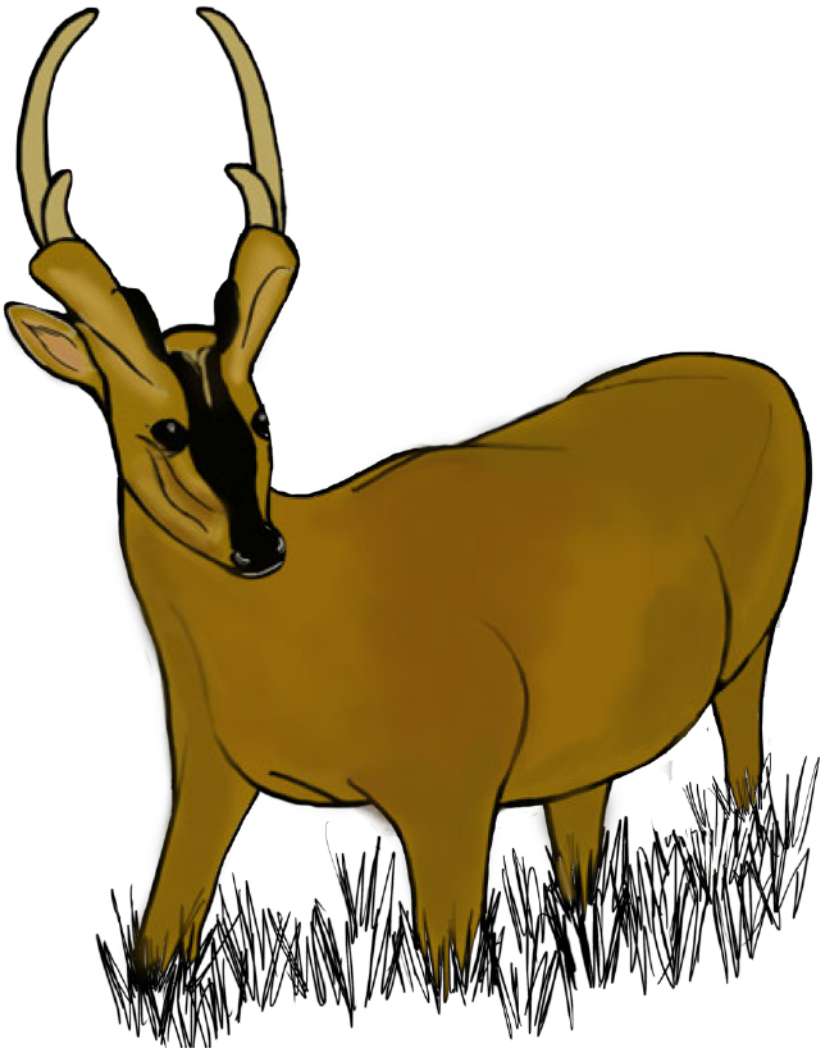
	Nam Mon	Thongkacheng	105.192624	18.316715	16/03/2010	20h46	1243
	Nam Mon	Thongkacheng	105.204318	18.290221	15/03/2010	03h04	1379
	Nam Mon	Thongkacheng	105.154583	18.328500	13/03/2010	21h22	1034
	Thong Xet	Thong Xet	105.535110	17.785326	16/12/2008	23h39	904
spotted linsang	Khamkeut	Nam San	105.232195	18.277933	18/04/2006	05h29	1594
	Khamkeut	Nam San	105.231243	18.230474	03/04/2006	04h59	1359
	Khamkeut	Thong Pae	105.128729	18.291489	18/04/2007	02h58	1242
	Nam On	Gnomalath	105.613360	17.677340	02/01/2007	04h11	839
yellow throated marten	Khamkeut	Thong Pae	105.357872	17.676470	07/04/2007	12h57	1792
	Khamkeut	Thong Pae	105.261983	17.744385	12/04/2007	15h19	1199
	Khamkeut	Nam San	105.593309	17.664196	27/03/2006	15h52	1437
	Khamkeut	Nam San	105.178260	18.354310	27/04/2006	18h06	1358
	Khamkeut	Nam San	105.140471	18.292113	18/04/2006	05h53	1305
	Khamkeut	Nam San	105.270446	18.253759	17/05/2006	06h43	1548
	Nam Chae	Navang	105.281637	18.253553	11/02/2008	08h59	758
	Nam Chae	Makfueng	105.193954	18.202433	26/12/2007	16h38	964
	Nam Chae	Makfueng	105.230272	18.290878	08/12/2007	08h36	1036
	Nam On	Gnomalath	105.567779	17.811111	21/01/2007	09h18	702
	Nam Theun	reservoir	105.230152	17.887499	12/11/2009	07h15	562
	Nam Theun	reservoir	105.322785	17.817571	23/11/2009	09h48	573
	Phou Vang	Nam Heuy	105.335498	17.874069	13/03/2008	10h00	-
	Phou Vang	Nam Heuy	105.301233	17.834671	18/03/2008	16h14	-
	Thong Xet		105.535110	17.785326	09/12/2008	10h42	904
ferret badger	Khamkeut	Nam San	105.232183	18.254822	05/04/2006	02h33	1377
	Khamkeut	Nam San	105.207102	18.204064	21/03/2006	23h18	901
	Khamkeut	Nam San	105.255323	18.230018	24/04/2006	04h14	1634
	Khamkeut	Nam San	105.244531	18.277068	29/04/2006	21h42	1675
	Khamkeut	Nam San	105.236266	18.266268	02/04/2006	20h21	1649
	Khamkeut	Nam San	105.232195	18.277933	02/04/2006	01h58	1594
	Khamkeut	Nam San	105.221656	18.188737	26/03/2006	21h12	981
	Khamkeut	Nam San	105.232228	18.217421	22/03/2006	23h25	629
	Khamkeut	Nam San	105.217971	18.267149	04/04/2006	01h10	1425
	Khamkeut	Nam San	105.230272	18.290878	01/04/2006	20h39	1548
	Khamkeut	Nam San	105.177319	18.266893	08/04/2006	03h17	583
	Khamkeut	Nam San	105.219300	18.240855	24/12/2010	19h01	1271
	Khamkeut	Thong Pae	105.128729	18.291489	24/04/2007	00h57	1242
	Khamkeut	Thong Pae	105.141786	18.279287	02/05/2007	01h21	1191
	Khamkeut	Thong Pae	105.180812	18.378323	11/05/2007	01h18	929
	Khamkeut	Thong Pae	105.203416	18.303499	04/04/2007	04h47	1189
	Khamkeut	Thong Pae	105.191503	18.303773	04/04/2007	19h47	1108
	Khamkeut	Thong Pae	105.204318	18.290221	08/04/2007	05h01	1245
	Khamkeut	Thong Pae	105.122925	18.327049	01/04/2007	18h56	761
	Khamkeut	Thong Pae	105.154583	18.328500	25/04/2007	00h33	1344
	Khamkeut	Thong Pae	105.122776	18.316556	06/05/2007	21h04	1152
	Nam On	Boualapha	105.701894	17.640339	21/10/2006	03h53	831
	Nam On	Boualapha	105.642574	17.667666	12/11/2006	05h16	827
	Nam On	Boualapha	105.666271	17.679093	17/10/2006	22h09	728

	Nam On	Boualapha	105.650763	17.653394	19/10/2006	02h52	791
	Nam On	Boualapha	105.651854	17.679015	28/10/2006	02h31	882
	Nam On	Boualapha	105.672071	17.692016	30/10/2006	03h08	933
	Nam On	Boualapha	105.639034	17.653080	20/11/2006	01h05	787
	Nam On	Gnomalath	105.551027	17.689898	24/01/2007	22h31	780
	Nam On	Gnomalath	105.607616	17.662760	19/02/2007	00h07	708
	Phou Vang	Nam Heuy	105.561112	17.809720	04/03/2008	22h27	-
	Phou Vang	Nam Heuy	105.562500	17.806941	05/03/2008	04h30	-
	Thong Xet		105.460385	17.758138	29/11/2008	20h19	846
	Thong Xet		105.535110	17.785326	06/12/2008	03h28	904
Hog badger	Khamkeut	Nam San	105.205559	18.227014	16/04/2006	01h59	1050
	Khamkeut	Nam San	105.204279	18.191802	24/04/2006	02h26	820
	Khamkeut	Nam San	105.244306	18.204291	15/04/2006	00h55	1481
	Khamkeut	Nam San	105.217444	18.216697	19/03/2006	09h54	716
	Khamkeut	Nam San	105.236423	18.200578	22/03/2006	02h59	1001
	Khamkeut	Nam San	105.245904	18.217278	30/03/2006	05h15	1356
	Khamkeut	Nam San	105.232228	18.217421	18/04/2006	05h08	629
	Khamkeut	Nam San	105.231728	18.240045	15/04/2006	20h20	1383
	Khamkeut	Thong Pae	105.191503	18.303773	04/04/2007	04h40	1108
	Khamkeut	Thong Pae	105.166632	18.290537	07/05/2007	23h42	1015
	Khamkeut	Thong Pae	105.153784	18.291533	14/05/2007	05h54	911
	Khamkeut	Thong Pae	105.178321	18.303678	01/05/2007	00h47	897
	Nam Chae	Makfueng	105.284597	17.806377	23/11/2007	00h39	612
	Nam Chae	Navang	105.250711	17.926277	12/03/2008	04h49	1063
	Nam Chae	Navang	105.297883	17.942742	10/03/2008	03h20	1052
	Nam Mon	Thongkacheng	105.338199	18.028497	02/04/2010	05h56	1097
	Nam Mon	Thongkacheng	105.370035	18.059305	09/03/2010	07h11	1622
	Nam Mon	Thongkacheng	105.351493	18.081637	21/04/2010	06h24	1352
	Nam Mon	Thongkacheng	105.344760	18.094131	17/04/2010	20h12	1152
	Nam Mon	Thongkacheng	105.346142	18.099742	22/03/2010	01h34	1175
	Nam Mon	Thongkacheng	105.339183	18.083864	27/03/2010	04h04	1221
	Nam Mon	Thongkacheng	105.343221	18.079926	17/04/2010	00h00	1065
	Nam Mon	Thongkacheng	105.341613	18.069426	11/03/2010	06h26	1033
	Nam Mon	Thongkacheng	105.364321	18.056107	11/03/2010	*night*	1424
	Nam Mon	Thongkacheng	105.313005	18.030130	17/03/2010	18h36	1034
	Nam On	Boualapha	105.686033	17.614192	07/11/2006	04h30	885
	Nam On	Boualapha	105.642574	17.667666	29/10/2006	19h13	827
	Nam On	Boualapha	105.727737	17.639305	19/10/2006	19h18	954
	Nam Theun	resevoir	105.317868	17.688786	14/11/2010	04h31	577
	Nam Theun	resevoir	105.359577	17.732498	21/11/2009	17h24	547
	Nam Theun	resevoir	105.301730	17.759621	25/11/2009	17h55	550
	Phou Vang	Nam Heuy	105.581490	17.820326	31/03/2008	*day*	-
	Phou Vang	Nam Heuy	105.583334	17.818368	21/03/2008	05h05	-
	Phou Vang	Nam Heuy	105.580567	17.814797	16/03/2008	19h22	-
	Phou Vang	Nam Heuy	105.579725	17.817222	-	-	-
	Phou Vang	Nam Heuy	105.581670	17.820552	20/03/2008	04h09	-
	Phou Vang	Nam Heuy	105.578332	17.818338	12/03/2008	04h01	-
	Phou Vang	Nam Heuy	105.566945	17.807227	06/03/2008	11h06	-

	Phou Vang	Nam Heuy	105.561112	17.809720	19/03/2008	22h58	-
	Phou Vang	Nam Heuy	105.567779	17.811111	26/03/2008	12h44	730
	Thong Xet		105.466893	17.732209	12/12/2008	09h54	725
	Thong Xet		105.516940	17.785709	19/12/2008	17h24	725
crab-eating mongoose	Khamkeut	Nam San	105.206023	18.179463	02/05/2006	10h16	630
	Khamkeut	Nam San	105.218817	18.277759	04/04/2006	16h40	1430
	Khamkeut	Nam San	105.193954	18.202433	10/04/2006	17h46	1305
	Khamkeut	Nam San	105.230272	18.290878	16/04/2006	11h46	1548
	Khamkeut	Nam San	105.217444	18.216697	27/03/2006	15h42	716
	Khamkeut	Thong Pae	105.178159	18.366602	01/05/2006	09h31	891
	Khamkeut	Thong Pae	105.154651	18.352117	28/04/2006	11h48	1031
	Khamkeut	Thong Pae	105.203416	18.303499	24/04/2007	07h48	1189
	Khamkeut	Thong Pae	105.178260	18.354310	27/04/2007	10h37	1792
	Khamkeut	Thong Pae	105.140974	18.316498	23/04/2007	05h48	1069
	Khamkeut	Thong Pae	105.154583	18.328500	02/05/2007	15h47	1344
	Khamkeut	Thong Pae	105.137566	18.338744	02/04/2007	08h04	661
	Khamkeut	Thong Pae	105.141011	18.327209	11/05/2007	05h00	845
	Khamkeut	Thong Pae	105.154379	18.365141	04/05/2007	09h57	796
	Nam Chae	Makfueng	105.302453	17.858892	15/12/2007	15h46	799
	Nam Chae	Navang	105.306614	17.901792	18/02/2008	14h40	856
	Nam Mon	Thongkacheng	105.351493	18.081637	23/03/2010	11h46	1352
	Nam Mon	Thongkacheng	105.317444	18.013727	01/04/2010	16h28	798
	Nam Mon	Thongkacheng	105.372549	18.068664	13/04/2010	09h25	1707
	Nam Mon	Thongkacheng	105.365480	18.081674	27/03/2010	08h20	1494
	Nam Mon	Thongkacheng	105.362525	18.055469	13/03/2010	06h45	1369
	Nam Mon	Thongkacheng	105.339484	18.048316	05/03/2010	10h30	934
	Nam On	Boualapha	105.658080	17.666693	10/11/2006	06h47	719
	Nam On	Boualapha	105.639034	17.653080	17/11/2006	10h08	787
	Nam Theun	reservoir	105.314897	17.731553	15/12/2009	11h36	541
	Nam Theun	reservoir	105.343833	17.716193	03/12/2009	15h04	531
	Phou Vang	Nam Heuy	105.585698	17.817024	11/03/2008	15h56	-
Binturong	Nam Chae	Makfueng	105.322402	17.871840		01h18	828

CHAPTER 8

ASSESSING THE NICHE OF THE ENDANGERED LARGE-ANTLERED MUNTJAC (*M. VUQUANGENSIS*) AND OTHER MUNTJAC SPP. IN NAKAI-NAM THEUN NATIONAL PROTECTED AREA, LAOS



Introduction

The Cervidae and Bovidae in Southeast Asia are diverse families but have been poorly studied and indeed much confusion remains on their taxonomy, distribution and ecology. The world's latest new discoveries of large mammals, belong to these two families and were only found two decades ago in the Annamite mountain range along the Lao-Vietnamese border. These include the saola (*Pseudoryx nghetinhensis*) (Vu Van Dzung et al., 1993; Schaller and Rabinowitz, 1995), the large-antlered muntjac (*Muntiacus vuquangensis*) (Tuoc et al., 1994; Duckworth et al., 1994; Evans and Timmins, 1995; Schaller and Vrba, 1996) and the Annamite muntjac (*M. truongsonensis*) (Giao et al., 1998). The saola has still never been observed directly in the wild by a biologist but has been camera-trapped from a few locations in Vietnam and Laos (Robichaud and Stuart, 1999; Hardcastle et al., 2004). The large-antlered muntjac has been more widely recorded since its discovery, mainly via camera-traps. The Annamite muntjac was described from a single skull holotype from central Vietnam (Giao et al., 1998), its taxonomic position remains debated given that morphological characteristics for this taxon are not objectively defined (Timmins et al., 2008a) (c.f. Table 8.1).

Table 8.1: note on taxonomic status of muntjac species referred to in the text

Taxon	Consensus on species validated?	Clear morphological characteristics to differentiate from other muntjac species?	Species complex (i.e. *sensu lato*, *s.l.*) to which taxon belongs	references
M. vaginalis Northern red muntjac	no	no	*M. muntjac s.l.*	Groves, 2003; Timmins et al., 2008b
M. truongsonensis Annamite muntjac	no	no	*M. rooseveltorum s.l.*	Giao et al., 1998; Timmins et al., 2008a
M. vuquangensis Large-antlered muntjac	yes	yes	-	Tuoc et al., 1994

Since their discovery, little information has been collected on these species. Indeed, direct sighting by biologists is too rare and tell-tale signs (i.e. tracks, droppings, and muntjacs calls) are unidentifiable to species level; this, coupled

with the difficulty of access of the habitats where they occur, make their study challenging. More recently, however, the use of camera-traps allowed wide records of images of these species with clear observation of species-specific morphology to confirm identification of at least some species.

Several of these species are found sympatrically in areas of the Annamite Mountains but their respective niche is poorly understood. Using the confirmed localities where they are photographed is very informative for the study of their ecology. Nakai-Nam Theun National Protected Area (NNT NPA), central eastern Laos is one of these areas and represents an ideal model to investigate the niche differentiation of sympatric species owing to its habitat heterogeneity. The area holds at least nine different species of ungulates, including three muntjacs: the Northern red muntjac *M. vaginalis,* the large-antlered muntjac *M. vuquangensis*, and a third species assumed to be the Annamite muntjac *M. truongsonensis.* In 2006, systematic camera-trap surveys were initialized in the area, deployed in various habitat types. I use the confirmed identifications of photographs of the large-antlered muntjac and other muntjac species as occurrence localities and model their respective habitat suitability to investigate a potential niche differentiation between the large-antlered muntjac and the two other muntjac species. I use two methods: maximum entropy (MAXENT) and ecological niche factor analysis (ENFA), that have recently been widely used to model habitat suitability, potential distribution and/or niche of various species worldwide (e.g. MAXENT: Chunco et al., 2012; Clements et al., 2012; Jenks et al., 2012; Junker et al., 2012; ENFA: Galparsoro et al., 2009; Jones et al., 2010; Rebelo and Jones, 2010; Rood et al., 2010). I discuss the implication of my results for the conservation of muntjac species in NNT NPA.

Methods

Study area

Nakai-Nam Theun National Protected Area (NNT NPA), ~3550 km^2, is located in the central-east of Laos within the Annamite mountain range (Figure 8.1). The area remains largely forested (Robichaud et al., 2009) with mixed semi-evergreen/coniferous, upper montane, dry-evergreen and wet evergreen forests (Timmins and Evans, 1996). Elevation throughout the NPA ranges mainly from ~500 m to c. 2300 m a.s.l. Annual precipitation ranges from 1865 mm to 2620 mm and annual mean temperatures from 14°C to 24° C, with extremes of 4°C to 32°C (Hijmans et al., 2005).

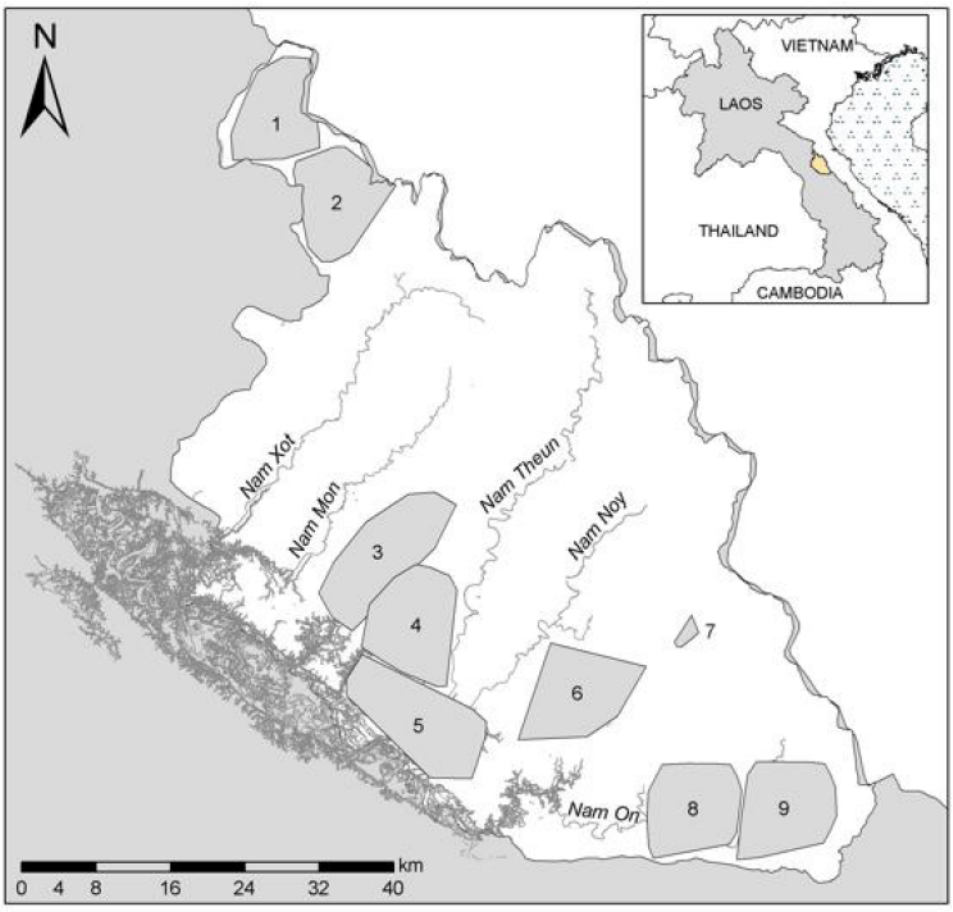


Figure 8.1: Nakai-Nam Theun National Protected Area with the ten camera-trap sampling sites visited in 2006-2011. Note: sampling sites delimitation was obtained from minimum convex polygon method around all camera-traps set at each site.

Biological data and Eco-geographical variables

I retrieved presence of muntjac species in NNT NPA from camera-trap data. From 2006 to 2011 systematic camera-trapping was carried out in the area by the Nam Theun 2-Watershed Management and Protection Authority (WMPA unpubl. data; Johnson and Johnston, 2007). The analysed data are from ten different sites sampled over the 2006-2011 period (Figure 8.1), totalling 20216 camera-trapping-days.

Images of muntjac species (Figure 8.2) were identified by experts (R.J. Timmins and W.G. Robichaud). Given the unclear morphological differentiation between *M. vaginalis* and *M. truongsonensis* of some individuals, the latter two taxa are modelled as a single group (and referred to as *M. vaginalis + M. truongsonensis* hereafter). Localities for *M. vuquangensis* and for *M. vaginalis + M. truongsonensis* were first mapped (projected to UTM WGS 84 zone 48N) in ArcGIS 9.3. To avoid autocorrelation and model over-fitting (Veloz, 2009; Merckx et al., 2011; Dormann et al., 2012), the data were pruned as to keep only one locality per 1km^2-grid cell. This resulted in a total of 48 locality points for *M. vuquangensis* and 35 for *M. vaginalis + M. truongsonensis* (Figure 8.3).

a

b

Figure 8.2: Photos taken by camera-traps in Nakai-Nam Theun NPA of a large-antlered muntjac (a) and a red muntjac (b) © WMPA

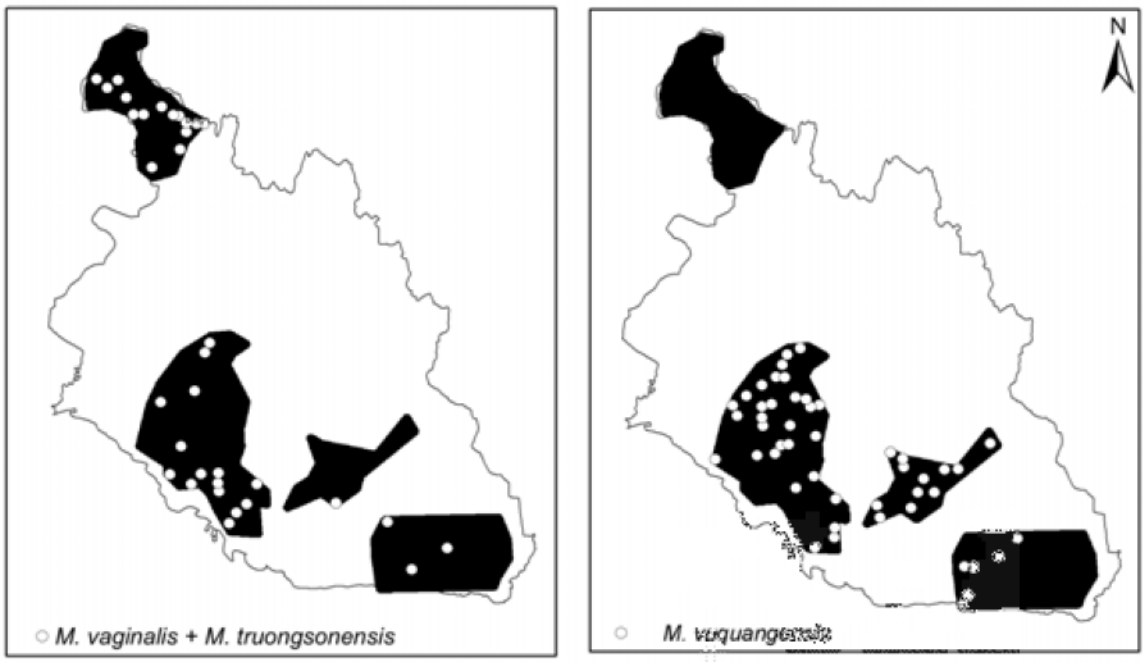


Figure 8.3: locality points within sampling areas (black) of *M. vaginalis + M. truongsonensis* and *M. vuquangensis* used in the models within Nakai-Nam Theun NPA.

Model over-complexity (i.e. number of variables > number of locality points) can decrease model predictions due notably to highly correlated variables (Warren and Steifert, 2011). To select variables, I built a correlation trees (Pearson' r) of between all initial 25 variables available (Appendix 8.1). For each group of variables highly correlated (r>0.95), I kept one (the most general; e.g. averaged over a larger period of time) and discarded the other(s). A final 13 variables (Table 8.2) are used for the models (however, due to too large eigenvalues when running the factor analysis for *M. vaginalis + M. truongsonensis,* I discarded one more variable from its ENFA model).

Table 8.2: Eco-geographical variables used in the models for *M. vuquangensis* and *M. vaginalis + M. truongsonensis* (13 variables).

	Eco-geographical variables	Source
	Climate	
1	bio2	WorldClim
2	bio3	(http://www.worldclim.org/)
3	bio4	
4	bio7	
5	bio12	
6	bio18	
7	bio19**	
	Topography/vegetation	
8	Elevation	(http://edc.usgs.gov/products/elevation/gtpo30/hydro/index.html)
9	Slope	derived from elevation layer in ArcGIS 9.3
10	distance to water	derived from river features in ArcGIS 9.3 (Euclidean distance)
11	percentage forest cover	MODIS vegetation field (http://modis.gsfc.nasa.gov/data)
	human impact	
12	categorical land use (in MAXENT) OR distance to forest (in ENFA)	Lao Department of Geography, 2002 derived from reclassified land use in IDRISI Selva v.17
13	distance to villages	derived from village features in ArcGIS 9.3 (Eucledean distance)

bio2=mean diurnal range (mean of monthly [max temp - min temp]); **bio3**=Isothermality [bio2/bio7]*100 ; **bio4**=temperature seasonality (standard deviation*100) ; **bio7**= temperature annual range (bio5-bio6); **bio12**=annual precipitation; **bio18**=precipitation of warmest quarter ; **bio19**=precipitation of coldest quarter
**bio19 was discarded for the ENFA of *M. vaginalis + M. truongsonensis* due to high correlation with bio12 which created too large factors' eigenvalues

MAXENT Models

The maximum entropy general purpose machine learning method has been adapted and developed as a software (MAXENT v.3.3.3k) for species distribution modelling (Phillips et al., 2004; 2006) and identified as one of the best methods for species niche modelling (Elith et al., 2006). The method combines biological data of species occurrence (presence-only data) with environmental characteristics (e.g. GIS layers with a grid of values for the geographic area considered) to estimate the probability distribution of maximum entropy (i.e. closest to uniform), subject to the set of constraints provided (i.e. environmental characteristics where the species occurs) (Phillips et al. 2006). The same projected coordinate system

(UTM WGS84 Zone 48N), cell size (90 m), and extent (NNT NPA) were selected for each variable layer.

I set a 10-fold cross-validation replication run type where a sample of the occurrence localities is randomly allocated for test data (to compute the model evaluation's AUC value, see below) at each of the ten replications. I chose to present the outputs with the cumulative format (i.e. continuous 0 to 100) for compatibility with the ENFA model outputs. I set all other settings as default (Phillips and Dudik, 2008).

I use the jackknife test option incorporated in MAXENT to assess variable importance for the prediction. The test consists in running models with each variable in isolation, and with each variable excluded at each run. This provides information on the variables that encompasses the most information to create the prediction (both the variables that increase the training gain the most when used in isolation and that decrease the training gain the most when it is omitted from the model).

ENFA Models

The Ecological Niche Factor Analysis (ENFA) computes suitability functions by comparing the eco-geographical variables of the localities where the species is known to occur to that of the whole study area (NNT NPA) (Hirzel et al., 2002). The method is based on the ecological niche theory defined as 'the hyper-volume in the multidimensional space of ecological variables within which a species can maintain a viable population' (Hutchinson, 1957). It identifies the principal factors that explain the *marginality* (i.e. how the species niche differs from the average habitat of the study area) and the *specialization* (i.e. how restricted is the niche of the species) within the area considered (Hirzel et al., 2002). This is achieved by transforming the *n* eco-geographical variables into *n* uncorrelated factors, which are then combined and extracted as different factors. The first factors account for the marginality of the species while the n remaining factors maximize the specialisation of the species. The first few factors that explain the highest

percentage information are retained to build the habitat suitability map over the study area.

The model was performed with the software BioMapper v.4 (Hirzel et al., 2004). All variables were converted from ESRI raster format (Grid format from ArcGIS) to IDRISI raster format (*.rst) using IDRISI Selva v.17 (Eastman, 2012) and all set to the same extent (NNT NPA), cell size (90 m), format (Integer) and background value (-9999 = *no data*). All variables used for the respective species-model were first transformed for normality with the Box-Cox (Box and Cox, 1964) function of the software. The number of factors retained for the habitat suitability map is chosen according to the MacArthur's Brocken stick rule (MacArthur, 1957).

I used the *harmonic-mean algorithm* to build the map as this puts more weight to any single locality than to the overall density of presences over the eco-geographical space (Hirzel, 2004). Mean algorithms have also showed better predictive performance than median algorithm (Hirzel and Arlettaz, 2003). The outputs of the ENFA models are interpreted in terms of the marginality and specialization scores and compared for the modelled taxa.

Ensemble Models

An ensemble model is built upon the resulting two methods by averaging the MAXENT and ENFA final outputs. The ensemble models are reclassified as binary maps (i.e. suitable vs. non-suitable) using the minimum presence threshold provided by MAXENT. I quantify an average of some general variables within the resulting predicted distributions.

Model evaluation

I evaluate the predictive performance of the models with the Boyce Index (Boyce et al., 2002). In addition, I present the area under the curve (AUC) of the receiver-operating characteristic (ROC), computed within MAXENT.

To compute a Boyce index from the MAXENT outputs, the continuous habitat suitability scores obtained (0 to 100) are reclassified into 100 bins (classes) of equal interval. For each class, two frequencies of pixels are calculated: the Predicted Frequency and the Expected Frequency. The Predicted Frequency is the number of occurrence points predicted by the model falling into in the class *i* divided by the total number of occurrence points. The Expected Frequency is the number of grid cells included in class *i*, divided by the total number of grid cells in the whole geographic area considered. A Predicted-to-Expected ratio is calculated for each class and a Spearman rank correlation coefficient *rho* (1-tailed test) evaluates if the ratio significantly increases as suitability increases ($p<0.05$) (Hirzel et al., 2006). Statistical tests are performed with SPSS.v.17. For the ENFA models, the continuous Boyce Index is computed within BioMapper software.

Results

Model performance

Validation tests indicate MAXENT models as predicting significantly better than random as opposed to the ENFA models (Table 8.3). Nonetheless, the habitat suitability maps from both methods (Figure 8.4) show a general similar distribution pattern for both species, mostly differing in the suitability score of each grid cell.

Table 8.3: Validation tests for the two modelling methods. The continuous Boyce Index and test AUC are computed in Biomapper and MAXENT, respectively; Boyce Index 100 is calculated as described in the method section.

Modelling Method	**ENFA**		**MAXENT**	
test / **species**	Boyce Index 100 pValue	continuous Boyce Index	Boyce Index 100 pValue	test AUC
M. vuquangensis	p=0.06	0.088	p<0.01**	0.826
M. vaginalis + M. truongsonensis	p=0.42	0.137	p<0.01**	0.783

** models has a significant predictive power (Spearman rho test)

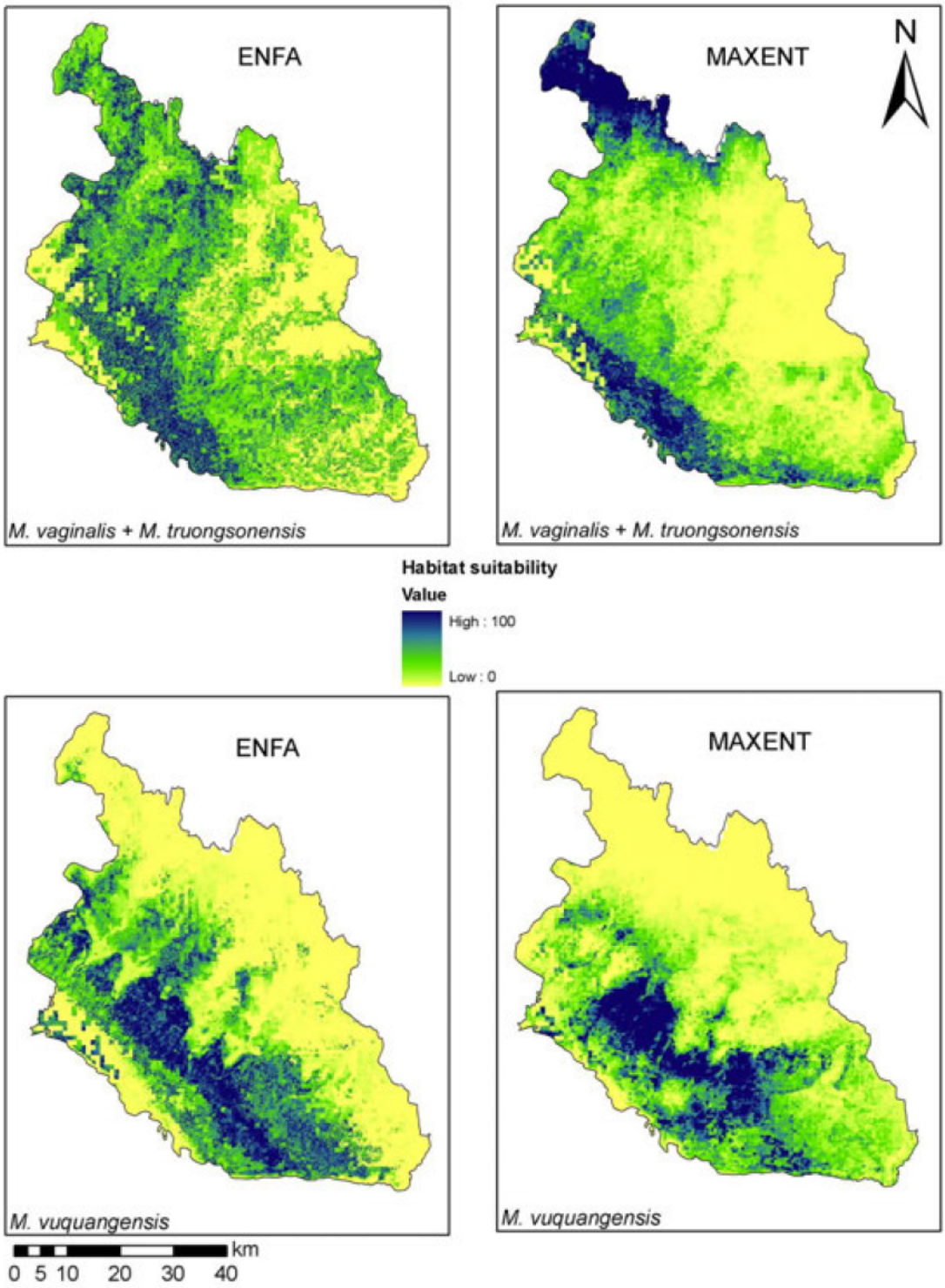
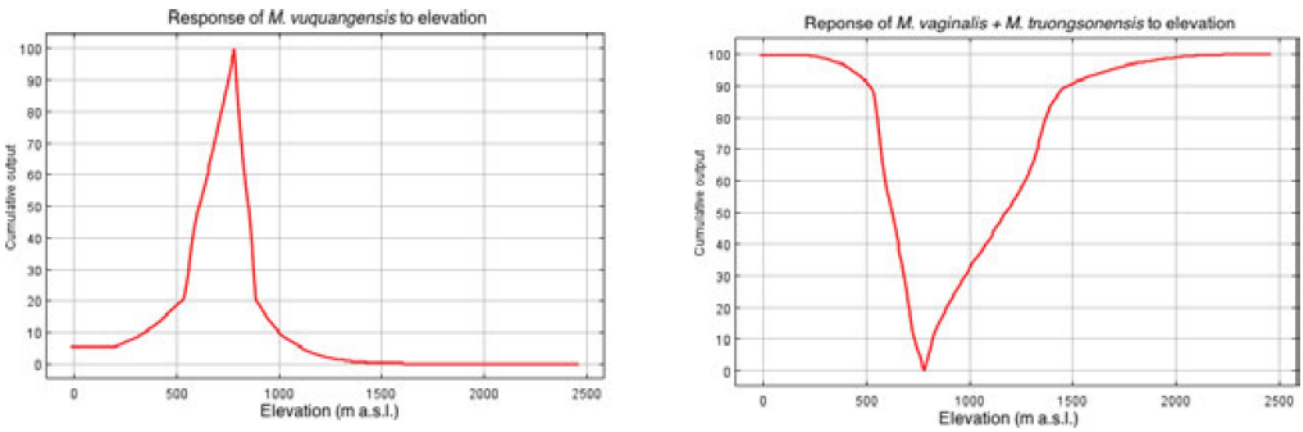


Figure 8.4: ENFA and MAXENT models of *M. vaginalis + M. truongsonensis* (top) and *M. vuquangensis* (bottom).

MAXENT models

The jackknife test shows that mean annual precipitation gives the highest gain to the model when used in isolation and distance to villages decreases the gain the most when omitted from the model for *M. vaginalis + M. truongsonensis,* while it is precipitation of warmest quarter and mean annual precipitation, respectively, for *M. vuquangensis*.

The response curve of species to elevation (when all other variables are excluded), reveals that suitable habitat for *M. vuquangensis* mostly ranges from 500 to 1000 m a.s.l. with a peak at ~800 m, whereas suitable habitat for *M. vaginalis + M. truongsonensis* ranges up to ~500 m a.s.l. and from 1500 to 2500 m a.s.l.



a b

Figure 8.5: Mean of the ten replications of response curves produced by MAXENT of the response of elevation on predicted suitability score, when all other variables are disregarded for (a) *M. vuquangensis* and (b) *M. vaginalis + M. truongsonensis.*

ENFA models

Two factors were retained for *M. vaginalis + M. truongsonensis* and three for *M. vuquangensis*, explaining a total of 85% and 71% of the variance, respectively (Table 8.5). Both *M. vaginalis + M. truongsonensis* and *M. vuquangensis* tend to occupy a niche that differs from the average conditions of the study area (c.f. Appendix 8.2), indicated by a high marginality value (Table 8.4). *M. vuquangensis* seems slightly more tolerant of the area's conditions than *M. vaginalis + M.*

truongsonensis. The habitat suitability map from ENFA indeed shows more grid cells with higher suitability for *M. vuquangensis* than for *M. vaginalis + M. truongsonensis* (Figure 8.3). Both are predicted to occupy a niche associated with higher precipitation and temperature than the area's average. While *M. vaginalis + M. truongsonensis* seems relatively specialized to higher elevations, *M. vuquangensis* is predicted associated with lower elevations within the area, confirming the response curve to elevation obtained from MAXENT modelling (Figure 8.5).

Table 8.4: Global Marginality, Specialization and Tolerance within Nakai-Nam Theun NPA, obtained from the Ecological Niche Factor Analysis for *M. vaginalis + M. truongsonensis* and *M. vuquangensis.*

species	Marginality	Specialization (S)	Tolerance (1/S)
M. vaginalis + M. truongsonensis	0.528	3.159	0.317
M. vuquangensis	0.596	1.974	0.507

Marginality: closer to 1 = species' niche differs from available average conditions of the study area
Tolerance = 1/Specialization: closer to 0 = occupying a narrower range of conditions over the study area

Table 8.5: Contribution of each of the variables to the retained niche factors for *M. vaginalis + M. truongsonensis* (**a**) and *M. vuquangensis* (**b**).

Note: The Factor 1 (Marginality) explains 100% of the marginality and the most part of the Specialization (% indicated in bracket) while the other factors (Specialization) explains the remaining parts of the specialization retained.
+: the species uses a niche with higher average than the average condition of the study area.
-: the species uses a niche with lower average than the average condition of the study area.
*: Narrowness of species' niche on the specialization factor
0: weak specialization
Number of symbols indicates the relative intensity of marginality or specialisation of the species within the study area.

a – *M. vaginalis + M. truongsonensis*

ecogeographical variables	**Marginality (53%)**	**Specialization (32%)**
mean temperature diurnal range (bio02)	+++++	**
Isothermality (bio03)	+++++	**
temperature seasonality (bio04)	----	***
precipitation of warmest quarter (bio18)	+++	********
temperature annual range (bio07)	+++	*
slope	--	0
vegetation cover	-	0
mean annual precipitation (bio12)	-	****
distance to villages	+	*
distance to forests	-	0
distance to water source	+	0
elevation	+	***

b – *M. vuquangensis*

ecogeographical variables	**Marginality (35%)**	**Specialization 1 (24 %)**	**Specialization 2 (12 %)**
precipitation of warmest quarter (bio18)	+++++	0	*
mean annual precipitation (bio 12)	+++++	****	*
mean temperature diurnal range (bio02)	+++	****	*******
temperature annual range (bio07)	+++	*	****
distance to forests	---	*	***
elevation	--	***	***
temperature seasonality (bio04)	--	**	0
distance to villages	--	*	0
Isothermality (bio03)	++	0	*
slope	--	0	0
precipitation of coldest quarter (bio19)	-	*******	***
vegetation cover	+	0	**
distance to water source	+	0	*

bio02=mean of monthly (max temp-min temp)

bio03=bio02/bio07*100

bio07=max temperature of warmest month-min temperature of coldest month

Ensemble Models

When ecogeographical variables are averaged within the predicted distribution of modelled taxa and compared to the average conditions of the study area, elevation differs the most with lower elevation for *M. vuquangensis* compared to available conditions (Table 8.6). The final habitat suitability maps (Figure 8.7) show a wider distribution of *M. vaginalis + M. truongsonensis* while *M. vuquangensis* is more restricted.

Table 8.6: Mean (with standard deviation, SD, and range) of general eco-geographical variables within the ensemble model (i.e. MAXENT and ENFA averaged) predicted distribution (under the minimum training presence threshold) of the two modelled taxa and over the study area.

	M. vuquangensis			*M. vaginalis + M. truongsonensis*			Nakai-Nam Theun NPA	
	Mean	SD	range	Mean	SD	range	Mean	range
annual temp.	22	1	15.5 - 24.8	21	2	14.4 - 24.8	21	14.4 - 24.8
annual precip.	2291	100	1970 - 2616	2237	133	1865 - 2617	2236	1865 - 2617
elevation	784	218	191 - 1942	891	306	248 - 2261	873	189 - 2272
slope	11	8	0 - 69	12	8	0 - 69	12	0 - 69
Dist. water (m)	392	397	0 - 2850	398	380	0 - 2896	393	0 - 2896
% vegetation	74	7	15 - 81	73	9	6 - 81	73	6 - 81
top 3 habitat types*	DEV; MBC; MDE	-	-	DEV; MBC; MDE	-	-	DEV; MBC; MDE	-
Dist. villages (km)	6	3	0 - 24	9	6	0 - 28	8	0 - 28

* DEV = Dry Evergreen forest; MBC = Mixed Broad-leaved/Coniferous; MDE = Mixed Deciduous/Evergreen

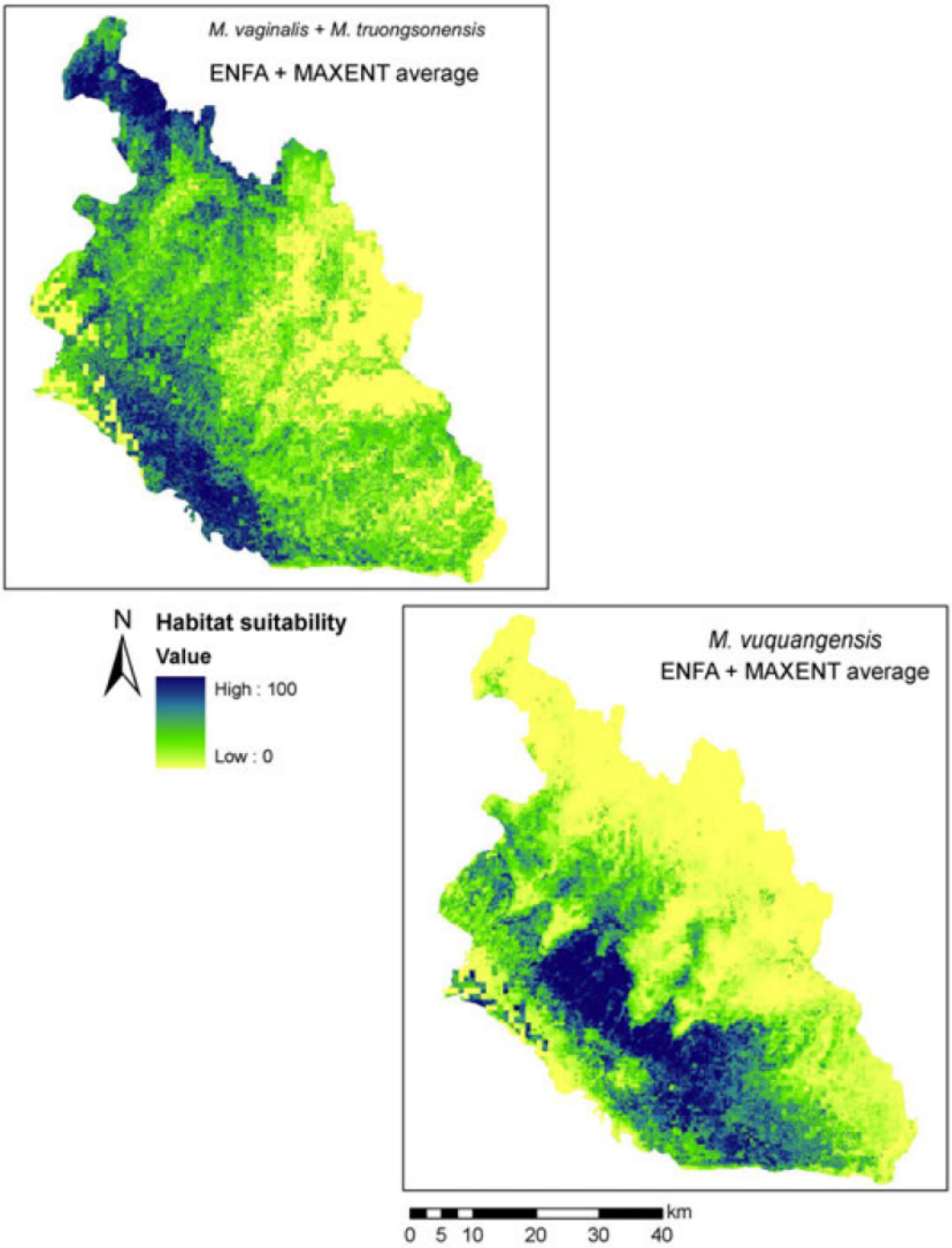


Figure 8.6: Average of ENFA and MAXENT models for *M. vaginalis + M. truongsonensis* (top) and *M. vuquangensis* (bottom).

Discussion

Models' performance

Performance tests revealed the ENFA as less powerful than MAXENT and may be due to the greater sensitivity of ENFA to small sample size compared to MAXENT, the latter being known for outperform other methods on low sample size training (Hernandez et al., 2006). Performance of the model for *M. vaginalis + M. truongsonensis* may also be altered when combining more than one species which may actually differ in their respective niches. The fact that occurrence points used in both methods are restricted to areas where sampling occurred (sampling bias), also likely influenced the outputs (Phillips et al., 2009). The choice of not including a sampling bias in the model setting within MAXENT allowed comparison with ENFA outputs which does not have the possibility to deal with sampling bias. Overall, the two methods gave comparative visual maps with similar areas that are predicted as unsuitable for the same species (-group). Given uncertainty of such models, it is useful to combine several methods for comparison and create averaged ensemble models used for final interpretation.

Muntjacs' niches in Nakai-Nam Theun NPA

Both methods indicated, to some extent, a niche differentiation of *M. vuquangensis* and *M. vaginalis + M. truongsonensis* within NNT NPA. The ENFA shows that *M. vuquangensis* occupies a slightly wider range of conditions (as opposed to geographical range) within NNT NPA than does *M. vaginalis + M. truongsonensis,* which indicates that the conditions found within the area are more optimal to the former species. Indeed, *M. vuquangensis* seems more tolerant of the overall conditions of NNT NPA. The ensemble model's output shows a wider distribution of *M. vaginalis + M. truongsonensis* over the area, but the suitability score remains relatively low throughout. This suggests the adaptability of *M. vaginalis + M. truongsonensis* to a habitat that does not encompass its optimal conditions. The wider geographical distribution of *M. vaginalis + M. truongsonensis* in NNT NPA is also likely due to the modelling two

species as one group, thus including a wider niche. The results make evident the importance of NNT NPA's habitat for *M. vuquangensis*.

Climate – Climate factors play an important role in the predictive niche of both modelled species (-group), although the arbitrary selection of particular variables over others due to auto-correlation does not allow the identification of the exact variables that influence their distribution. Nonetheless, the models indicated a marginality and specialisation of *M. vuquangensis* in habitats with higher annual precipitation, while *M. vaginalis + M. truongsonensis* is predicted in habitats where annual precipitation is lower than the area's average conditions. The latter was also predicted in habitats where mean annual temperature is slightly higher than for *M. vuquangensis*. The model however does not allow to test if these variables are actually environmental determinants for the species.

Topography – Similarly, both species differ in their predicted association with a range of elevation and slope. The niche of *M. vuquangensis* being predicted at lower average elevations than for *M. vaginalis + M. truongsonensis*. Indeed, the ENFA shows the marginality of *M. vuquangensis* at lower elevation than the averaged elevations in NNT NPA and its speciality to these lower elevations. In contrast, *M. vaginalis + M. truongsonensis* is predicted at and specialized to higher elevations than the averaged area's conditions. MAXENT's response curve similarly shows a clear differentiation in the suitability of habitats when the elevation variable is isolated. The optimal suitability score for *M. vuquangensis* is at an elevation of 800 m a.s.l. (suitability score of 50 from ~700 to 900 m), while for *M. vaginalis + M. truongsonensis* is at the two extremes of the elevation range of NNT NPA: up to 200 m a.s.l. and 2000 to 2500 m a.s.l. (suitability score of 50 up to 600 m and 1200 to 2500). This large variability in elevation suitability for *M. vaginalis + M. truongsonensis* confirms what has been speculated of the ecology of *M. vaginalis* and *M. truongsonensis*: in Indochina, the former is believed to range up to 1500 m a.s.l., while the latter above this (Timmins et al., 2008a; 2008b). The average slope profile where *M. vaginalis + M. truongsonensis* is predicted is lower than for *M. vuquangensis*, and for both lower than the averaged area's condition.

Anthropogenic – The niche of *M. vuquangensis* is predicted at greater distance from agricultural areas (closer to forest areas) compared to *M. vaginalis + M. truongsonensis.* This is also suggested by the fact that the latter is predicted to be associated with habitats with lower vegetation cover than is *M. vuquangensis.* The ensemble model map confirms this pattern where village clusters are predicted as unsuitable for *M. vuquangensis*.

Although there are undoubtedly regions of sympatry between *M. vuquangensis* and *M. vaginalis + M. truongsonensis, M. vuquangensis* seems limited to some areas with optimal ecogeographical variables. Where they occur in sympatry, more local, micro-habitat variables may play a role in their niche use. However, the vegetation layer used in this analysis not being detailed at the micro-habitat level, it was not possible to assess a particular tendency to use a forest type over the other by the species; this may be considered in the future with refined vegetation data. The preferential use of different forest types within the same area has been observed in sympatric deer species elsewhere in the world (e.g. Hemami et al., 2004). The activity peak of related and competitive deer species that co-exist may also differ (e.g. Forde, 1989; Chapman et al., 1993), and/or they may choose different sleeping sites with particular characteristics (Teng et al., 2004; Brodie and Brockelman, 2009), these behaviours ultimately reducing inter-species competition. The overall difference in niche use of *M. vuquangensis* and *M. vaginalis + M. truongsonensis* in NNT NPA likely results in difference in main diet.

Implications for conservation

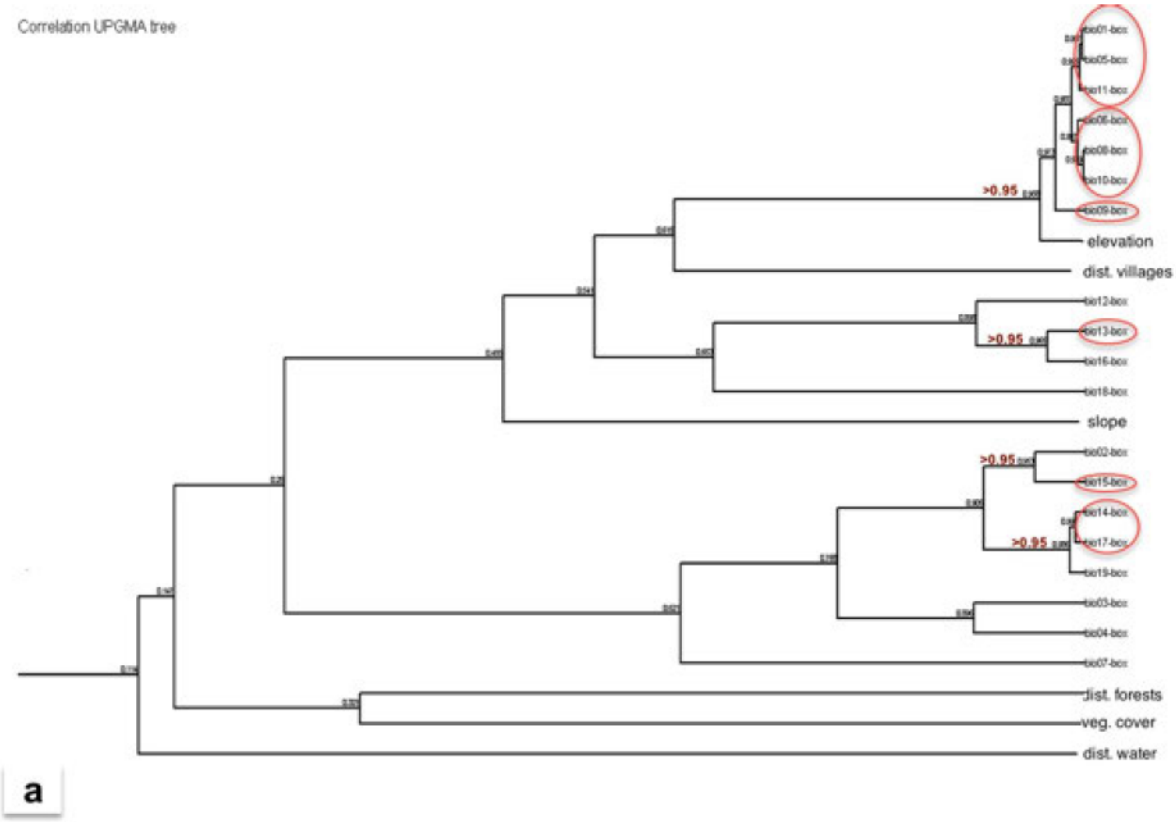
In Laos, the Endangered large-antlered muntjac *M. vuquangensis* is classified under the *Prohibition* category of the Lao hunting regulation, which groups species "rare, near extinct, high value and are of special importance in the development of social-economic, environmental, educational, scientific research" (National Assembly Laos, 2007: Article 11: 4). Species in this category should be "managed, inspected, preserved" (National Assembly Laos, 2007: Article 11: 4); their hunting is not permitted at anytime or anywhere. The Annamite muntjac *M.*

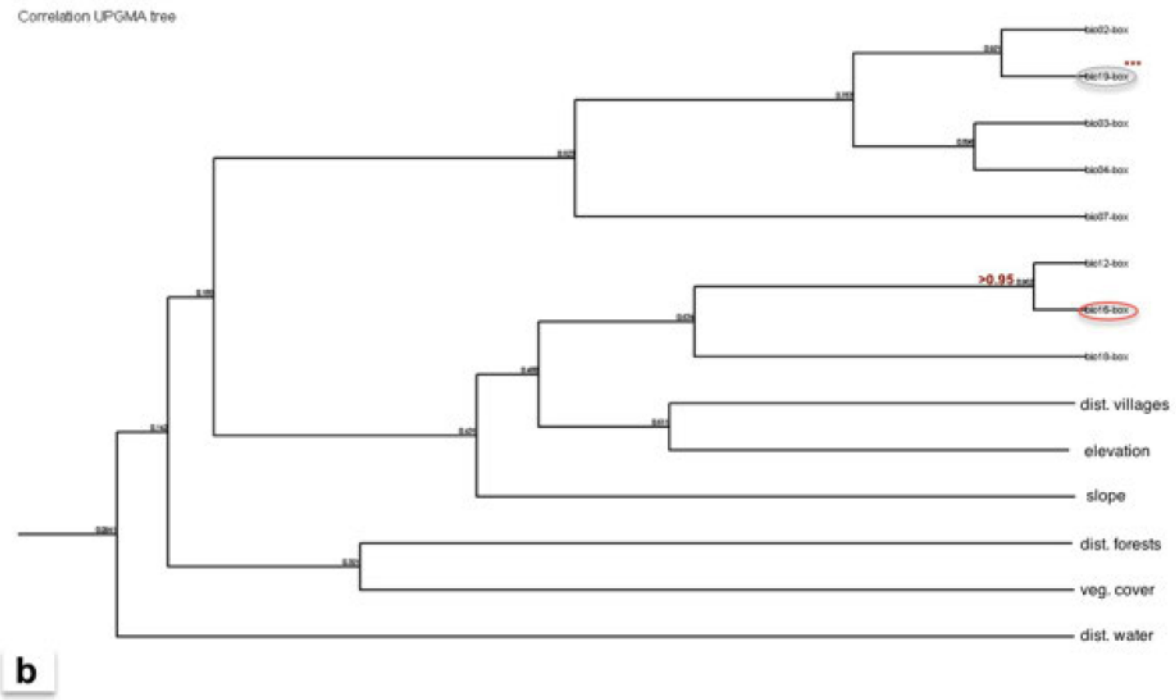
truongsonensis is not listed in the regulation and the red muntjac *M. vaginalis* is under the *Management* category, which includes "wildlife and aquatic that are able to reproduce widely in nature, and are very important for social - economic development, and educational scientific research" (National Assembly Laos, 2007: Article 11: 5); species in this category may be hunted in zones delimited and during certain seasons only (National Assembly Laos, 2007). This classification, however, does not ensure the protection and sustainable use of either species for several reasons. (1) In NNT NPA, the main and widely used hunting technique is ground snares. These are non-selective and can catch any ground-dwelling animal from the small bird or civet to any of the deer species, and totally indiscriminative of age and sex. If *M. vuquangensis* is limited by elevation and mainly occurs around village clusters, as indicated by the models, this means that hunting by Lao villagers may catch a greater number of this species. In the late 1990s in NNT NPA, the number of antlers *M. vuquangensis* kept as trophies in village houses was twice as numerous as the ones from the red muntjac (Timmins et al., 1998). (2) Hunting pressure is dramatically increased from the Vietnamese poachers illegally crossing the border to set a large amount of snares in the area (c.f. CHAPTER 9). This is encouraged by the – mainly Vietnamese and Chinese – trade demand for wildlife used in traditional medicine (Nooren and Claridge, 2001). Although muntjac species are unlikely targeted for the trade, this has no influence on the numbers being caught by snares. (3) Hunting regulation is often not well-communicated to Lao villagers and/or enforced resulting in over-harvesting outside the permitted zones; this is also intensified by the growing human population in NNT NPA's villages and by the trade demand that leads to increasingly hunting for the trade rather than for local consumption.

This has considerable implications for the conservation of the Endangered large-antlered muntjac, which remains poorly known even after its discovery over a decade ago. The models reveal that NNT NPA encompasses optimal habitats for the species and confirms what had been speculated following its discovery that "The Nakai-Nam Theun National Biodiversity Conservation Area (NBCA) may be both a centre of the giant muntjac's Lao distribution and its population's core area" (Timmins et al., 1998: 61). Management of the species in NNT NPA should

therefore be considered as a priority given its restricted global distribution and the potential that NNT NPA still holds for its conservation. The apparent restriction in elevation range of *M. vuquangensis* in NNT NPA means that special protection zones targeted for the protection of the Critically Endangered saola (*Pseudoryx nghetinensis*), may not serve as an 'umbrella' for *M. vuquangensis*. Focussing on the conservation of both species however may benefit all key species occurring in NNT NPA.

Appendix 8.1: correlation trees for stepwise variables selection.(a) first tree from which 11 variables were discarded for their high correlation (r>0.95) with other variables; (b) second tree from which one more variable was discarded (r>0.95). ***Bio19 was later discarded for ENFA model of *M. vaginalis + M. truongsonensis* because of too high correlation with bio02, creating too large eigenvalues.





Appendix 8.2: Average (and range) conditions of the selected variables included in the model over Nakai-Nam Theun National Protected Area.

	average	range
mean temperature diurnal range (bio02)	93	(82 - 98)
Isothermality (bio03)	50	(52 - 46)
temperature seasonality (bio04)	2815	(2482 - 3245)
temperature annual range (bio07)	185	(193 - 176)
mean annual precipitation (bio12)	2236	(1865 - 2617)
precipitation of warmest quarter (bio18)	1011	(640 - 1260)
precipitation of coldest quarter (bio19)	63	(36 - 162)
elevation (m a.s.l.)	873	(189 - 2272)
slope (°)	12	(0 - 69)
distance to water (m)	393	(0 - 2896)
percentage forest cover (%)	73	(0 - 81)
distance to forest (m)	59	(0 - 2849)
distance to villages (km)	8	(0 - 28)

CHAPTER 9

THE EXTENT OF WILDLIFE HUNTING IN NAKAI - NAM THEUN NATIONAL PROTECTED AREA, LAOS: IMPLICATIONS FOR MANAGEMENT

Introduction

There is now a consensus that wildlife hunting has a dramatic impact on animal communities in tropical forests throughout the world (Robinson et al., 1999; Robinson and Bennett, 1999). Some species have already been extirpated from certain forests due to overharvesting (e.g. Campbell et al., 2001; Redford, 1992; Corlett, 2007; Wilcox et al., 2007; Brooks et al., 2012) or have been severely reduced in numbers and could face local or global extinction in the near future if hunting is not controlled (e.g. Wilkie and Carpenter, 2000; Fa et al., 2001; Noss, 1998; Corlett, 2007; Johnson et al., 2003). This phenomenon will not only have negative impacts on the integrity of the ecosystem with for instance the loss of important seed dispersal species (Redford, 1992; Fa et al., 2005), but also affects the livelihoods of local people relying on forest resources. Bushmeat is an important source of protein for local people living alongside forests in almost all parts of the world. It has also become an increasing source of income for farmers by selling their catch (Milner-Gulland et al., 2003). Worldwide, wildlife is sold either as food, for traditional medicine, pet trade or trophies/decoration (eg. Redford, 1992; World Bank, 2005). The trade in wildlife has particularly increased overharvesting of wildlife; as the most targeted species for trade decline, their market price increases exponentially, leading to higher pressure on them (Newton et al., 2008; Courchamp et al., 2006). To increase their intake, hunters have shifted from 'traditional' hunting techniques (e.g spears, blow darts, traps) to more advanced methods (e.g. guns, wire snares) (Corlett, 2007).

In an attempt to avoid depletion of animal and plant communities in the remaining tropical forests across the globe, protected areas have been designated (Rodrigues et al., 2004) and biodiversity hotspots identified (Myers et al., 2000) to represent as best as possible the world's biodiversity and where available resources can be allocated to the development, implementation and monitoring of management plans (Margules and Pressey, 2000). Local communities living in and around protected areas rely on natural resources for their livelihoods (e.g. Negi and Palyal, 2007). Wild meat is often the major protein source for them (Bennett and Rao, 2002; Milner-Gulland et al., 2003) but is most of the time

harvested unsustainably even within designated zones where hunting of only certain species is allowed (Robinson and Bennett, 2000). In addition, illegal activities (e.g. logging, poaching) from local people and/or outsiders remain very common inside protected areas. One major challenge of wildlife conservation is therefore to manage protected areas in a way that will balance conservation of wildlife and meet local people's livelihood requirements (McShane et al., 2011; Sodhi et al., 2011).

In Southeast Asia, although wildlife hunting has existed for some 40,000 years (Robinson et al., 1999), it has only become a more serious issue in the last 30-50 years due to the increased accessibility of forested areas via infrastructure development and population growth (Corlett, 2007; Milner-Gulland et al., 2003). Regional and international trade is considered one of the most challenging issues for wildlife conservation in the region (Nijman, 2010). In Southeast Asia, as in other parts of the world, wire snares and guns are now the major hunting techniques used (e.g. Noss, 1998a; Noss 1998b; Fa et al., 2001; Nielsien, 2006; Cadman, 2007; Muchaal and Ngandjui, 1999), with perhaps snares being most commonly and heavily used because of their low cost and effort for relative high catch (Noss, 1998a; Fa et al., 2001). Snare hunting is a non-selective technique – catching any species between 2 and 5 kg or more in size but indiscriminative of age and sex – and wasteful, with high proportion of caught animals lost to scavengers, predators or decomposition (Noss, 1998a). Snares are typically made out of wire tied to a pole and are set along man-made or natural animal trails (Noss, 1998; Newton et al., 2008; Coudrat, pers. obs.); wires can differ in size to target different species size (Wato et al., 2006) and different types of snare traps exist (c.f. Noss 1998a; Newton et al., 2008).

I present records of illegal hunting encountered during ~ 9 months (2011-2012) of wildlife surveys (not focusing on the finding of threats) in one of the most biodiversity-rich area of the Lao People's Democratic Republic (Laos, hereafter): Nakai-Nam Theun National Protected Area.

Methods

Research site description

Nakai-Nam Theun National Protected Area (NNT NPA) (~3550 km^2) is located within the Annamites mountain range, central-eastern Laos and shares ~ 155 km border with Vietnam (Figure 9.1). The area was designated as protected area in 1993 by Prime Minister decree 164/PM. It is considered one of the country's most important area for key birds and mammals including endemic species (Robichaud et al., 2001; Ling, 1999). Altitude ranges from ~500 m to ~2500 m a.s.l. (Timmins and Evans, 1996). Mountainous areas are primarily covered with dry evergreen forest, with some restricted wet evergreen forest sites close to the Vietnamese border; mixed coniferous-broad leaf forest is found at lower altitudes and cultivation, shrub, secondary and bamboo forests are mainly found around the 31 villages occurring within the NPA (Timmins and Evans, 1996). In 2005, the Nam Theun 2 (NT2) dam – one of the largest in Southeast Asia – was built which greatly increased access to the protected area through road construction and a large reservoir.

Protected area management system

The area is under the management of an independent governmental organization, the Watershed Management Protection Authority (WMPA) (PM, 2010), which is responsible for protection and monitoring of the area's wildlife and the improvement of villagers' livelihoods (NT2 WMPA, 2005). Patrolling activities and infrastructures include four permanent ranger stations (Navang, Thaipaiban and Teung clusters and Boualapa district), patrolled 30 days per months by a team, three patrolling teams operating in three sectors of the NPA (Khamkeut district, Teung cluster and Navang cluster) for 18 days/months, two road checkpoints (Thaland and Parkatan) and reservoir checkpoints (Nakai District and Khamkeut District, 2010; NT2 WMPA, 2011). WMPA staff has the authority to collect and destroy guns and other illegal hunting gears and bring offenders to the district

police. Regulations related to forest resource use include designation of Controlled Use Zones where cultivation and collection of certain wood, non-timber forest products (NTFPs) and some animal species are allowed and controlled (NA, 2007a).

Surveys

From January 2011 to April 2012, I conducted transect surveys in 10 sites within NNT NPA (Figure 9.1). Data collected were part of a larger wildlife survey project in the NPA. At each site, four to 20 transects were walked. Each transect was pre-selected on a 1:50,000 map of the area with a baseline starting point along a main watercourse. Transects were placed approximately perpendicular to the river and ~1 to 2 km of length. At each encounter of hunting signs (snare lines, individual snare traps, camps, gunshots), I recorded the geographic coordinates with a hand-held GPS (India Thailand datum). Snare wires that were old (years old) and therefore inactive are not included in the count in this analysis (only the ones recently set and/or still active or about to be set are). Snare wires (at hunter camps or already set) were collected or otherwise destroyed and counted (the retrieval of snares was not always possible because of logistic and time constraint). All animal species (remains or live) encountered at hunter camps and/or in snares were recorded and all live animals released.

Analysis

Mean distance of each research site from closest village and Vietnamese border were in ArcGIS 9.3 using the Eucledean distance tool. For each site, the threat encounter rate was calculated with the formula: T = N/A where T= threats per km^2, N= total number of threats encountered (only including gunshots, camps and snare records), A= approximate area covered. The area covered was obtained by drawing a minimum convex polygon + 100 m buffer around transects.

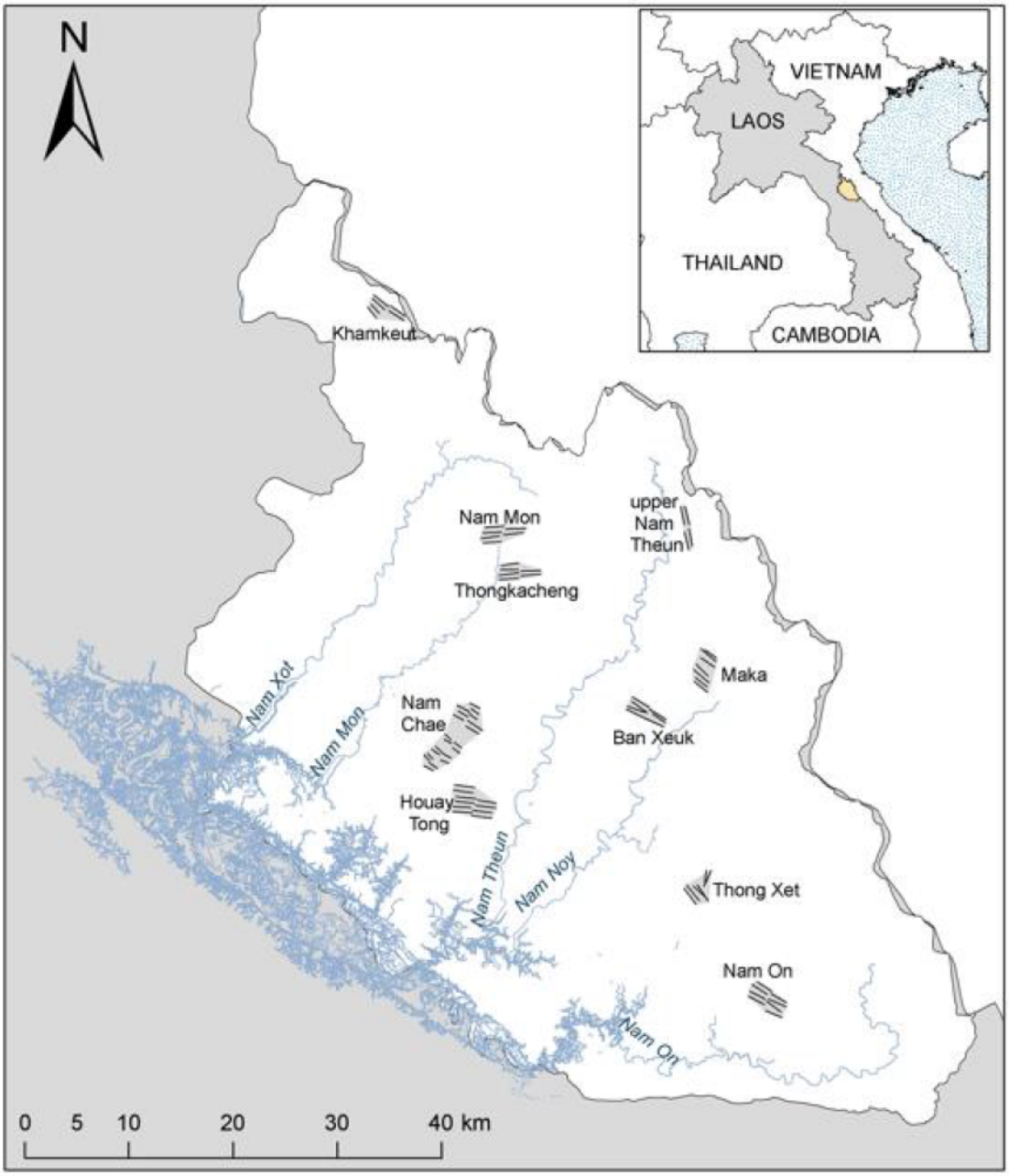


Figure 9.1: Map of Nakai-Nam Theun National Protected Area and location of the 10 study site visited (with representation of the transects walked).

Results

A total of 3239 snares were collected and/or destroyed, 41 poacher camps encountered (including old and recent camps) and 14 gunshots heard within the ~87 km^2 covered (Table 9.1). All snares found in NNT NPA were made out of bicycle brake-cable. Thicker wire snares (e.g. made out of truck-winch cable) targeting larger mammals such as big cats, bears and wild cattle were never found over the study period.

Table 9.1: Survey dates and effort at each site visited

Site name	Survey dates	nb Transects	km walked	Approximate area covered (km^2)
Nam Chae	19 Jan – 2 Feb 11	20	21.47	14.75
Ban Xeuk	17 Feb – 6 Mar 11	19	36.16	5.23
Maka	13 Mar – 31 Mar 11	23	40.29	7.10
Thong Xet	18 Jul – 3 Aug 11	6	9.80	5.93
Khamkeut	16 Sept – 28 Sept 11	6	10.55	5.67
Nam On	19 Oct – 4 Nov 11	24	42.45	7.66
Upper Nam Theun	11 Jan – 23 Jan 12	12	22.08	2.90
Houay Tong	10 Feb – 27 Feb 12	30	58.02	10.98
Thongkacheng	12 Mar – 24 Mar 12	18	34.38	5.55
Nam Mon	25 Mar – 5 Apr 12	18	35.01	6.05
total	5 months	176	310	72

Threats encountered varied between the different sites. Threats were the highest in Thong Xet and lowest in Thongkacheng (Table 9.2).

Table 9.2: Illegal hunting signs encountered at each site visited

Site name	Number of snares collected and/or destroyed	Number of camps encountered	gunshots heard	Approximate Threat encountered per km^2	Mean distance from Vietnam border (km)	Mean Distance villages (km)
Nam Chae	6	0	1	0.47	28.45	6.06
Ban Xeuk	156	0	0	29.83	14.86	2.81
Maka	308	4	0	43.94	7.98	4.44
Tong Xet	2550	12	2	432.38	15.19	7.72
Khamkeut	0	3	0	0.53	1.32	3.14
Nam On	37	5	3	5.87	15.34	18.49
Upper Nam Theun	113	6	0	47.93	2.48	17.42
Houay Tong	41*	10	8	5.37	31.84	5.01
Tongkacheng	0	0	0	0	11.87	11.74
Upper Nam Mon	0	1	0	0.17	8.83	15.64
total	3211	41	14			

* During a second short visit (4 days, 6-9 Jan 2012) around the same general area, 28 snares were collected from active traps, number not included in the calculation of Threat encounter rate.
Note: These figures are likely to be underestimations, as the study did not focus on the collection of snares

Live or remains of small to medium-sized mammals, birds and reptiles were found in snares and/or at poacher camps (Table 9.3).

Table 9.3: list of animals alive or remains found in snares and/or poacher camps (c.f. PLATE 1)

Animals	Details
Macaque (*Macaca spp)*	One skull and hair in hunting camp; hair remains on a snare; one jaw at hunter camp
Stump-tailed macaque (*M. arctoides*)	Live individual in a snare
Red-shanked douc (*P. nemaeus*)	Skin at a rocky land, close to Lao poachers, armed with gun
Brush-tailed porcupines (*Atherurus macrourus)*	Two live individuals in a hunting; a drying stomach in poacher camp (used for traditional medicine); remains in poacher camp
Asian porcupine (*Hystrix Brachyura*)	Spines at hunter camp
Keeled box turtle (*Cuora muhotii*)	Two live individuals in a hunting camp
Box turtle (unidentified sp)	One dried shell at hunter camp
Snake (unidentified sp)	Bones at hunter camp
Monitor lizard (unidentified sp)	Skin at hunter camp
Grey peacock pheasant (*Polyplectron bicalcaratum*)	Feather remains in a Vietnamese camps; remains in snares
Silver pheasant	Feathers and 2 hunter camps
Wild pig (*Sus scrofa*)	Remains in snares and hunter camps
Hog badger (*Arctonyx collaris*)	Remains in snares (2 skulls)
Ferret badger (*Melogale* spp)	Remains at poacher camp
Black-giant squirrel (*Ratufa bicolor*)	Remains (tail) next to a snare
Lesser Oriental chevrotain (*Tragulus javanicus*)	Remains (back leg) in snare
Civet (unidentified sp)	Remains in snares
Mask palm civet (*Paguma larvata*)	Live individual in a poacher camp
Hornbill (unidentified sp)	Feather remains in a poacher camp

Notes: includes all species that could be identified. Other animals were not identified from the remains in snares. All live animals found were released.

Discussion

A high level of illegal activity occurs in NNT NPA. Notably, the impressive density of snares found across the visited sites indicates the dramatic situation in this biodiversity valuable area. Across Laos, this is worsened by several factors including population growth, infrastructure development leading to increase access to forest areas, geographic position of the country with neighboring countries highly involved in international trade, and local communities living within protected areas relying on natural resources. Although the data only presents a small portion of the actual threats in the area and do not give species off-take hunted, it indicates the high level of hunting occurring in NNT NPA. This problem is rampant in the region of Laos and Vietnam; from 2011 to 2012, over 26,000 wire snares were destroyed by patrolling teams in only three sites along the Lao-Vietnamese border (Saola Working Group, 2013). In Equatorial Guinea, a snare density was found to be of 56/km^2 in the Monte Mitra forests, where bushmeat off-take was estimated at over 2000 total captures per annum and harvest was calculated as unsustainable for most species (Fa et al., 2001). In Central African Republic snare density was 4.2/km^2 in the Bayanga region with an estimate of annual harvest of over 9000 animals (Noss, 1998a).

My data did not allow to observe a particular pattern of threat density related to distance to villages or Vietnamese border, although this cannot be ruled out since surveys did not specifically focused on finding snares and survey effort varied between sites. Threats within the area seem to be seasonal with a higher pressure during rainy season, when animal movement is increased and patrolling are limited due to difficult field conditions.

In NNT NPA, trade is the major driver for illegal wildlife hunting, though small-bodied animals probably still represent an important part of villagers' diet. Camps encountered were primarily from Vietnamese hunters (identified from Vietnamese products left behind by poachers), illegally crossing the border. Intrusion of outsiders in NNT NPA is a great challenge as control is extremely difficult given the large border that the area has in common with Vietnam.

Villagers in the region have reported over 4000 Vietnamese entering the area each year (World Bank, 2005). Several Vietnamese traders also enter the NPA legally to sell various goods, which however may be traded for wildlife meat. Subsistence hunting for Lao villagers is allowed in certain areas and for certain species (c.f. NA, 2007a; NA, 2007b), but illegal hunting by local villagers was also observed and certainly destined for trade.

In Laos, hunting practices are mostly unsustainable. In some areas, villagers inhabiting remote forested areas have been observed shifting their protein-diet from large-bodied animals (e.g. deer, wild pigs, primates) to small-bodied animals (e.g. birds, frogs, squirrels), suggesting a decline of the preferred hunted species (Krahn and Johnson, 2007; Johnson et al., 2003; Kranh, 2005). This seems a common phenomenon across the globe where hunting is unsustainable (Fa et al., 2005). Reliance on wildlife for subsistence is still unclear in Laos. In the most remote areas, wild meat constitutes a major part of the diet for villagers with few alternatives available, posing food security issues (Krahn and Johnson, 2007). However, in other areas this may as well be related to a tradition and taste preference rather than dependence (Singh, 2010). The growing market in wild meat for wealthy urban population and for the international trade has also become a driver for the unsustainable hunting in rural Laos since the 1990s (Nooren and Claridge, 2001). In other parts of the world, needs for food and income generation also drive wildlife hunting (Noss, 1998a; Noss, 1998b; Fa et al., 2001; Nielsen, 2006; Wilkie and Carpenter, 2000; Willcox et al., 2007).

Snares are the most commonly used hunting techniques in NNT NPA. The use of hunting dogs was observed and a few gunshots were heard. This figure is different from the Nam Ha NPA, in northern Laos where guns and hunting dogs were reported as the most often used techniques (Johnson et al., 2003). A governmental gun collection program in the mid-1990s decreased the number of guns owned in Laos but governmental issued guns to village militia and police are still found in all villages across the country and sometimes used to hunt (Hansel, 2004), which may also be the case in NNT NPA. Hand-made muskets or modified guns are also found in NPAs (Johnson et al., 2003; Hansel, 2004). Some

Vietnamese hunters coming in the area for hunting were also observed with guns, despite the same ban on guns by the Vietnamese government. Across the world, snare hunting is largely used (Noss, 1998a; Fa et al., 2001). Where hunting occurs, animals the most commonly caught include ungulates, primates and rodents (Wilkie and Carpenter, 2000; Fa et al., 2001; Wright and Priston, 2010), with primates being predominantly hunted with guns (Wright and Priston, 2010; Fa et al., 2005). In NNT NPA, most commonly snare-caught animals are likely to be ungulates, rodents, small carnivores and terrestrial birds. Primates are most likely hunted primarily with guns, although occasional individuals can get caught in snares (pers. obs.; Robichaud W.R. pers. comm.); frequency of primate capture is unknown but given their low reproductive rate, any kill can have negative consequence on a group, plus one hunter with a gun can kill an entire group (Muchaal and Ngandjui, 1999). Snares pose a major threat to some untargeted and threatened species such as the Critically Endangered saola (*Pseudoryx nghetinhensis*), which can often be caught as a result of snare density in the area despites it having no value for the international trade. Other animals such as turtles and pangolins, highly prized in the international trade, are mostly sought for with the use of trained hunting dogs (Robichaud et al., 2009; pers. obs.).

Priorities to improve wildlife conservation in the area have to be targeted (c.f. Sheil, 2001; Leader-Williams and Albon, 1988). A maximum of the funding available should be directed to patrolling and law enforcement (as has been recommended; PoE, 2013, and is indeed currently planned; NT2 WMPA, 2012; SWG, 2013). Scientific data should therefore not be a priority to the management authority but rather be conducted by external researchers. The best strategy for management of NNT NPA is to direct available resources to priority areas and extend to further areas once successful. So far, the areas patrolled have not effectively been controlled for illegal activities. The long-term survival of the diverse biodiversity in NNT NPA will only depend on sound management strategy and adaptive management.

CHAPTER 10

CONCLUDING REMARKS - THE FUTURE OF BIOLOGICAL RESEARCH AND CONSERVATION IN THE INDO-BURMA REGION: THE NEED FOR OPTIMISM

Southeast Asia (i.e. Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, the Philippines, Singapore, Timor-Leste, Thailand, and Vietnam) has an impressively high degree of endemism of animal and plant species due to its unique geological history (Sodhi et al., 2004; Woodruff, 2010). The entire region encompasses four of the 25 biodiversity 'hotspots' designated as global conservation priorities (Myers et al., 2000). One of these hotspots is Indo-Burma, which comprises Cambodia, Laos, Myanmar, Thailand, Vietnam and parts of southern China (Tordoff et al., 2012). Seventy-one of the 430 mammals (as of 2004) in the Indo-Burma hotspot are region endemic (Van Dijk et al., 2004). At the Global scale, Indo-Burma is the hotspot regions with the third highest number of vertebrate species and with the sixth highest number of vertebrate endemism (Myers et al., 2000).

Within the Indo-Burma hotspot (or Lower Mekong), 1642 new species (including plants, reptiles, amphibians, fish, birds and mammals) were newly described during the 1997-2011 period, of which 29 of mammals (WWF, 2008, 2009, 2010, 2011, 2012). This increase in species discoveries since the early 1990s corresponds to the ending of a long history of wars throughout the region, followed by biological explorations in areas that had remained until then nearly unexplored (MacKinnon, 2000). While these numbers may not be exclusive to this region of the world, what is most surprising is the number of *large* mammals that were discovered in these past two decades, concentrated in the Indo-Burma region itself. Indeed, no less than five large mammals were discovered since 1992. The first of these was the Saola (*Pseudoryx nghetinhensis*), discovered in and endemic to the Annamite mountains of Vietnam and Laos (Dung et al., 1993; Schaller and Rabinowitz, 1995), an ungulate so distinct that it was classified in its own genus. Three other muntjac species were subsequently discovered, two in the same region of the Annamite mountains: the large-antlered muntjac *Muntiacus vuquangensis* (Tuoc et al., 1994; Duckworth et al., 1994; Evans and Timmins, 1995; Schaller and Vrba, 1996) and the Annamite muntjac *M. truongsonensis*/*M. rooseveltorum s.l.* (Giao et al., 1998; Timmins et al., 1998) and one in Myanmar: the leaf muntjac *M. putaoensis* (Amato et al., 1999). The most recent discovery of a large mammal, which startled the scientific community, is a primate species, the

Burmese snub-nosed monkey *Rhinopithecus strykeri* (Geissmann et al., 2010). These fascinating and recent new discoveries attest of how still little the natural world has been explored and suggest how much remains to be uncovered in the near future. MacKinnon (2000) predicts several more new mammal discoveries expected in the 21st century notably in areas that have remained poorly explored, including areas within Laos and Myanmar. Similarly, a more recent meta-data analysis estimates that mammals inventory in Southeast Asia is far from complete (Giam et al., 2010). These predictions will convey enthusiasm among the scientific community.

This is unfortunately overshadowed by the biodiversity crisis that is currently taking place in Southeast Asia (Sodhi et al., 2004, 2010; Koh, 2007; Koh and Sodhi, 2010) principally through forest conversion and overhunting for bushmeat and/or wildlife trade (Nijman, 2009; Nijman and Nekaris, 2012). In this context, the principal wildlife conservation organisations are coming together in coalition to assist projects acting at local and species scales in implementing lasting impacts on the biodiversity of the region (Duckworth et al., 2012).

Nakai-Nam Theun National Protected Area (NNT NPA) has been ranked in the priority protected areas for its high biodiversity contribution at the National and Global scale (Robichaud et al., 2001); it falls in the heart of one of the richest regions of Southeast Asia in terms of biodiversity and endemism (Catullo et al., 2008) and is one of the identified 'key biodiversity area' within the Indo-Burma hotspot based on species vulnerability criteria (Tordoff et al., 2012). In terms of mammals only, NNT NPA is of National and/or Global importance for the occurring 15 species of small carnivores (i.e. Viveridae, Herpestidae, Prionodontidae, Mustellidae) (CHAPTER 7), nine species of primates (c.f. CHAPTER 3; CHAPTER 5 [APPENDIX VI]) including the world's largest population of red-shanked douc *Pygathrix nemaeus* (Coudrat et al., in press [CHAPTER 4]; Coudrat et al., 2012 [APPENDIX VII]) and likely of Southern white-cheeked gibbon *Nomascus siki*, and three ungulate species: Critically Endangered Saola, Endangered large-antlered muntjac and Data Deficient Annamite muntjac (CHAPTER 8). It may still represent a National important area for small and medium-sized cats although populations

seem to have dramatically decreased (CHAPTER 6) due to high hunting pressure (CHAPTER 9). Indeed, the 'protection' status of many forested areas in the Indo-Burma region often does not imply long-term viability of their fauna and flora community (Catullo et al., 2008; Duckworth et al., 2012). Nonetheless, that numerous uncertainties remain about species occurrence, taxonomy, distribution and general behaviour, means that long-term site-based, species-focussed research, such as in NNT NPA, will greatly improve our current knowledge of the biodiversity in the Indo-Burmese region, while being protected.

In light of the present research, it appears evident that a long-term conservation and research project in NNT NPA initiated by external partners would greatly benefit wildlife conservation at the local, National and Global scale. Failure to protect the area's wildlife effectively since the management authority has started its activities in 2005, means that current strategy need to be revised. Though it is currently being redesigned, implementation remains to prove its success.

The following recommendations should be taken into consideration to improve wildlife conservation in NNT NPA:

- Redirect resource available to a few areas only where illegal activities must be fully controlled. Areas suggested are the Navang and Teung clusters, in particular Nam Chae/Kokatiao and Tongkacheng/Nam Mon sites (in Navang cluster) and Tong Xet/Phou Vang sites (in Teung cluster). Together these areas may still retain all the historical wildlife species of the NPA with the exception of tigers which may be extinct from the area. Notably, these also hold Critivally Endangered saola, Critically Endangered large-antlered muntjac and Data Deficient Annamite muntjac, and indeed may represent (some of) the world's last habitats for the conservation of these species. Only once law enforcement patrols are successful in the areas of focus, that effort could be extended to further areas.
- Wildlife monitoring activities should be conducted simultaneously with patrolling trip with camera-traps. This would allow allocation of all financial and human resources to patrols rather than disperse funding

to patrol vs. biodiversity monitoring teams. In the past, WMPA had been conducting transect surveys, which is extremely time and resource consuming; the data resulting from these surveys are however unlikely to be used compared to more reliable camera-trap data. It is also strongly recommended to continue the input of all camera-trap data into WMPA's current database in order to make the data easily analysed and available to researchers. The data collected during camera-trap surveys will be of no use (though effort consuming) if it is not systematically managed.

- Increase awareness-raising of villagers within NNT NPA. This should include the development and inclusion of a curriculum in village schools on wildlife conservation and/or follow the model of the Mobile Conservation Education Unit implemented in Bolikhamxay Province (Hansel et al., 2010). This is of crucial importance so that villagers become actors in the conservation of wildlife in the area.
- Experiment alternative livelihoods project in focus villages. For instance, mushroom farming which has been successful at reducing wildlife hunting in communities living alongside National Parks; FREELAND, 2011).
- Develop a long-term conservation and research project at one site in NNT NPA. Such long-term research projects have been shown to protect wildlife effectively (Laurance, 2013) without necessarily deploying additional patrolling teams in the area.
- Lao or International researchers and/or students should conduct future wildlife research in the area. This will allow gathering data on the area's wildlife as well as provide training opportunities for Lao students.
- Initial research in the area should focus on:
    - Long-term behavioural ecology study on red-shanked douc population
    - Long-term behavioural ecology, taxonomy and density of gibbon population

- Survey on otters species with strategically positioned camera traps
- Small-carnivore species-specific ecological studies
- Sound recording of different muntjac species as potential proxy for taxonomic differentiation and survey technique

Other National priority research recommendations on primates are (c.f. CHAPTER 3):

- Taxonomy and biogeography of *T. francoisi s.l., T. germaini s.l., P. nemaeus* and pale-cheeked crested gibbons *(Nomascus spp*). This would require range-wide DNA and/or sound records (for gibbons).
- Surveys should be conducted in north-eastern Laos (Houaphan and Xieng Khuang Provinces along the Vietnam border) particularly in karst areas, where potentially new colobine populations could be found.

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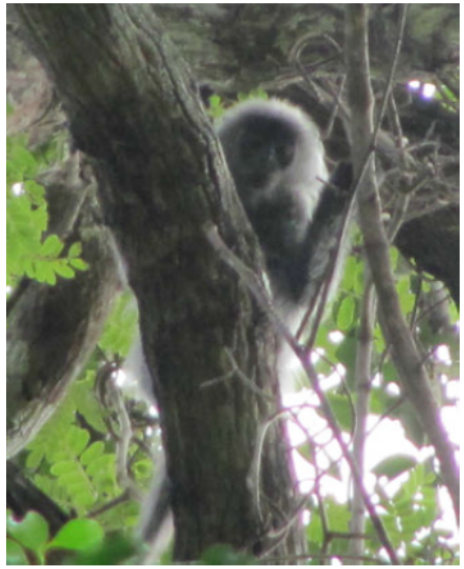
APPENDICES

APPENDIX I: The two reports from a short-term conservation project in Dong Phou Vieng National Protected Area, Lao PDR, conducted in collaboration with Veterinary Without Borders Canada and the Eco-Guides Unit of Savannakhet in May-June 2011.

The Silvered Leaf Monkey of Dong Sakee Sacred Forest:

Report 1 of a short Study Tour in Dong Sakee Sacred Forest, Dong Phou Vieng National Protected Area, Lao PDR.



silvred leaf monkey photographed during the study tour

- May 2011 -

By
Camille N. Z. Coudrat

To
Veterinarians Without Borders-Canada and
the Eco-Guide Unit of Savannakhet

VETERINARIANS WITHOUT BORDERS
VÉTÉRINAIRES SANS FRONTIÈRES

EGU Eco Guide Unit

Content of report 1

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Introduction

Veterinarians Without Borders-Canada (VWB/VSF) was asked by the Eco Guides Unit of Savannakhet to conduct a survey in Dong Sakee Sacred Forest, Dong Phou Vieng National Protected Area focussing on the silvered leaf monkey (*Trachypithecus germaini/margarita*). As a conservation primate biologist, I was approached by *VWB/VSF* to lead the project. Due to administrative issues related to obtaining research permits the team was allowed to access the site only on a study tour of 4 days on 17-20 May 2011 (possibly to be repeated 2-3 times). This document reports the activities and results of the project so far.

Research site

The Dong Phou Vieng National Protected Area (NPA) is located in Phin District, Savannakhet Province, southern part of Lao PDR (Figure 1). Dong Phou Vieng NPA was established by Prime Minister Decree in 1995. The total area of the NPA is approximately 200,000 hectares. Very little information is available on the NPA, Only one previous short mammal survey was conducted in 1997 in three different sites within the NPA (Steinmetz, 1998).

The Dong Sakee Sacred Forest (Dong Sakee hereafter) is situated in the west of Dong Phou Vieng NPA, close to Ban Vongsikeo. Dong Sakee is accessible from Savannakhet via road 9 to Ban Phin and Road 23 to Ban Vongsikeo, from which the forest is reached after a short walk. Very little information, if any, is available in the literature about Dong Sakee. Villagers living alongside the forest (at least in Ban Vongsikeo) share spiritual beliefs in relation to Dong Sakee and the silvered langurs inhabiting it. The population size of silvered langur in that forest is unknown. Similarly, no one

exactly knows the size of Dong Sakee. Villagers of Ban Vongsikeo are from the Katang ethnic group.

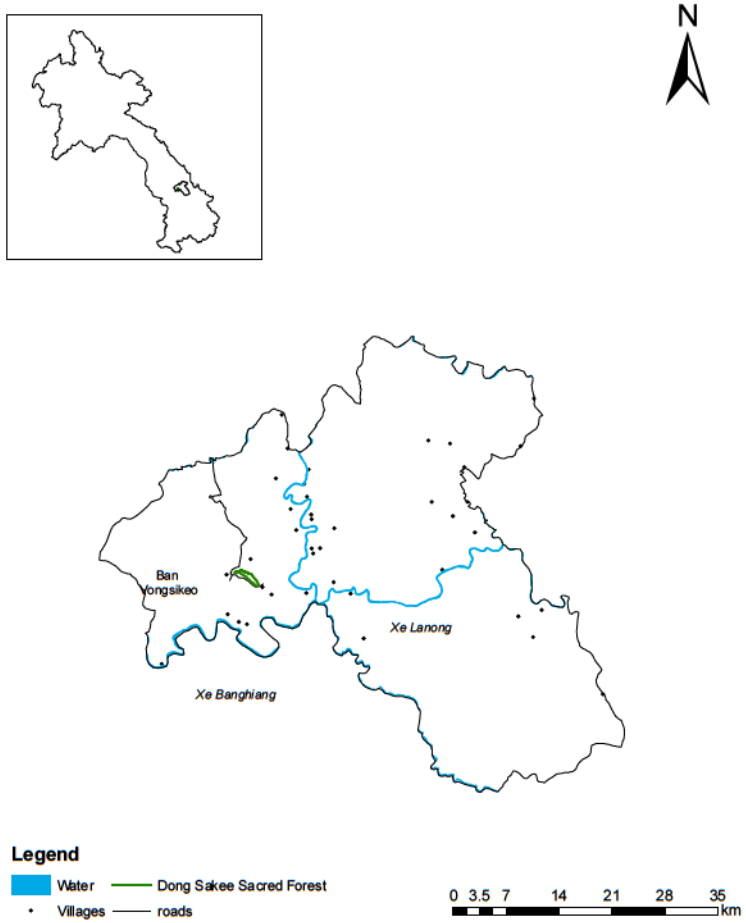

Figure 1: Location of Dong Phou Vieng National Protected Area and Dong Sakee Sacred Forest within the NPA.

Focus Species

The Indochinese silvered leaf monkey or silvered langur (*Trachypithecus germaini/margarita*) is globally classified as Endangered by the *International Union for Conservation of Nature* (IUCN, 2008). It is endemic to Lao PDR, Cambodia, Vietnam, Thailand, and possibly Myanmar. In Lao PDR, the species is the 'rarest and

most threatened monkey' (Timmins et al., in press). It has yet received very little attention in the country. It has indeed never been studied in the wild in Lao PDR, and little information is available on the species from the neighbouring countries of Cambodia and Vietnam. A recent review presents the distribution and conservation status of the species in Lao PDR (Timmins et al., in press).

Taxonomy of the species remains very uncertain and has been subject to debates between authors. The species is thought to comprise two distinct species by Nadler et al. (2005): one restricted to the east of the Mekong River, the Indochinese silvered langur (*Trachypithecus germaini*) and one occurring west of the Mekong River, the Annamese silvered langur (*T. margarita*). Small genetic and morphological data samples were used to come to that conclusion, however no theory can yet be ruled out. If the theory of *T. germaini* and *T margarita* is true, Lao PDR might hold the two species.

The two forms vary in their morphology as follow: *T. germaini* form has long light grey whiskers and fleshy black face. The back is darker (dark grey) compared to lighter parts of arms and legs (Nadler et al., 2005); *T. margarita* is of a lighter grey overall colour but with clear contrast with darker (blackish) feet and forearms. The face is grey surrounded by long light grey whiskers. Forehead is characterised by a black patch contrasting with the rest of the face and the whiskers. Clear light grey spectacles surround the eyes (Nadler et al., 2005). Describing the two forms with morphological characters cannot be conclusive on its own as the species may present intraspecific and even inter/intragroup morphological variations (Timmins et al., in press).

The species has mainly been recorded throughout its range in lowland semi-evergreen, semi-deciduous forests associated with dry dipterocarp/deciduous forest. They seem to be associated with streams (Timmins et al., in press).

In Lao PDR, the species has a very restricted range with Dong Phou Vieng NPA considered the northern limit (Timmins et al., in press). Figure 2 shows the distribution of the species in Lao PDR (based on the map in Timmins et al., in press).

The fact that the species is very rare in Lao PDR can be attributed to its habitat, which is easily accessible to humans and has been largely converted for agriculture (Timmins et al., in press) resulting in higher hunting pressure on the species. Timmins and colleagues (in press) emphasise the urgent need to focus attention on the Dong Phou Vieng NPA population [of the Dong Sakee Sacred Forest] to ensure its future survival.

The species is protected in Lao PDR under the Wildlife and Aquatic Law (National Assembly, 2007). The species is indeed classified in the *Prohibition Category*: it is forbidden to hunt it. However, like numerous other primates and other wildlife

classified under the same category, silvered leaf monkeys have been hunted for decades for local consumption and/or trade.

Figure 2: Distribution of the silvered leaf monkey in Lao PDR. Black circles represent the modern records of confirmed identification of the species. (after Timmins et al., in press).

Project's Aims

The aims of this project are:

- To raise capacity of the Ecoguide unit for wildlife conservation through a training on field techniques;
- To conduct a short preliminary survey in Dong Sakee Sacred Forest focussing on the silvered leaf monkey in order to collect baseline information for future study.
- To produce a map of Dong Sakee Sacred Forest and determine its area.
- To understand the spiritual beliefs of local residents about the Dong Sakee Sacred Forest and wildlife present in the forest through informal discussions with villagers from Ban Vongsikeo.
- To raise awareness of the species status amongst local people through discussions, presentations, dissemination of educational materials and activities.
- To provide recommendations for future conservation of the species in Dong Sakee.

Project Activities

Activities of this project include:

1. Training of eight Ecoguides (Appendix 1; Plate 1) from Savannakhet on survey methodologies. Training was given on:

- Data collection along transect walks;
- Design of transect in research site;
- Use of equipment (range finder, GPS, compass, topographic map).

2. Study Tour in Dong Sakee Sacred Forest (Table 1) to survey silvered leaf monkeys including:

- Mapping of Dong Sakee;
- Survey walk in Dong Sakee;
- Informal discussions with villagers of Ban Vongsikeo.

Table 1: Description of the Dong Sakee Study Tour activities

Dates	Activity	Description
17th May 2011	Savannakhet to Ban Vongsikeo	6 hours trip. Arrive at Ban Vongsikeo at 2 pm
18th May 2011	Mapping of Dong Sakee	Walk around the forest with the team
19th May 2011	Survey in Dong Sakee	Walk within Dong Sakee from one end to the other with a team of three.
20th May 2011	Informal discussions with villagers, children book reading to children Back to Savannakhet	Questions were asked about Dong Sakee, the wildlife present in the area and the spiritual beliefs. Translation was done by Sinakhone.

3. Creation of material for tourists and local people living around Dong Sakee Sacred Forest (villagers from Ban Vongsikeo).
This will include:

- Presentation of the results to villagers followed by discussion
- Map of Song Sakee Sacred Forest
- Children activity book focussing on the silvered leaf monkey
- Stickers featuring the silvered leaf monkey
- Posters on the silvered leaf monkey
- Leaflets on the silvered leaf monkey
- Wooden signs to put up around Dong Sakee Sacred Forest in English and Lao language to emphasize the status of the forest and importance of its protection.

Survey Methods

Team

The study tour team was composed of seven persons:

- Ms Sinakhone Sengphalichanh (Ecoguide Unit)
- Mr. Sonexay Lotvilaithong (Ecoguide Unit)
- Mr.Somevilay Sitthiphanh (Provincial Tourism Department, Savannakhet)
- Mr. --- (District Tourism Office, Phin)
- Miss Tiffany Gamelin (Vets Without Borders, Volunteer)
- Miss Nicole Mayne (Vets Without Borders, Volunteer)
- Miss Camille Coudrat (PhD candidate Primate Conservation, Oxford Brookes University)

Dong Sakee Mapping

Mapping was done walking around Dong Sakee, with the help of two local guides from Ban Vongsikeo. GPS points were taken at 50-200 m intervals. Data collected was then used to map the forest with the software ArcGIS. Area of the forest was calculated using the Measure tool in ArcGIS. The whole study tour team as well as 2 local guides were present during the walk around the forest.

Dong Sakee Survey

As only one day was available to make a preliminary survey, we walked one transect along the forest (c.f. Figure 2) and recorded basic transect-walk data at each mammal sighting. At each sighting of silvered leaf monkey, I recorded description of their morphology as much as I could. Data on feeding behaviour of the monkeys were recorded with food remains on the ground that clearly showed teeth marks belonging to the monkeys. Any other information about threats encountered was also recorded with GPS points. The team for the survey consisted of three people (Mr. Sonexay, one local guide and myself).

Results

Map and size of Dong Sakee Sacred Forest

Map of Dong Sakee Sacred Forest prepared with ArcGIS is presented in Figure 4. Dong Sakee is formed by two patches of forest: a smaller patch (9.45 hectares), 'small Dong Sakee' and a bigger patch (171.96 hectares) 'big Dong Sakee'. The total size of Dong Sakee Forest is approximately of 180 hectares (1.80 km^2) with a perimeter of 8.6 km.

Delimitation of the forest can clearly be identified with the change of forest type. The two patches of Dong Sakee Forest are of thicker semi evergreen forest while surrounded by less dense dry deciduous forest. Figure 3 shows the vegetation looking outside Dong Sakee and towards Dong Sakee at the edge of the forest.

Figure 3: pictures taken at the edge of Dong Sakee.
Top: looking towards Dong Sakee; Bottom: looking outside Dong Sakee.

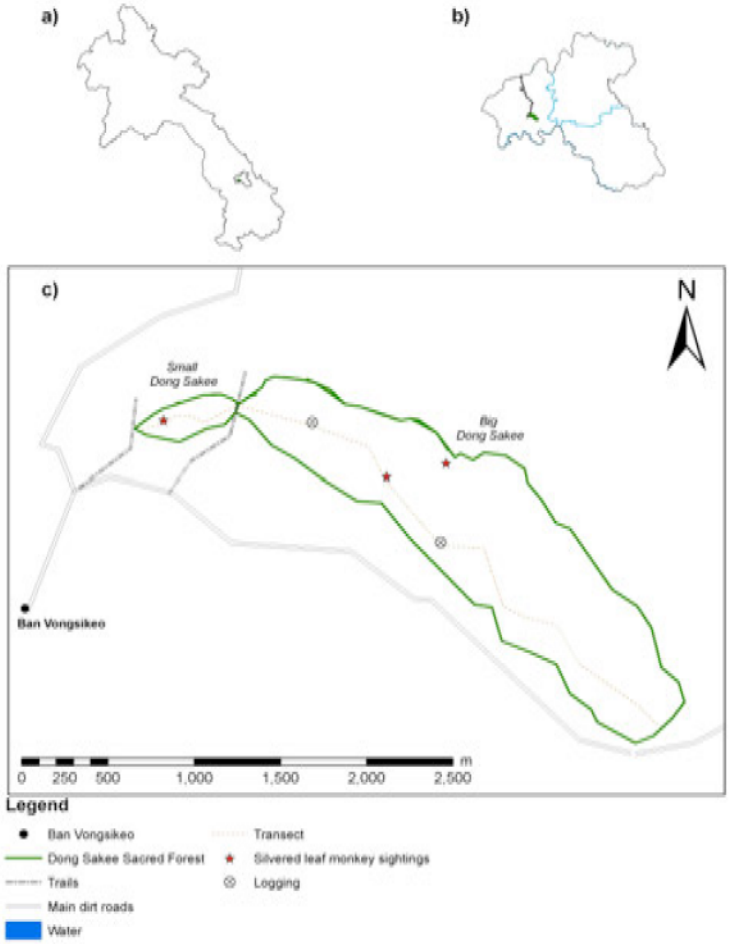

Figure 4: Location of Dong Phou Vieng NPA (a), Dong Sakee Sacred Forest (b) and Map of Dong Sakee Sacred Forest including results of the survey (c).
Note that sightings of silvered monkeys in the 'big dong sakee' are from 2 consecutive days and are presumed to be of the same group.

Silvered leaf monkey data
The species was sighted on three occasions. The first sighting (N 16°23'36.5" E 106°03'40.2") occurred during the mapping walk on 18th May at an elevation of 188 m. The group was sighted at the northern edge of the big Dong Sakee forest (c.f. Figure 4). Group size was not possible to estimate due to dense canopy. The group fled from the observers after approximately 10-15 minutes of observation. Animals were hiding in the canopy. One alarm call was heard.

The second sighting (N 16°23'44.8" E 106°02'45.0") occurred at an elevation of 172 m in the small Dong Sakee during the transect walk (19th May), five minutes after entering the forest at 8h15. About five animals were seen, however the group seems to be large and spread. Alarm calls were regularly heard, but the animals did not flee right away from the observers. Some individuals were observed feeding on leaves (from '*kanyom*' tree).

The third sighting (N 16°23'34.0" E 106°03'28.6") occurred at 10h07 (19th May) along the transect in the big Dong Sakee, at an elevation of 187 m. Loud alarm calls were heard from adult males while staring at the observers. The group was largely spread, group size is estimated at ~20-30 individuals. Clear pictures were taken of an individual above the team (Plate 2).

For all sightings, no infants (characterized by a bright orange fur) were observed.

Morphological data was collected: the face was black with long white whiskers around the face. I did not observe clear spectacles around the eyes. The tail was white grey, overall body colour was grey ('frosting' of longer white hair on top of darker hair). I did not assess the contrast of colour between forearms and feet and rest of the body nor between underparts and back, which are characteristics of *T. margarita* form as described in Nadler et al. (2005). Observations were taken from one single individual, which stayed long enough in clear view but had his body hidden behind a branch (See Plate 2). These observations do not allow to distinguish between the two forms east vs. west of the Mekong described in Nadler et al., (2005). Further observations will be made if possible during a second visit of the site end of June.

Feeding data was collected from fruit remains on the ground. Fruit trees were relatively varied. Five different fruits were observed to be eaten by the monkeys (see Plate 3) (although certainly a small part of the overall diet of the species). Some of which are also collected by villagers for local consumption.

The single day survey cannot allow estimation of the abundance of silvered leaf monkey in Dong Sakee, however from the data collected we know that at least 2 groups inhabit the forest: one in the small Dong Sakee and one in the big Dong Sakee (the 2 sightings in big Dong Sakee likely to be of the same group). The path dividing the small and big Dong Sakee is large enough to break the canopy, which may

suggests that groups cannot go from one forest patch to the other (although some monkeys can come to the ground to cross between forest patches). The forest is surrounded by either degraded dry deciduous forest, a large dirt road or plantations, the population of silvered langurs is therefore most likely confined within the semi-evergreen patches of Dong Sakee. A local guide reported that sometimes silvered leaf monkeys go out of Dong Sakee (into the dry deciduous forest) towards the road, but are afraid of people, cars and motorbikes. Vehicles passing on the main dirt road are heard from inside the forest. A group follow would be interesting to conduct in the future to establish its movements and home range. This would be easy to realise in a short period of time given that the forest is easily walkable and groups are easy to be found.

Remains of past logging were observed (recent and old) in and out of Dong Sakee (see plate 4). Tree fall resulting from logging created discontinuity through the canopy. Other threats are discussed in the next section.

Informal discussions with villagers

Two villagers (our homestay host and the village chief) were asked to explain the story of Dong Sakee. Both stories were the same and were as follows:

It is believed that an old village formerly existed within Dong Sakee, but people from all other villages around 'Dong Sakee village' could never see the inhabitants of the latter. However, there existed a strong sense of trust and honesty between invisible villagers from Dong Sakee and other villagers from surrounding villages, the latter often hanging defaulted clothes in 'Dong Sakee village' and coming back a few days later to find the clothes repaired (by invisible villagers) or borrowing things from Dong Sakee villagers and having to return them a few days later (otherwise it would bring bad luck to the family if they did not return the borrowed things). One day the son of Dong Sakee's village chief died in a weaving room in 'Dong Sakee village'. This is where the name Dong Sakee comes from: Dong Sakee = Forest Room. It is nowadays believed that the monkeys inhabiting the Dong Sakee Forest are reincarnations of people from the former village of Dong Sakee. People therefore continue to respect the forest and the monkeys.

When asked, our host said that this belief continues to be transmitted from generation to generation.

Trees and monkeys of Dong Sakee are sacred to the people of Ban Vongsikeo. Villagers however often collect other wildlife, vegetables, fruits and medicinal plants. Animals collected from Dong Sakee are only for local consumption (never kept as pets).

Outsiders (not from Ban Vongsikeo) also enter Dong Sakee; Vietnanmese people were often seen during the Vietnamese war, but are less seen nowadays. When

outsiders come to hunt the monkeys, villagers from Ban Vongsikeo stop them. Other villages around Dong Sakee also protect the monkeys.

Our host reported that he did not observe any change in the abundance of the silvered leaf monkey population. He also reported that the silvered leaf monkeys go in and out of the Dong Sakee forest.

A group of villagers were asked about other wildlife present in Dong Sakee (Figure 4). I used the mammal field guide (Parr, no date) for species identification.

Villagers notably reported the presence of wild pigs (which they hunt for consumption), mouse deer, and they report seeing footprints of sambar deer and muntjac.

Primate species reported in Dong Sakee are lorises ('*ling lom*'), pig-tailed macaque, Rhesus macaque, silvered leaf monkey ('*taloung*') and douc monkey ('*khadeng*'). The latter was repeatedly reported each time I asked, over the study period. Villagers were describing the characteristic red shanked of the species. The village chief said that he used to see a lot of red-shanked doucs but now only sees a few.

This latter report about the red-shanked douc is intriguing, notably considering the habitat of the forest, which is not typically where doucs are found – found in non degraded hilly evergreen forests. Further investigation would be needed. It is also possible that reports are erroneous and refer to other parts of Dong Phou Vieng NPA where villagers have travelled in the past. Red-shanked doucs were indeed confirmed to be present in the NPA in 1997 in the hilly forest of Phou Lapeung, although this region is far from Ban Vongsikeo.

The silvered leaf monkey was the only mammal encountered during the transect walk.

Figure 4: informal discussion at the village chief's house with villagers from Ban Vongsikeo about wildlife.

Recommendations

- Raise awareness of the species to local people: the fact that villagers from Ban Vongsikeo already protect the species through spiritual beliefs makes the concept of wildlife (here, the silvered leaf monkey in particular) conservation more accessible and easier to discuss with them. Discussion with villagers should tackle the conservation status of the species throughout Lao PDR; given its rarity and restricted range, emphasis should be made on the importance of the Dong Sakee population to ensure survival of the species in Lao PDR. This, in addition to the spiritual importance given to the species, could give further value to the species for its conservation. All of the above will be done through the present project with a presentation to the villagers on results and silvered leaf monkey status; awareness raising activities (see section above 'Project Activities') and discussions will be carried out. During the discussion, villagers will be asked if they feel the forest and the monkeys are facing threats, if so, what would *they* feel would be needed to help protection of the forest.
- Encourage older people to transmit spiritual beliefs and conservation value of the species to youngsters: this will be done through the present project through the discussion with the villagers.
- Put up some wooden signs in Lao and English around Dong Sakee Forest to inform outsiders, and as a reminder to residents, of the status of the forest: this will be

done through the present project during our second visit to Ban Vongsikeo, after discussion and approval from the village chief.

- To stress the importance of the Dong Sakee silvered leaf monkey conservation to the Provincial (PAFO) and District (DAFO) Agriculture and Forestry Offices: this will be done through the present project with final meeting with representatives of DAFO and PAFO offices and other relevant stakeholders, and presentation of the present report in July (translated in Lao by Mrs Sinakhone Sengphalichanh).
- During visits of officials (Dong Phou Vieng staff, Provincial and District Agriculture and Forestry Office staff, Tourism Department staff, Ecoguide Unit staff), assess the situation through more discussion with villagers and more awareness raising and identify ways in which Ecoguides can help support conservation.
- Encourage scientific research on the species: the situation in Dong Sakee would make an interesting research site (easy access and easy visibility of the animals) to collect important data on the species, which is very little known. Scientific research should however be kept small scale to avoid disturbing the forest and the people.
- Conduct more surveys within the Dong Sakee forest to find out the number of silvered leaf monkey groups inhabiting the forest and understand their movement in and out Dong Sakee (if this is the case). Surveys should also try to assess the presence of doucs and macaques in the forest as reported.
- Visit other villages around Dong Sakee to find out if they also share the same spiritual beliefs which protects the silvered leaf monkeys and if so, apply the same activities (raising awareness, visit of officials etc.) to these villages. If there are no existing spiritual beliefs in these villages, discussion should be made on hunting practices (notably on the silvered monkeys).
- Visit other patches of similar forest in the NPA, particularly those with the same ethnic group living around, and see if there are any others like Dong Sakee.
- Continue collection of basic data on the species when the Ecoguide Unit of Savannakhet visit the site. This should include any information from villagers related to the monkeys, GPS points of observed groups, group size estimations etc. The present project already included training of the ecoguides to collect this information.

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Timmins, R. J., Steinmetz, R., Poulsen, M. K., Evans, T. D., Duckworth J. W. and Boonratana, R. (In Press) The Indochinese Silvered Leaf Monkey *Trachypithecus germaini* (*sensu lato*) in Lao PDR. *Primate Conservation*.

Appendix 1 – Participants of the 13th May training on field techniques.

Name	Affiliation
Miss Camille Coudrat	Oxford Brookes University
Mr. Chanthalaphone Nanthavong	Watershed Management Protection Authority – Nam Theun 2 (Nakai District)
Mrs Sonia Fèvre	Veterinarian Without Border Programme Manager
Miss Nicole Mayne	Vets Without Borders Volunteer
Miss Tiffany Gamelin	Vets Without Borders Volunteer
Mr Champa Inthilad	Ecoguide Unit of Savannakhet
Miss Lisa Lonxathilath	Ecoguide Unit of Savannakhet
Miss Saphaphay Chanthavongsack	Ecoguide Unit of Savannakhet
Mr. Vixai Ketphommavong	Ecoguide Unit of Savannakhet
Mr. Somboun	Ecoguide Unit of Savannakhet
Mrs Sinakhone Sengphalichanh	Ecoguide Unit of Savannakhet
Mr. Sonexay Lotvilaithong	Ecoguide Unit of Savannakhet
Mr Pasert Chanthavilar	Ecoguide Unit of Savannakhet
Mr. Somevilay Sitthiphanh	Provincial Tourism Department, Savannakhet

Plate 1: Training session on field techniques at the Provincial Tourism Department Office, Savannakhet, 13th May 2011.

Training on compass use. Sonexay, Camille and Sonia.

Training on map reading.

Plate 2: Photographed silvered leaf monkey during the survey walk in Dong Sakee.

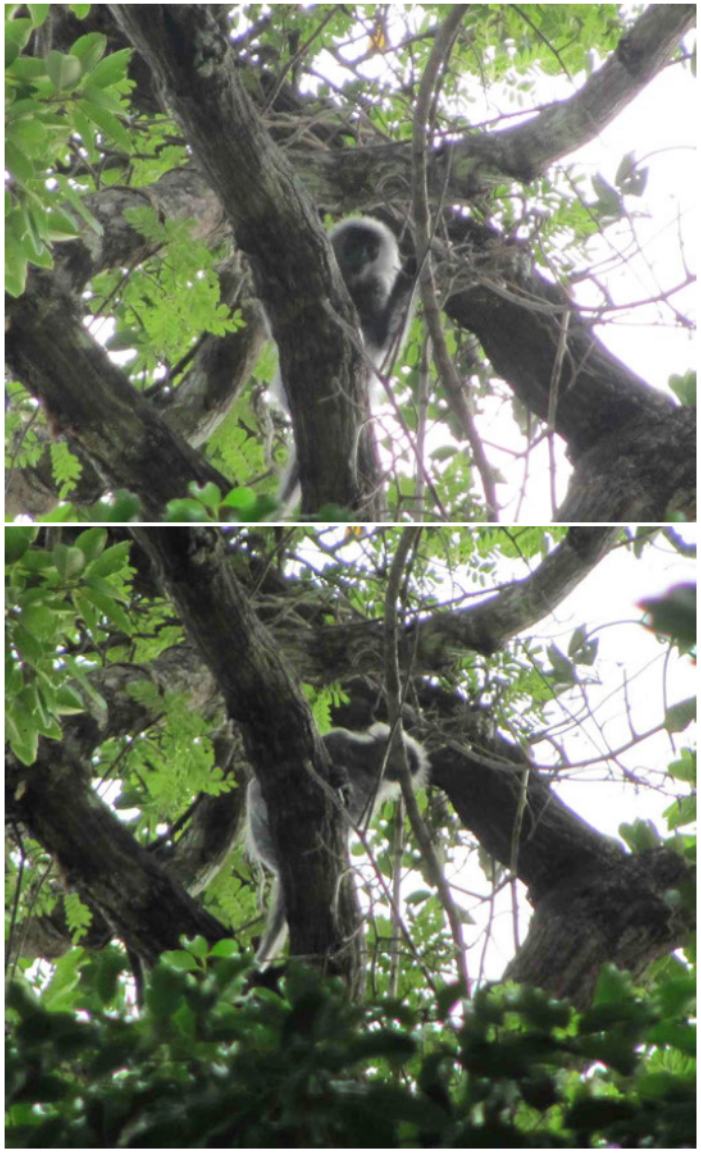

Plate 2: Continued

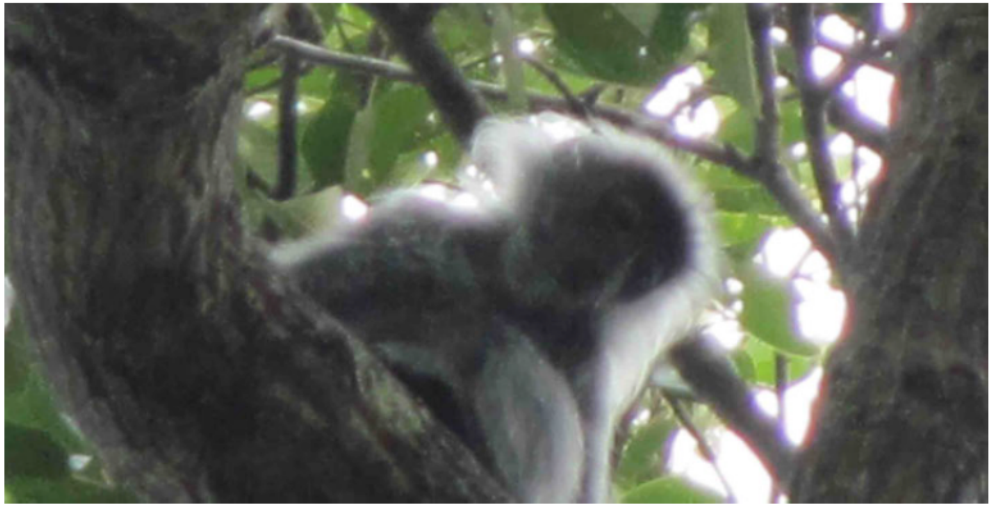

Plate 3: Fruit remains eaten by silvered leaf monkey in Dong Sakee.

Plate 4: Logging in Dong Sakee and creation of discontinuity in the canopy.

Conservation of Dong Sakee Sacred Forest:

Report 2 of a second study tour in Dong Sakee Sacred Forest, Dong Phou Vieng National Protected Area, Lao PDR.

- June 2011 -

By
Camille N. Z. Coudrat

To
Veterinarians Without Borders-Canada and
the Eco-Guide Unit of Savannakhet

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Introduction

This report presents the results of a second study tour in Ban Vongsikeo and Dong Sakee Sacred Forest, western Dong Phou Vieng National Protected Area, in June 2011, and a subsequent Stakeholder Meeting held in Savannakhet. In May 2011, a first study tour was conducted at the same site over four days (please refer to Report #1 for background and previous results: *"The Silvered Leaf Monkey of Dong Sakee Sacred Forest: Report of a short Study Tour in Dong Sakee Sacred Forest, Dong Phou Vieng National Protected Area, Lao PDR"*) to collect baseline information on the conservation of Dong Sakee Sacred Forest with a focus on the silvered leaf monkey (*Trachypithecus germaini/margarita*). The second study tour to Ban Vongsikeo and Dong Sakee Sacred Forest had as its aims to present the results of Study Tour 1 to villagers, provide educational materials, put up signs, and have discussions on the conservation of Dong Sakee Sacred Forest with villagers from Ban Vongsikeo. This document reports on the activities of the second study tour and the Stakeholder meeting.

Activities of the second study tour
Table 1 presents study tour's schedule.

Table 1: Description of the Dong Sakee Study Tour activities

Dates	Activity	Description
13th June 2011	- Savannakhet to Ban Vongsikeo - Evening meeting and discussion with village chief and other village decision makers	- 6 hour trip. - Presentation of the materials (posters, signs, children books) and discussion on Dong Sakee conservation
14th June 2011	- a.m.: Putting up wooden signs and walk in Dong Sakee - p.m.: Children's activities at the school	- 1 team putting up signs; 1 team walking in the forest - reading of *Save Douky, the Red-shanked Douc* and use of *Silvered langur activity book*
15th June 2011	- Visit of Ban Nyang to give poster in Lao language to village chief - Back to Savannakhet	

The second study tour team was composed of four persons:

- Ms Sinakhone Sengphalichanh (Ecoguide Unit, Savannakhet – Project counterpart)
- Ms Camille Coudrat (PhD candidate Primate Conservation, Oxford Brookes University – Project Leader)
- Ms Tiffany Gamelin (Veterinarians without Without Borders (VWB)--Volunteer)
- Ms Nicole Mayne (Veterinarians without Borders -- Volunteer)

The methodology and activities of the second study tour is described below):

1. Forest walk in Dong Sakee Sacred Forest to collect more information on the silvered leaf monkey. We walked along the same transect as the first study tour with the intention to take pictures and videos of the species.

2. Discussion with village chief and other village decision makers of Ban Vongsikeo about Dong Sakee conservation. Discussion with villagers was structured around two questions: (1) Do you feel that Dong Sakee and silvered leaf monkeys are threatened and how? (2) What do you think would be needed for the conservation and protection of Dong Sakee and the monkeys?

3. Presenting results of first study tour to villagers via posters in Lao and English language. Posters contained information on Dong Sakee (map, size) and on the silvered leaf monkey (conservation status, facts). All the information figuring on the posters was explained to the villagers; approval from the village chief was received to put a poster in Lao language in his house and one in English language in the village (for tourists).

4. Installation of wooden signs around Dong Sakee Sacred Forest to increase awareness and value the villagers have for Dong Sakee. Four wooden signs read "*You are entering a sacred forest protect its inhabitants*", one sign read "*Dong Sakee Sacred Forest*". All signs were written in English and Lao language. Signs were placed at strategic sites around the forest where people usually enter the forest. Local guides helped to put up and choose locations to put up the signs.

5. Educational activities with children of Ban Vongsikeo via children books. Two children's books were used for educational activities: a storybook on primate pet trade "*Save Douky, the red shanked douc*" (authored by Camille N.Z. Coudrat, as part of her PhD research); and a colouring and game book "*Silvered langur activity book*" created for the project, featuring the project's focus species. Activities were conducted in the village school. Ten boxes of colouring pencils were also distributed.

6. The whole project was completed through a stakeholder meeting in Muang Savannakhet, at the Provincial Tourism Department on the 17th June 2011.

Results

Forest walk

A group of silvered leaf monkey clearly identified was sighted (N 16°23'46.2" E 106°03'03.8"). Group size was not possible to estimate. Individuals started to react to human presence with loud alarm calls and then fled. When the researchers tried to follow the group, the monkeys were constantly hiding in the canopy, preventing us from getting pictures and videos. Individuals more clearly observed with binoculars appeared dark grey/blackish in colour.

Throughout the two study tours, a total of 4 sightings were made over the two days of forest walk and one day walking around the forest, giving an encounter rate of 1.3 groups per day. Total number of groups was not possible to assess, however at least 2 groups inhabit the 180 ha forest of Dong Sakee.

Discussions with villagers

Present for the discussion were Ban Vongsikeo's village chief in addition to other decision makers of the village (Plate 1). When asked if they felt that Dong Sakee was threatened, they said that all animist Katang villages around Dong Sakee respect the forest and the monkeys. They reported that Lao Loum and Vietnamese do not come to hunt in Dong Sakee. However, some villagers from neighboring villages (Ban Alao Mai, Alao Mao) come to cut trees in Dong Sakee as they do no share the same beliefs as other Katang villages around Dong Sakee.. Respondents stated that this lead to the loss of spiritual beliefs through generations among animist villagers as observing other people cutting trees, not

followed by any bad events on the family, decreases the belief among animists villagers. They said that respect of spiritual beliefs is not as strong as in the past.

When asked what they feel would be needed for the conservation of Dong Sakee, they listed three points:

1. Involvement of government authorities (PTD, PAFO, DAFO); a Report to authorities on the situation of Dong Sakee and its threats;
2. Governmental rules and sanctions for the conservation of Dong Sakee and make these known to all villages around Dong Sakee;
3. Training on wildlife conservation and advice on how to continue protecting the forest (both Villagers from B. Vongsikeo and B. Nyang expressed interest).

Posters

All information figuring on the posters were explained to the villagers present at the discussion meeting (Plate 1). One poster in Lao language was put up in the village chief's house and one in English language was put up in the village (on the house's wall where women deliver their baby) where tourists can read it. One poster in Lao language was also put up in Ban Nyang on the last day after explaining to the village chief the project (Figure 1). Figure 2 presents the English version of the poster.

Figure 1: Meeting with Ban Nyang Village chief, and put up of the poster in Lao language (on the right in the picture)

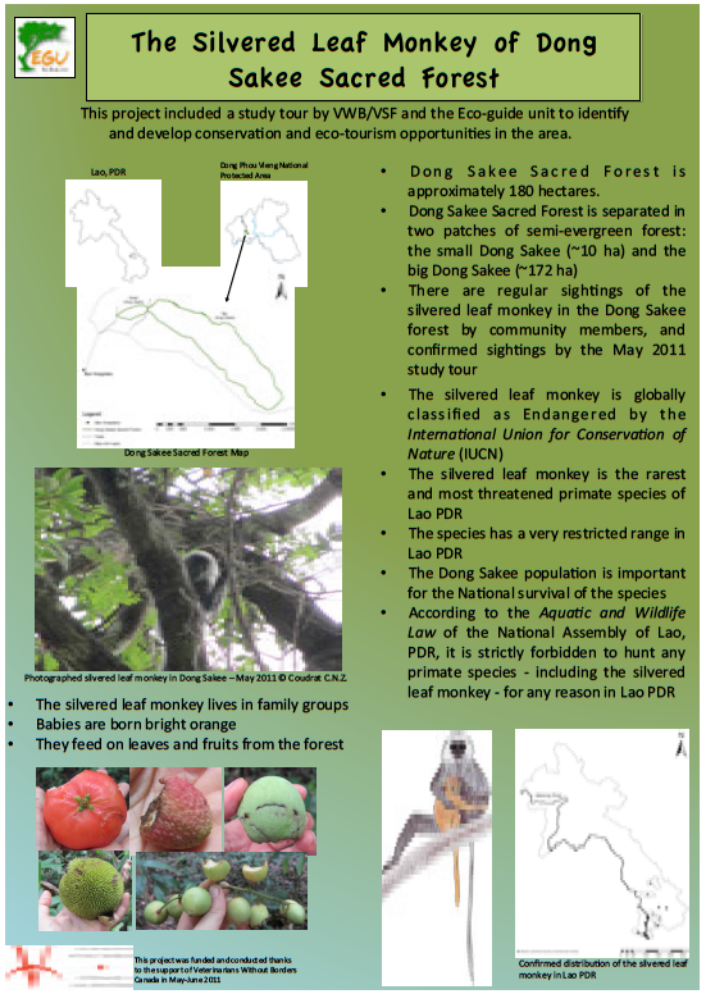

Figure 2: Poster presenting results of the project and information on the silvered leaf monkey

Wooden Signs

Four signs "*You are entering a sacred forest: protect its inhabitants*" (English and Lao) were put up around Dong Sakee Forest. The first one at the western most end of the forest where a path enters the forest, the second one on the path which separates the small Dong Sakee and the big Dong Sakee, and the two last ones along the southern edge of the forest where people usually access the forest. The sign "*Dong Sakee Sacred Forest*" (English and Lao) was placed at the beginning of the path that separates the two patches of Dong Sakee forest (small DS and big DS), and was visible from the main dirt road of the village. Plate 2 shows photos of the signs.

Children's activities

Approximately 70 children from Ban Vongsikeo were gathered in the village's school to participate in activities. Ms Sinakhone Sengphalichanh read the storybook in Lao to the children. Twenty storybooks were distributed to children who answered correctly to question during a game. This was followed by distribution of the silvered langur activity book to all children present as well as distribution of one colouring pencil box to each table. All the children started colouring with enthusiasm and stayed in the classeroom for ~ 3 hrs. Plate 3 shows photos of the children's activities session.

Stakeholder meeting

Appendix 1 lists the persons present at the stakeholder meeting. The opening of the meeting was by Ms Sinakhone Sengphalichanh and a brief introduction to the NGO Veterinarians Without Borders-Canada given by Nicole Mayne, followed by a presentation by Camille N.Z. Coudrat on the overall project including background information on the research site and focus species, project aims and activities, methodology, results and recommendations (presentation slides available upon request); the presentation was translated in Lao language by Ms Sinakhone Sengphalichanh. The presentation was followed by questions and a discussion session. Mr. Vanyenh Nansounphavong (PAFO, responsible for law enforcement in Dong Phou Vieng) said PAFO was lacking personnel to patrol the area and also stated that the situation of Dong Sakee was difficult due to the different religions, which creates conflicts over conservation. Rules already exist for conservation of Dong Phou Vieng, however they are not focused on Dong Sakee. Mr Siha (Director of the Provincial Tourism Department, Savannakhet) expressed his interest in the project and his concern with the current fragile situation in the area. Ban Vongsikeo and Dong Sakee are indeed of high value for tourism (mainly from the presence of the silvered leaf monkeys) and therefore for the Tourism Department of Savannakhet. Mr. Siha was grateful for the project and its results and recommendations, and said the information in the report was very valuable. He stated that the report will be sent to the Asian Development Bank for a proposal to receive funding to develop a conservation plan in Dong Sakee Sacred Forest and surrounding villages. Dr. Bounheuang Ninchaleune (Savannakhet University) suggested the idea to organise field trips to Dong Sakee with

Biology students to learn about forest and animal ecology. Plate 4 shows pictures of the meeting.

General Recommendations for Dong Sakee Conservation and the protection of silvered leaf monkeys

The first three recommendations (in *italics*) are the ones given by the villagers.

1. *Involvement of officials (Dong Phou Vieng staff, Provincial and District Agriculture and Forestry Office staff, Tourism Department staff, Eco-Guide Unit staff)*
2. *Create governmental rules and sanctions for the conservation of Dong Sakee and make these known to all villages around Dong Sakee (→ would involve long term conservation strategy with patrolling system for law enforcement and sanction implementation)*
3. *Provide training on wildlife conservation to villages aroung Dong Sakee and advice on how to continue protecting the forest*
4. Raise awareness of monkey species to local people
5. Encourage older people to transmit spiritual beliefs and conservation value of the species to youngsters
6. Encourage scientific research on the species
7. Conduct more surveys within the Dong Sakee forest to find out the number of silvered leaf monkey groups inhabiting the forest and understand their movement in and out Dong Sakee
8. Visit other villages around Dong Sakee to find out if they also share the same spiritual beliefs which protects the silvered leaf monkeys and if so, apply the same activities (raising awareness, visit of officials etc.) to these villages.
9. Continue collection of basic data on the species when the Ecoguide Unit of Savannakhet visit the site.

Acknowledgements

On behalf of Veterinarians without Borders/Vétérinaires sans Frontières-Canada (VWB/VSF), we would like to thank the Provincial Tourism Department, the District Tourism Office, Savannakhet University, Ian Burrows and Mr Oudomsay (WCS) and PAFO. We are particularly grateful for the collaboration of the Eco-Guide Unit of Savannakhet, especially Mrs Sinakhone Sengphalichanh for her hard work and relentless optimism.

Plate 1: Discussion with villagers in Ban Vongsikeo

Plate 2: Wooden signs placed around Dong Sakee Sacred Forest

Plate 3: Children's activities

Children participating in educational activities

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ildren receiving the silvered langur activity book

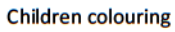
Plate 3: continued

Children colouring

Children colouring

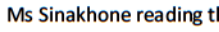
Children colouring

Plate 3: continued

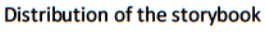


Children colouring

Plate 3: continued



Ms Sinakhone reading the storybook



Distribution of the storybook

Children receiving and listening to the storybook

Plate 4: Stakeholder meeting, Provincial Tourism Department Office, Muang Savannakhet, 17th June 2011.

Appendix 1: participants of the stakeholder meeting

	Name	Affiliation
1	Mr. Siha Phannavong	Provincial Tourism Department Office
2	Mr. Somsanouk	Provincial Tourism Department Office
3	Mr. Vanyenh Nansounphavong	PAFO
4	Mr. Nouansisavad Sombounsack	Savannakhet University
5	Dr. Bounheuang Ninchaleune	Savannakhet University
6	Mr. Ian W. Burrows	Wildlife Conservation Society
7	Mr. Oudomxay	Wildlife Conservation Society
8	Ms Lisa Lonxathilath	Ecoguide Unit of Savannakhet
9	Mr Champa Inthilad	Ecoguide Unit of Savannakhet
10	Mr. Sonexay Lotvilaithong	Ecoguide Unit of Savannakhet
11	Mr Pasert Chanthavilar	Ecoguide Unit of Savannakhet
12	Ms Saphaphay Chanthavongsack	Ecoguide Unit of Savannakhet
13	Ms Sinakhone Sengphalichanh	Ecoguide Unit of Savannakhet
14	Ms Nicole Mayne	Veterinarians Without Borders, Volunteer
15	Ms Tiffany Gamelin	Veterinarians Without Borders, Volunteer
16	Ms Camille Coudrat	Oxford Brookes University, Project leader

APPENDIX II: Survey effort and habitat characteristics of each of the ten sites visited over the study period

Sites	nb Transects*	km walked	Approximate area covered (km2)**	tree density (per ha)	Tree diversity Index	Elevation (m a.s.l.)	Slope (°)	Mean annual Precipitation (mm)	Mean annual Temperature (°C)	dist water (m)	dist villages (km)	Dist to Viet. Border (km)
1- Nam Chae	20	21.47	14.75	682.30	4.05	801.61	8.77	2232.49	21.44	312.90	6.06	28.45
2- Ban Xeuk	19	36.16	5.23	845.30	3.21	835.31	15.67	2190.29	21.06	509.91	2.81	14.86
3- Maka	23	40.29	7.10	914.68	3.56	817.25	18.41	2171.41	21.16	257.14	4.44	7.98
4- Khamkeut	6	9.80	5.67	901.56	3.18	1592.98	11.58	2049.72	17.02	311.52	31.41	1.32
5- Tong Xet	6	10.55	5.93	1166.72	3.20	893.34	11.75	2263.98	20.87	420.75	7.72	15.19
6- Nam On	24	42.45	7.66	738.23	2.70	1265.87	17.04	2105.32	18.87	140.56	18.49	15.34
7- Nam Theun	12	22.08	2.90	1193.82	2.13	1094.53	9.02	2092.54	19.55	157.57	17.42	2.48
8- Houay Tong	30	58.02	10.98	954.99	3.19	793.20	8.77	2271.20	21.57	261.75	5.01	31.84
9- Tongkacheng	18	34.38	5.55	530.37	3.13	1292.77	16.42	2126.09	18.56	304.35	11.74	11.87
10- Nam Mon	18	35.01	6.05	948.63	2.30	799.17	10.25	2316.73	21.58	283.16	15.64	8.83

* number of transects includes replicates

** Approximate area covered is estimated via a minimum convex polygon drawn around all transects (does not include areas covered to reach research site

APPENDIX III: Unconditionnal ethic approval from the Oxford Brookes University's Ethical Committee

University Research Ethics Committee

Headington Campus, Gipsy Lane, Headington, Oxford OX3 0BP UK
t. +44 (0)1865 483484
ethics@brookes.ac.uk
www.brookes.ac.uk/research/ethics

Dr. K. A. I. Nekaris (Director of Studies)
Dr. V. Nijman (2nd supervisor)
Department of Anthropology and Geography
School of Social Sciences and Law
Gipsy Lane Campus
Oxford Brookes University.

23rd June, 2010.

Dear Dr. K. A. I. Nekaris (Director of Studies) & Dr. V. Nijman (2nd supervisor)

UREC Registration No: 100478: "Ecology and conservation of the red-shanked monkey (*Pygathrix Nemaeus*) in Kakai Nam Theun National Protected Area, central-east Laos, and its conservation status in Indochina"

Thank you for your email of the 21st June in respect of your research student **Ms. Camille Coudrat**, outlining your responses to the points in my previous letter about your study and attaching the revised documents.

In due course you will send to UREC:
1. Any permission(s) in respect of the NGOs.
2. Confirmation that a Risk Assessment is completed with the PhD supervisors at school level before research commences.
3. Details of the research assistants to be sent to UREC once they have been recruited.
I am pleased to confirm that, on this basis, I have given Chair's Approval for the study to begin.

The UREC approval period for this study is two years from the date of this letter, so the 23rd June 2012. If you need the approval to be extended please do contact me nearer the time of expiry.

In order to monitor studies approved by the University Research Ethics Committee, we will ask you to provide a (very brief) report on the conduct and conclusions of the study in a year's time. If the study is completed in less than a year, could you please contact me and I will send you the appropriate guidelines for the report.

Yours sincerely

Dr Elizabeth Hurren
Chair of the University Research Ethics Committee

cc. Louise Wood, Ethics Officer
Jill Organ Graduate Office
Morag Maclean, SSL.

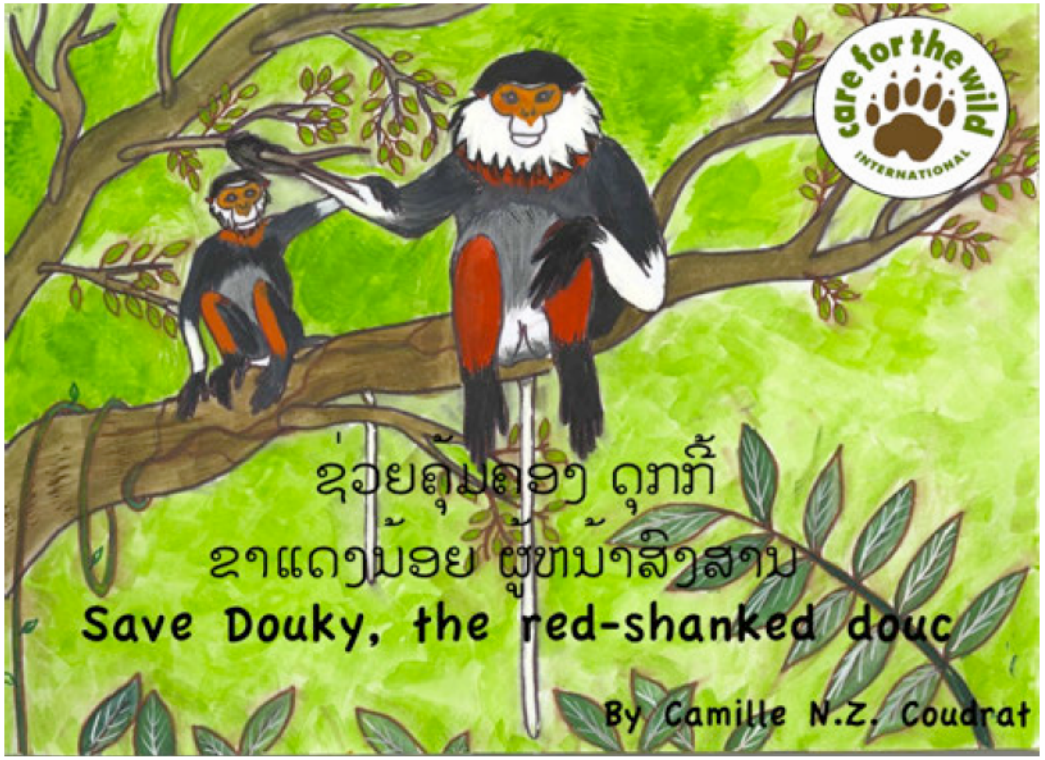
APPENDIX IV: Children's book *'Save Douky, the red-shanked douc'* disseminated in Laos in 2011-2012

Printing of this book was made possible by initial financial support from Care for the Wild International. Funding was provided for a first launch in Lao, PDR in 2011.

Care for the Wild International (CWI) is a charity dedicated to the conservation and welfare of wildlife around the world. Working with our partners, we aim to protect wildlife and its habitat, rescue and rehabilitate displaced wild animals, and act as a voice for wildlife protection through campaigns, research and education.

We believe in empowering local people and communities worldwide to protect their wildlife through education. Young people are the future guardians of our planet. By providing them with tools like this book to increase their knowledge, we aim to help pave the way for this future responsibility. Through sharing this knowledge with family and friends, children can also influence our actions now.

www.careforthewild.com
The Granary, Tickfold Farm, Kingsfold,
West Sussex, RH12 3SE, United Kingdom.



ຊ່ວຍຄຸ້ມຄອງ ດຸກກີ້ - ຂາແດງນ້ອຍ ຜູ້ຫນ້າສົງສານ

Save Douky, the red-shanked douc

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ຂ້ອຍແມ່ນຄ່າງຂາແດງ, ຂ້ອຍແມ່ນຄ່າງຊະນິດນຶ່ງ, ຂ້ອຍຊື່ ດຸກາ, ຂ້ອຍອາໃສຢູ່ໃນປ່າ

Here is Douky, a baby monkey who lives in the forest.

ດຸກາ ແລະ ຄອບຄົວ ອາໃສຢູ່ໃນປ່າຢ່າງມີຄວາມສຸກ

Douky lives with all his family in the forest.

ນອກຈາກຄອບຄົວຂອງດຸກກີ້ແລ້ວ ຍັງມີສັດປ່າອີກຫຼາຍຊະນິດ ອາໃສຢູ່ໃນປ່າແຫ່ງນີ້

Douky and his family are not the only animals in the forest.

ມື້ນຶ່ງ, ມີຄົນເຂົ້າມາລົບກວນປ່າທີ່ເປັນບ້ານອັນແສນສະຫງົບ ແລ້ວ ຈັບເອົາ ດຸກກີ້ ກັບ ແມ່ ຂອງລາວ ໄປ, ສຳນະຊີກໃນຄອບຄົວທີ່ເຫຼືອກໍ່ຢ້ານ ແລະ ຫວາດກົວຫຼາຍ.

One day, men came to disturb the peaceful forest and caught Douky and his mum! Douky's family was so frightened!!!

ດຸກກີ້ ແລະ ແມ່ ຂອງລາວ ຖືກຂັງໄວ້ໃນກົງເຫຼັກ ແລ້ວທັງສອງກໍ່ຖືກສົ່ງຂຶ້ນລົດ ຈາກບ້ານ ຂອງ ເຂົາເຈົ້າໄປໄກແສນໄກ. ດຸກກີ້ ແລະ ແມ່ ຂອງລາວ ຢ້ານຈົນຕົວສັ່ນ ແລະ ບໍ່ເຂົ້າຮູ້ວ່າຈະເກີດຫຍັງກັບເຂົາເຈົ້າອີກ.

Douky and his mum were terrified and did not understand what was going on. They both were locked up in cages and transported far away from their forest on a truck.

ຜ່ານມາຕນເດີນທາງອັນຍາວໄກ, ດຸກກີ້ ແລະ ແມ່ ຂອງລາວ ກໍ່ເດີນທາງມາຮອດຕະຫຼາດແຫ່ງນຶ່ງ ທີ່ມີແຕ່ສຽງໜົດນັບ ເປັນຕາຢ້ານ, ຫນ້ອຍນຶ່ງກໍ່ມີແມ່ຍິງຄົນນຶ່ງເອົາເງິນສອງສາມໃບໃຫ້ຜູ້ທີ່ຈັບ ດຸກກີ້ ກັບ ແມ່ ຂອງລາວມາ ແລ້ວກໍ່ດຶງເອົາ ດຸກກີ້ ໄປຈາກອ້ອມເອິກແມ່ຂອງລາວ, ດຸກກີ້ ແລະ ແມ່ ຂອງລາວ ທັງຮ້ອງທັງ ໃຫ້ຈົນໃຈຈະຂາດ, ແຕ່ກໍ່ບໍ່ມີໃຜສົນໃຈ ໃນທີ່ສຸດ ດຸກກີ້ ກໍ່ຖືກພາກາຈາກແມ່ຂອງລາວຢ່າງບໍ່ມີວັນຫວນກັບ.

Douky and his mum ended up in a very noisy and frightening market! After a while, a woman took Douky with her in exchange of a few bills! Douky and his mum yelled and cried, but unfortunately, Douky was separated from his mum forever.

ແມ່ຍິງ ຜູ້ທີ່ຊື້ ດຸກກີ້ມາ ກໍ່ຮ້ອງລາວວ່າ “ຄິມ, ຕາມ
ມາເບິ່ງດຸແມ່ຊື້ຫຍັງມາຕ້ອນພວກລູກນໍ” ຄິມ ແລະ ຕາມ ຕື່ນເຕັ້ນ ແລະ ດີໃຈຫຼາຍ
ທີ່ແມ່ຂອງເຂົາເຈົ້າຊື້ ຂາແດງ ນ້ອຍທີ່ເປັນຕາຮັກມາຕ້ອນ.

The woman who had taken Douky went back home and called her children:
“Kim, Tam, I brought you something from the market!”
Kim and Tam were delighted to see that their mum had brought a nice and so cute baby monkey !

ແຕ່ພໍເມື່ອ ຄິມ ແລະ ຕາມ ເບິ່ງໜ້າ ຂາແດງນ້ອຍໄກ້ໆ
ແລ້ວທັງສອງກໍ່ແປກໃຈທີ່ເຫັນໜ້າອັນເສົ້າ ໜມອງ ຂອງຂາແດງນ້ອຍ.

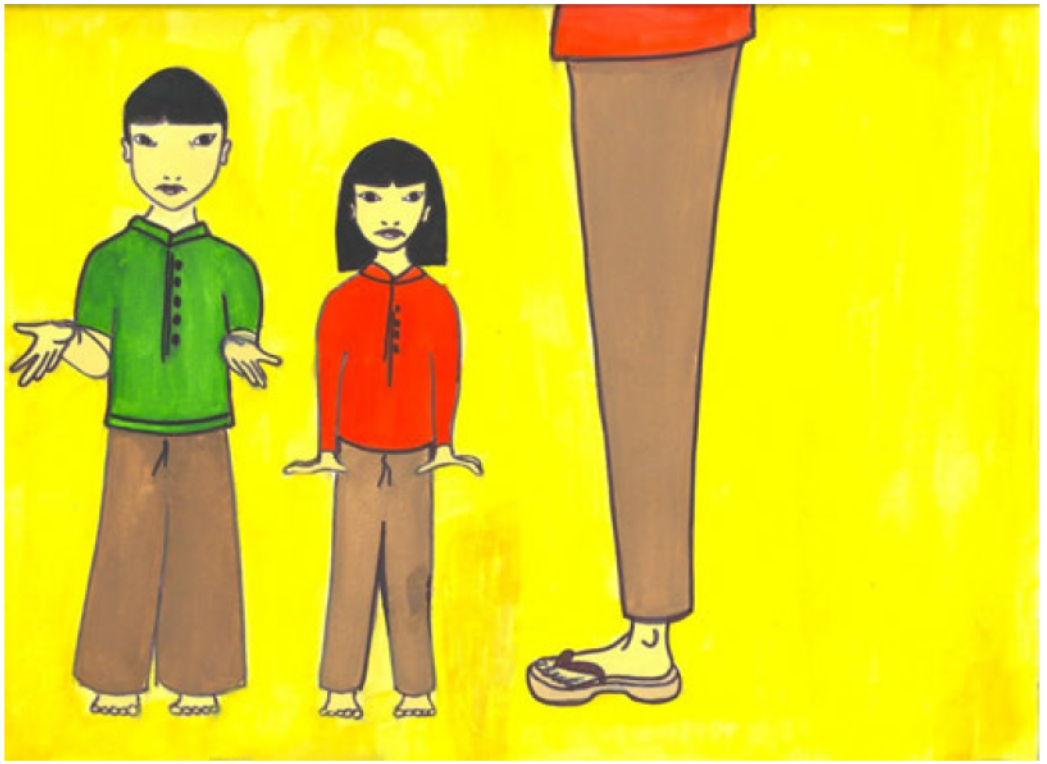
But when Kim and Tam got closer to Douky, they were very surprised to see him so sad...

ເມື່ອເຫັນດັ່ງນັ້ນທັງສອງຄົນຈຶ່ງແນະນຳໂຕເອງ. “ສະບາຍດີ, ຂ້ອຍຊື່ ຄິມ ແລະ ນີ້ແມ່ນນ້ອງສາວຂອງ ຂ້ອຍຊື່ວ່າ ຕາມ. ເຈົ້າຊື່ຫຍັງ?” ຄິມຖາມ.
ຂາແດງນ້ອຍຕອບແບບອາຍໆວ່າ ຂ້ອຍຊື່ ດຸກາ
ເປັນຫຍັງເຈົ້າຄືໂສກເສົ້າແທ້? ຕາມຖາມຕໍ່ຈາກອ້າຍລາວ
ດຸກາ ຕອບຢ່າງໂສກເສົ້າວ່າ: ຍ້ອນຂ້ອຍຖືກພັດພາກຈາກແມ່, ຈາກຄອບຄົວ ແລະ ຈາກປ່າຂອງຂ້ອຍ.
ຄິມ ແລະ ຕາມ ເວົ້າພ້ອມກັນວ່າ ເປັນຕາອີ່ຕົນເນາະ

“Hi, my name is Kim and here is my sister Tam. What is your name ?” Kim asked
“Douky” shyly answered the little monkey.
“Why are you so sad ?” Tam asked
“Because I have been separated from my family, my mum and my forest... “ explained Douky
“Oh! Poor Douky” answered Kim and Tam together

ຕາມ ເວົ້າຂຶ້ນວ່າເຈົ້າຄືຊິຫິວເນາະ! ດຽວຂ້ອຍຈະຫາຂອງກິນມາໃຫ້. ຕາມ ໄດ້ໝາກກ້ວຍ ແລະ ເຂົ້າມາ ແລ້ວຕາມກໍ່ເອົາໃຫ້ດຸກາ ກິນ, ແຕ່ຫຼັງຈາກທີ່ ດຸກາ ກິນເຂົ້າ ແລະ ໝາກກ້ວຍເຂົ້າໄປລາວກໍ່ບໍ່ສະບາຍ ຂຶ້ນມາທັນທີ. ຄິມ ຖາມ ດຸກາວ່າ “ເຈົ້າເປັນຫຍັງ?”
ດຸກາ ຕອບວ່າ ອາຫານທີ່ຂ້ອຍກິນເປັນປະຈຳບໍ່ແມ່ນແນວນີ້, ອາຫານຂອງຂ້ອຍແມ່ນປະເພດໃບໄມ້, ດອກໄມ້ ແລະ ໝາກໄມ້ ທີ່ມີຢູ່ແຕ່ໃນປ່າທີ່ເປັນບ້ານ ຂອງຂ້ອຍພຸ້ນ.
ຄິມ ແລະ ຕາມ ຕົກໃຈ ແລະ ຢ້ານ ແລ້ວເວົ້າເປັນສຽງດຽວກັນວ່າ: “ຄັນຊັ້ນເຈົ້າກະຢູ່ທີ່ນີ້ ກັບພວກບໍ່ໄດ້, ເຈົ້າຕ້ອງກັບໄປຢູ່ປ່າ”

“You must be hungry? I am going to bring you something to eat” suggested Tam. Tam came back with bananas and rice that she gave to Douky
But after he ate, Douky felt suddenly very sick. “What is happening to you?” Kim asked
“I cannot eat the same things as you... In the forest I feed on leaves, flowers and fruits that are found only where I live”
Kim and Tam started to panic: “But then, you cannot stay here, you must go back in the forest!” decided Kim and Tam



ຄິມ ແລະ ຕາມ ເລົ່າເລື່ອງລາວຂອງ ຂາແດງນ້ອຍ ສູ່ແມ່ຟັງ ແລະ ອ້ອນວອນໃຫ້ແມ່ເອົາ ຂາແດງ ນ້ອຍ ໄປປ່ອຍໃນປ່າ ເພື່ອໃຫ້ຂາແດງນ້ອຍ ໄດ້ຢູ່ກັບແມ່ ແລະ ຄອບຄົວ.

Kim and Tam explained the situation to their mum: “Mummy, please, you have to help us to *save Douky*, he cannot stay here, he must go back in the forest and be with his family !”

ຫຼັງຈາກໄດ້ຟັງເລື່ອງລາວຂອງ ຂາແດງນ້ອຍ ຈາກ ຄິມ ແລະ ຕາມ ແລ້ວ ແມ່ຂອງເຂົາເຈົ້າກໍ່ເຂົ້າໃຈ ວ່າ ຄົນບໍ່ສາມາດລ້ຽງຂາແດງໃຫ້ມີຄວາມສຸກໄດ້. ຂາແດງ ຈຳເປັນຕ້ອງອາຢູ່ໃນປ່າ ກັບຄອບຄົວ ບ່ອນທີ່ ຂາແດງ ຫາອາຫານກິນຢ່າງມີຄວາມສຸກ. ເອົ້າແລ້ວ ຄິມ, ຕາມ ແລະ ແມ່ ກໍ່ເອົາ ດຸກກີ້ ໄປປ່ອຍໃນປ່າບ່ອນທີ່ ດຸກກີ້ ເຄີຍຢູ່.

With the insistence of Kim and Tam, their mother understood that monkeys cannot stay with humans but only in the forest where they happily live with their family and find all the food they need to survive. The children and their mother took Douky back in the forest from where he came from.

ໃນທີ່ສຸດ ດຸກກີ້ ກໍ່ໄດ້ພົບກັບຄອບຄົວ ຂອງລາວ, ດຸກກີ້ ດີໃຈທີ່ສຸດ ທີ່ໄດ້ກັບຄືນມາປ່າແຫ່ງນີ້ ເຊິ່ງ ເປັນບ້ານ ອັນແສນອົບອຸ່ນ.

ສ່ວນ ຄິມ ແລະ ຕາມ ກໍ່ເຂົ້າໃຈວ່າ: ຂາແດງ ແລະ ສັດປ່າທຸກຊະນິດ ຄວນອາຢູ່ຕາມທຳມະຊາດ ແລະ ບ່ອນທີ່ໄດ້ ຮັບການຄຸ້ມຄອງ

Douky finally met with his family again, and was very happy to be back in his forest, his home...

Kim and Tam understood after this that monkeys and all other animals should always stay where they come from: their natural habitat, where they have to be protected...

PRIMATES OF LAO, PDR

(Note: Lao names can vary across the country)

LORISES (family Lorisidae)

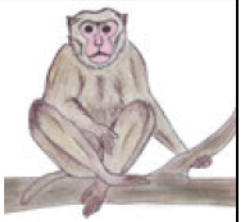
Pygmy loris ลิงลม้ัอย
(Nycticebus pymaeus)

Bengal slow loris [ลิงลม]
(Nycticebus bengalensis)

MACAQUES (family Cercopithecidae – subfamily Cercopithecinae)

Long-tailed macaque
ลิงหางยาว
(Macaca fascicularis)

Northern pig-tailed ลิงกัง
macaque (***Macaca leonina)***



Assamese macaque
ลิงแสมแบ่ว (ลิงอาซาม)
(Macaca assamensis)

Stump-tailed/bear macaque
ลิงเสม (ภะพีก, ลิงหมู)
(Macaca arctoides)

Rhesus macaque
ลิงออก (ลิงแกง)
(Macaca mulatta)

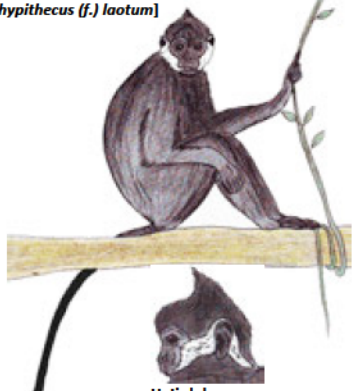
COLOBINES (family Cercopihecidae – subfamily Colobinae)

Red-shanked douc monkey
อาแกง
(Pygathrix nemaeus)

Silvered langur
ตะหลุง (โต่ง, ฮูง)
(Trachypithecus germaini/margarita)

[Lao langur
ค่างลาว
Trachypithecus (f.) laotum]

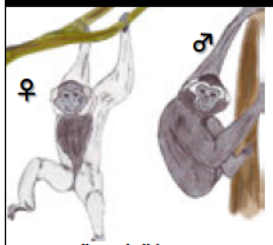
[Black langur
[no Lao translation]
Trachypithecus (f.) ebenus]



Hatinh langur
ค่างฮาติง
(Trachypithecus (f.) hatinhensis)

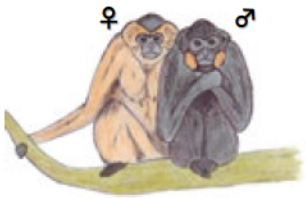
Phayre's langur
ค่างแว่นถิ่นเหนือ
(Trachypithecus phayrei)

GIBBONS (family Hylobatidae)



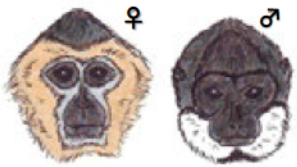
Pileated gibbon
ชะนีมงกุฎ
(Hylobates pileatus)

Northern white cheeked gibbon
ชะนีแก้มขาวถิ่นเหนือ
(Nomascus leucogenys)

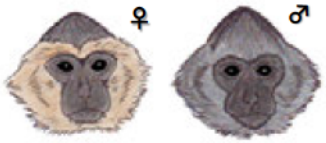


Northern buffed-cheeked gibbon
[ชะนีแก้มเหลือง]
(Nomascus annamensis)

White handed gibbon
ชะนีมือขาว
(Hylobates lar)



Southern white cheeked gibbon
ชะนีแก้มขาวถิ่นใต้
(Nomascus siki)



Black crested gibbon
ชะนีแก้มดำ
(Nomascus concolor lu)

Illegal wildlife trade is a major threat to non-human primates in Lao PDR. Primate conservation will only be achievable with the involvement of the Government, Non-Governmental Organizations, researchers and in particular the local people.

Camille C.

Distribution and use of the book in Lao, PDR is supported by:

GREEN DISCOVERY

VETERINARIANS WITHOUT BORDERS / VÉTÉRINAIRES SANS FRONTIÈRES

WILDLIFE CONSERVATION SOCIETY

WWF

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GAPE

Report on

The use of the children storybook
'Save Douky, the red-shanked douc'
in Lao PDR

Camille Coudrat

March 2012

Introduction

In April 2011, a grant from **Care for the Wild International** was received for the launch of a children storybook '*Save Douky, the red-shanked douc*' in the People's Democratic Republic of Lao (Lao PDR, or Laos). With the funding received, 900 copies were printed. Printing process was coordinated by Santi Saypanya from the *Wildlife Conservation Society*-Lao Program (WCS-Lao Program). Before final printing, the book was improved with new insertions of the primate species of Laos and the Lao translation was revised and finalised by Santi Saypanya.

The main objective of this children story book are **(1)** to raise awareness of the existence of primate pet trade in Indochina among young children living in the region, **(2)** to give them a simple and specific message about why humans should not keep primates as pets, **(3)** via this children book, to make a new environmental education material available for children in rural areas and urban areas.

The book was disseminated in Laos via ongoing projects of non-governmental and governmental organisations, schools and through my own PhD project currently being conducted in the Nakai-Nam Theun National Protected Area, central-eastern Laos.

This document is the second report concerning this project; a first progress report was previously sent to detail the first steps of the dissemination of the storybook including printing process (please refer to progress report 1). The present report comes with the end date of the Memorandum of Understanding (31st December 2011) between myself, Camille Coudrat, and Care for the Wild International (c.f. Appendix 1).

Partnerships

A total of nine (9) partners agreed to distribute the book through their projects:

- 100 copies to *Wildlife Conservation Society*-Lao Program (WCS)
- 100 copies to *World Wildlife Fund for Nature*-Lao Program (WWF)
- 100 copies to *International Union for Conservation of Nature*-Lao Program (IUCN)
- 100 copies to *Global Association for the People and the Environment* (GAPE)
- 100 copies to teacher Catherine O'Brien for use in *Vientiane International School* (VIS)
- 80 copies to *Green Care Fund* (program which organises short trips in forest for urban children from Vientiane to teach them about the environment)
- 20 copies to *Veterinarians Without Borders/Vétérinaires sans Frontières* (VWB/VSF) – *Canada*
- 100 copies to the *Nam Theun 2-Watershed Management and Protection Authority* (NT2-WMPA) (governmental organisation for the management of Nakai-Nam Theun National Protected Area – NNT NPA)
- 40 copies to *ElephantAsia* (ElephantAsia became a new partner only recently when they approached me to ask if I could provide books for their Elephant Mobile Library project)
- 4 copies to *Lycée Français Josué Hoffé* Vientiane (for reading in 2 classrooms of 5-6 year old children)
- The remaining copies are used through my own project in Nakai Nam Theun NPA

All partners signed a letter of agreement between them and myself (Camille Coudrat) (see Appendix 2). At the exception of some partners which came after printing process, all had their logo appearing on the back cover of the book.

APPENDIX V: continued

Uses of the book

1. **Question answering with 5-6 year old children at Lycée Français Josué Hoffé (see Plate 1):** I was invited to visit two classrooms of 5-6 year old children at *Lycée Français Josué Hoffé* Vientiane on the 8th May 2011 to answer children's questions about the story after it was studied with the teachers. Some questions asked were: how many monkeys [primates] there are in Laos? How many species? Where do they live? Why do people hunt them? What is your job? -- I also asked them some questions: have you ever seen monkeys kept as pets? Do you think monkeys eat the same things as humans? Do you think the monkey in the book (*Douky*) was happy living with the humans?
   These questions allowed me to educate my audience on the conservation of primates and other wildlife in a simple way, suitable for their age. The teachers also made photocopies of the pictures-to-colour-in for the children to all have a copy and colour it.

2. **Book distribution and activities in Village Vongsakeo, Dong Phou Vieng NPA with VWB/VSF Canada (see Plate 2):** I was asked to lead a Conservation project initiated by *Veterinarians Without Borders/Vétérinaires Sans Frontières-Canada* focussed on the silvered leaf monkey (*Trachypithecus germaini*) in Dong Sakee Sacred Forest, Dong Phou Vieng National Protected Area, southern part of Lao, PDR from May to June 2011. The red-shanked douc monkey is reported to occur in the area as well, however, unconfirmed; the villagers are familiar with the species. Twenty (20) copies were brought to the research site and distributed to kids in the village where we were based for the research (Ban [=village] Vongsikeo). An afternoon activity session was organised at the village school to do some games, songs, use another activity book I created for the project (focussed on the silvered langur), and read to them '*Save Douky the red-shanked douc'* storybook.

3. **Green Care Fund Project (see Plate 3):** The Green Care Fund Project was initiated by Green Discovery Laos in 2011 and aims to raise awareness of Lao teenagers (10-18 years old) about the importance of wildlife and habitats conservation. Green Care Fund vision is that "awareness of the young people is

the key to develop an efficient nature conservation policy and should be promoted and fostered". Green Care Fund brings Lao kids from urban areas into the forest for 2-day trips during which they learn about the environment and the wildlife. All kids are given books related to the topic. Eighty (80) copies of the book were given to Green Care Fund to use with their first trips.

On the 5th and 6th July 2011, one trip was organised by Green Care Fund at the WCS Training and Research Center inside the Nam Kading NPA. Thirty (30) 11-15 year old children attended the trip: 15 from the Pakkading Secondary School and 15 from the Saman Sophao secondary school (ethnic minorities) in Thakkek. For many of the kids aged 12 to 14 years it was an experience of their life time since they are coming from poor families. The Thakek school comprised mainly minority students from different ethnic groups while the other half of the group came from a secondary school near Pakkading. The young students enjoyed nature-related team building games in order to create bonds between them. They were professionally guided by Mr. Saming, a gifted 'animator' working with the provincial Department of Forestry and WCS.

4. **ElephantAsia Mobile Library Project (see Plate 4):** The Elephant Mobile Library brings ElefantAsia's and other Nature Protection INGOs' posters and books on elephant back directly to children in remote rural villages in Sayaboury province, Laos. Each children of the school visited are given one book while 50 more books are left at the school, temple, or other suitable spot, where children can trade their book for a new one after they read it.

   Forty copies of the book were provided to ElephantAsia to use through this project. From 15th to 20th October 2011, a first trip reached four primary schools in Sayaboury Province: Natak Primary School (183 children), Namon Primary School (229 children), Langkon Primary School (140 children), Houey Sao School (160 children).

5. **Distribution in Nakai Nam Theun NPA villages (see Plate 5 and 6):** Through my own ongoing project of wildlife conservation in NNT NPA, I go to extremely remote places, where school children do not have access to educational materials. At each field trip, some copies of the book are brought ad given to village chiefs to transfer to teachers of the local school who will be able to use it with the children. Twenty copies are distributed to each village visited.

APPENDIX V: continued

So far 80 copies were distributed in 3 villages (previous villages visited when book was not printed, will be provided with copies of the book as well through other means) (c.f. **Plate 5**).

In addition, 100 copies of 'Douky' were used for 3 'book parties' and a mobile library project on February 2012 (c.f. **Plate 6**): *'A Book for Every Child'* project led by Australian volunteer Karlee Taylor in 3 clusters within NNT NPA. Lao National volunteers, Australian volunteers and NNT NPA's staff conducted the book parties in 3 remote village schools of the NPA, which included interactive games, art, songs story telling activities. Each child was given the choice to choose one book to keep; the remaining books are kept at the schools as a mini-library for book exchange and education tools for the teachers. The mini-library will circulate between schools in each of the 3 clusters targeted. This project aims to "contribute to the strengthening of literacy levels within the National Protected Area whilst improving the capacity of teachers, District Education staff and NPA's staff to promote education and literacy through schools." (Karlee Taylor, project leader). In addition, to raise funds for the implementation, the project was previously linked to a preschool in Australia where 4-5 year old kids participated in activities related to the Lao culture; One copy of the book was sent to Australia for the teacher to read to the kids (c.f. **Plate 6**). The project's story was featured in the Lao National newspaper in English language, *The Vientiane Times* (c.f. **Plate 6**).

6. **Global Association for the People and the Environment (GAPE):** The books were given out to schools in villages in two districts (Pathoumphone and Paksong) in Champasak Province, Southern Laos, attempting to distribute the books to villages close to the forest where monkeys live. The villages are mostly isolated and the schools small. With the books, GAPE also replaced many of the book bags they gave out in the schools 6 years ago. The books will serve as a valuable component of the school libraries for years to come. In total, the books were given out in 25 different schools (18 in Pathoumphone and 7 in Paksong district) with kids from 4 to 15+ year old.

7. **Vientiane International School (VIS):** 100 copies of the book were given to schoolteacher Catherine O'Brien, working at the Vientiane International School. The 100 copies were distributed as follow:
   a) The story was used with Catherine's international student class of 8 year olds at VIS. Both the English and the Lao versions were read to the srudents and a reader's report was completed.
   b) A set of 5 books were given to the Lao primary school teacher for sole use in the Lao language class; it was noted that the books were welcome due to lack of resources in the school.
   c) A set of 5 books was given to the school library at VIS for class borrowing. The librarian noted that the set has been well used by classes completing the Unit of Inquiry called, "Sharing the Planet".
   d) A set of 25 books were given to the English Project in Luang Prabang (northern Laos), a private funded organization dedicated to working with Lao students to improve their studies across the curriculm, give them access to books, cameras, computers and a place for them to receive free tutoring in all areas of their studies. One of the projects is to develop, stock and distribute children's libraries to villages across Northern Lao. The donated books were to be put into these libraries.
   e) A set of 25 books was given to the local, Lao Sister school of VIS. The VIS community has just funded the building of a library at this school. The books were introduced to the students by VIS students and have been placed in the Lao school library.
   f) The remaining 60 books were taken by VIS for distribution by the secondary students when they went on study trips to the South and North of Lao. During these study trips the students work with designated local village schools for a week at a time. They were able to make good use of the books by introducing the books through shared experiences and then leaving the books with the schools.

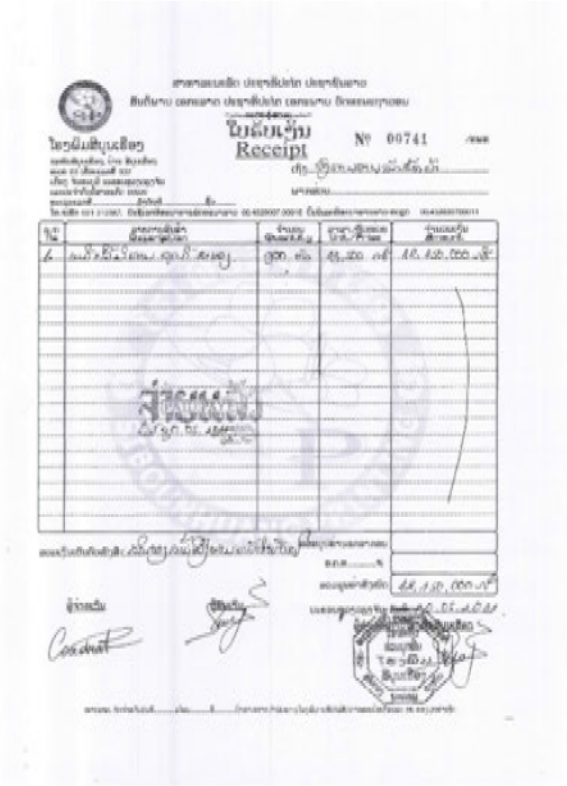
Teacher Catherine O'Brien said *"There is such a shortage of local content, bi-lingual books in Laos that for someone like myself working in Education it is not difficult to find appropriate places for the books to be sent to. Moreover students are receptive to the environmental content of the story. Thank you Camille for giving me the opportunity to distribute this book. I learnt that there is such a need for material like this and even a hundred books can be given away quickly to where they are needed."*

APPENDIX V: continued

8. **Others:**
   Copies of the book were also distributed to International NGOs who are using the books through various projects and events, mostly in Vientiane. So far, I did not receive detailed report from these NGOs.

Budget

Printing costs for the 100 copies was £ 945 (12,150,000 kip) (cf Receipt below). The remaining £ 180 is used for distribution of the book through my own project (transportation costs).



Future projects with the book

- The remaining copies (~40) will be distributed in a village (Ban Nathan) which I will be visiting early May 2012 where I will be conducting a small reconnaissance project on primate species in the Phou Hinpoun NPA, Laos in collaboration with a team of French scientists.
- Copies that were distributed to International NGOs (e.g. IUCN, WWF, WCS) will continue to be used through projects and public events.
- ElephantAsia intends to conduct more mobile library projects in Laos and are very interested in receiving more copies of the Douky book if funding allows me to reprint.
- If funding allows more reprints, more copies would be distributed to school teacher Catherine O'Brien (VIS School Vientiane for distribution to several projects).
- GreenCare Fund will continue to organise more field trips for young Lao students and are interested in reprinting the book.
- Any further activities with the book in Laos will be reported to Care for the Wild International.
- I was recently approached by the International organisation *Room to Read* that has worldwide projects to improve education in developing countries. They are interested in providing me with more funding to reprint the book 'Douky' and eventually more titles to distribute in Laos, where they have a National wide project.
- **Care For the Wild International** may be interested in staying involved in this project and in providing further funding for reprints in Laos. Reprints could this time be sold in Vientiane libraries with a percentage of the sales going back to Care for the Wild International, or to the Lao Wildlife Conservation Association – I hope to further investigate and discuss future possibilities with Care for the Wild International.

APPENDIX V: continued

Acknowledgements

This project would never have been possible without financial support from *Care for the Wild International*; thanks to CWI, Lao kids had access to a new book, many of them had never owned a book before.

I am extremely grateful to Santi Saypanya for kindly volunteering translating the English text to Lao and for his help throughout the printing process.

I thank all the organizations that agreed with enthusiasm to help with the dissemination of the storybook through their projects (in no particular order): WWF, WCS, IUCN, GAPE, GreenCare Fund, Catherine O'Brien (VIS), NT2-WMPA, VWB/VSF-Canada, ElephantAsia.

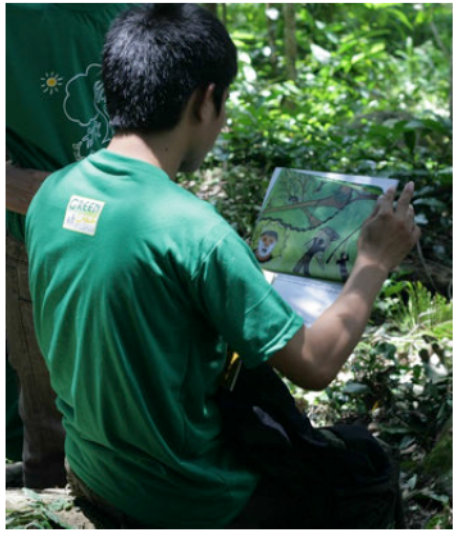
Thank you to Valérie Caralp and Hélène Delhumeau for inviting me in their classroom at *Lycée Français Josué Hoffé* Vientiane to talk to the children about the book.

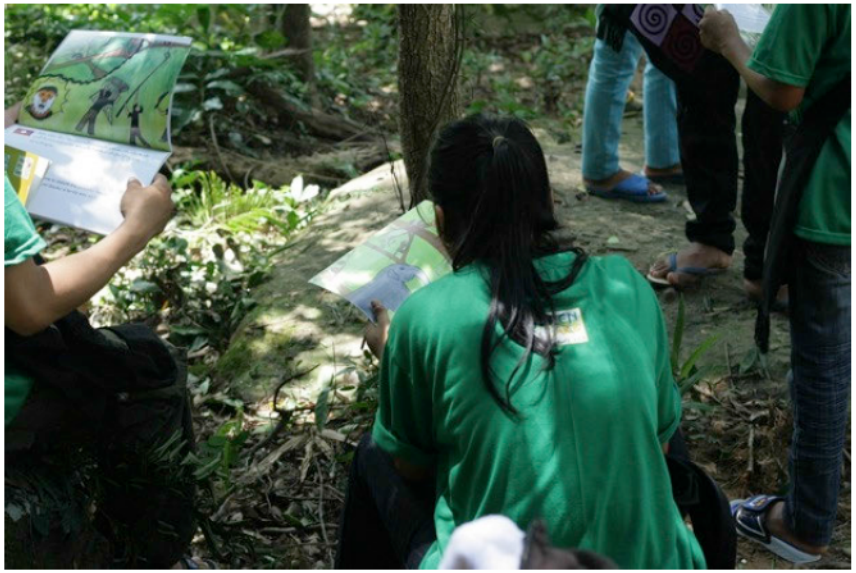
I thank Miss Karlee Taylor for her hard work with *'A book for Every Child'* project which was very successful and through which copies of Douky book were disseminated in Nakai Nam Theun NPA as well as read to Australian preschool kids.

Plate 1: Discussion with 5-6 year old children at *Lycée Français Josué Hoffé* Vientiane on May 8th 2011 about the storybook '*Save Douky, the red-shanked douc*'.

Plate 2: Distribution of the book in Ban Vongsikeo, Domg Phou Vieng National Protected Area, Southern central Lao, PDR.

Plate 3: GreenCare Fund trip to the WCS Training and Research Center inside the Nam Kading NPA, 5-6th July 2011.





Secondary school kids with '*Save Douky, the red-shanked douc*' story book, July 2011. (photos from GreenCare Fund)

Plate 4: ElephantAsia Mobile Library Project, 15-20th October 2011, Sayaboury Province.

Primary school kids with '*Save Douky, the red-shanked douc*' story book, Sayaboury Province, Laos, Oct 2011. (photos from ElephantAsia)

Plate 5: Distribution of the book in Nakai-Nam Theun National Protected Area. 100 copies donated to NT2-WMPA (were used through '*A Book for Every Child*' project – see below) and 100 copies disseminated through Camille's project in the NPA.

Plate 6: '*A Book for Every Child*' Project in Nakai-Nam Theun National Protected Area, led by Australian volunteer Karlee Taylor.

Kids receiving from project leader, Karlee Taylor, a copy of Douky book as a price for their participation in some activities.

Copies of the book given to villages chiefs of Korbong, Thapaiban and Tong villages (no picture taken for Xiengdao village)

Mini-library sets (including copies of Douky book) ready for dissemination in Nakai Nam Theun NPA.

PLATES

Plate 1: Photos of hunting evidence in Nakai Nam Theun National Protected Area in 2011-2012.

snares found at poacher camp

Vietnamese poachers

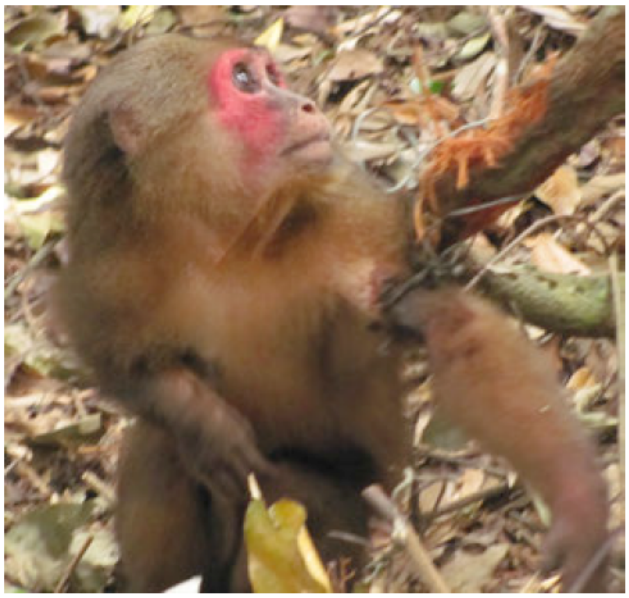
released civet from poacher camp

black-giant squirrel tail

commonly seen Vietnamese mark on tree

snare trap

man-made snare trail



bear macaque caught in snare (was released)

hog badger remain in snare

snares collected

ferret badger skull in poacher camp

civet remain in snare

hog badger skull in snare

grey peacock pheasant remain in snare

snare trap (possibly to catch pangolin)

Plate 1: continued

mouse deer remain in snare

macaques skull in poacher camp

snares collected

snares at poacher camp

wooden cages in poacher camp

poacher camp

infant gibbon in a village

douc skin

Plate 2: Photos of primates and hornbills taken in Nakai-Nam Theun National Protected Area, Laos in 2011-2012

2.a – red-shanked doucs (*P. nemaeus*)

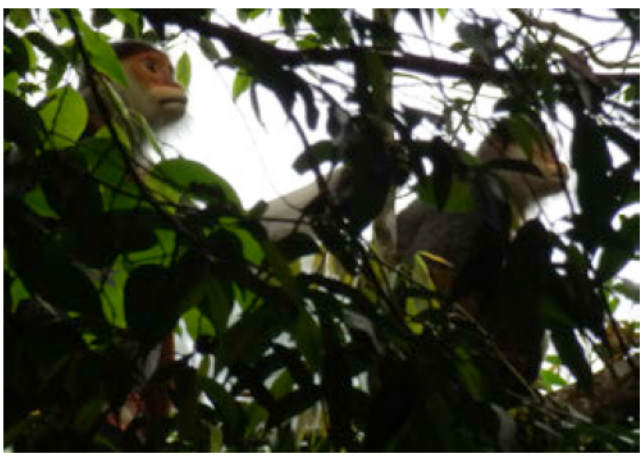
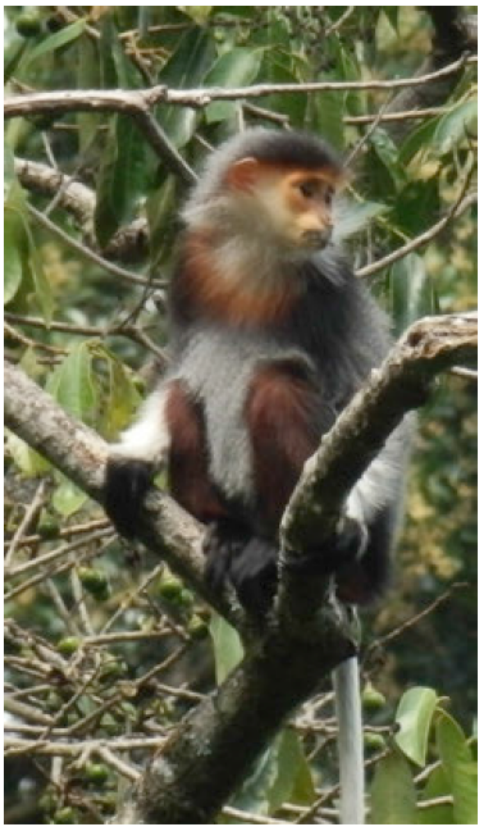
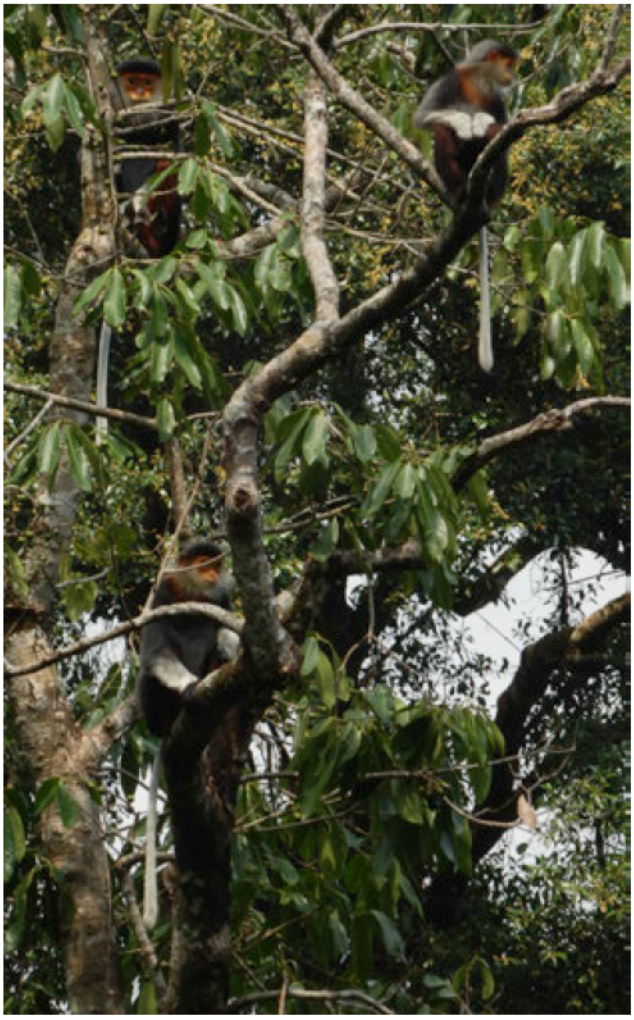


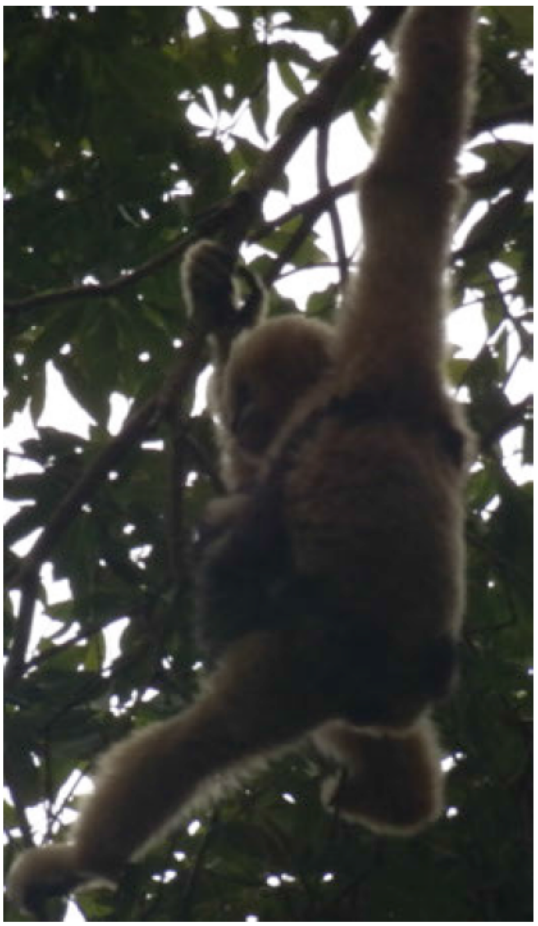
Plate 2: continued



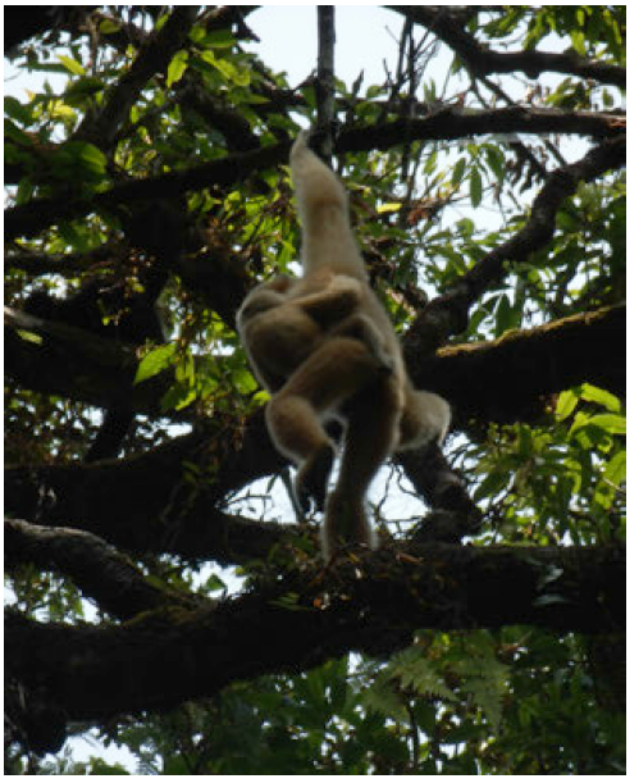


2.b – white-cheeked gibbons (*N. siki/leucogenys*)

female



female with infant

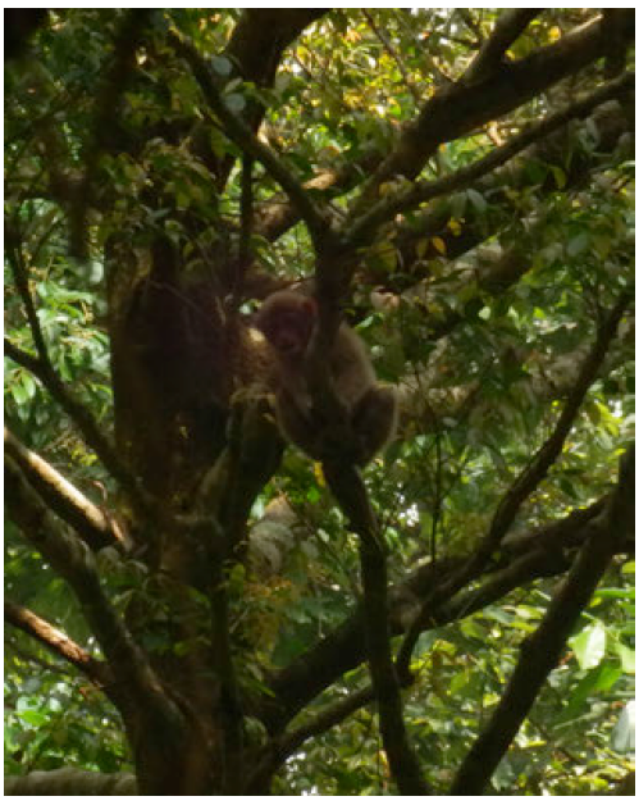


female with infant

female

Plate 2: continued

2.c – Assamese macaques (*M. assamensis*)



2.d – hornbills

rufous-necked hornbill (*Aceros nipalensis*)

brown hornbill (*Anorrhinus tickelli*)