The status and habitat of Yellow-cheeked Crested

# Phnom Prich Wildlife Sanctuary

## Gibbon *Nomascus gabriellae*, Mondulkiri

WWF Greater Mekong-Cambodia Country Programme

Phan Channa and Tom Gray

# Contents

# List of figures

# សេចក្តីសង្ខេប

ទោចថ្ពាល់ឈ្វឹងគឺជាប្រភេទដែលកំពុងទទួលការគំរាមកំហែងលើពិភពលោក ហើយមានវត្តមាននៅភាគខាងកើតទន្លេមេគង្គនៃប្រទេសកម្ពុជា និងភាគខាងត្បូងនៃប្រទេសវៀតណាម និងឡាវ។ ស្ថានភាពអភិរក្សសំរាប់សត្វប្រភេទនេះនៅភាគខាងជើងប្រទេសកម្ពុជាពុំទាន់មានការធ្វើអត្តសញ្ញាណកម្ម និងការសិក្សាប៉ាន់ស្មានចំនួនទោចប្រភេទនេះច្បាស់លាស់នៅឡើយ។ ការអង្កេតដើម្បីប៉ាន់ស្មានចំនួនក្រុមទោចថ្ពាល់ឈ្វឹងត្រូវបានធ្វើឡើងនៅក្នុងដែនជំរកសត្វព្រៃភ្នំព្រេចខេត្តមណ្ឌលគីរីនៃប្រទេសកម្ពុជា។ របាយ និងចំនួនក្រុមទោចថ្ពាល់ឈ្វឹងផ្អែកទៅការប្រមូលទិន្នន័យតាមរយៈសំណាកនៃការស្តាប់សំលេងរបស់វា ដែលបានសិក្សាពីខែមករារហូតដល់ខែមេសាឆ្នាំ២០០៨។ ការអង្កេតដោយប្រើបុស្តិ៍ស្តាប់សំលេងទោច ដែលក្នុងបុស្តិ៍នីមួយៗត្រូវចំណាយពេលបីព្រឹកជាប់ៗគ្នា ដើម្បីប៉ាន់ស្មាននៃចំនួនក្រុមទោច។ បុស្តិ៍ស្តាប់ចំនួន៥៣ ត្រូវបានគេរៀបចំឡើងនៅលើផ្ទៃដី៨៦៦គីឡូម៉ែត្រការេ ដែលជាជំរកសមស្របសំរាប់សត្វទោចថ្ពាល់ឈ្វឹង។ ការប៉ាន់ស្មានចំនួនក្រុមសរុបរបស់ទោចថ្ពាល់ឈ្វឹងនៅក្នុងដែនជំរកសត្វព្រៃភ្នំព្រេចគឺមានចំនួន១៤៩ក្រុម ក្នុងនោះមាន ៨៥ក្រុមជាទីជំរកព្រៃពាក់កណ្តាលស្រោង ១៨ក្រុមជាទីជំរកព្រៃពាក់កណ្តាលស្រោងតាមដងអូរ ៣៦ក្រុមជាទីជំរកព្រៃស្រោង និង៦ក្រុមជាទីជំរកព្រៃស្រោងតាមដងអូរ។ ប្រភេទទីជំរកដែលសមស្របសំរាប់ទោចថ្ពាល់ឈ្វឹងនៅភាគខាងជើងឈ្វេងខាងលិច និងក្នុងដែនជំរកសត្វព្រៃលំផាត់ខេត្តរតនគីរីគឺពុំមានវត្តមាននៃប្រភេទទោចនេះទេ ហើយភាគខាងជើងនៃដែនជំរកសត្វព្រៃភ្នំព្រេចអាចមិនមានវត្តមានប្រភេទទោចថ្ពាល់ឈ្វឹងផងដែរ។ ការប៉ាន់ស្មានចំនួនក្រុមទោចថ្ពាល់ឈ្វឹងរបស់យើងនៅក្នុងដែនជំរកសត្វព្រៃភ្នំព្រេចគឺធ្យើបទៅនឹងចំនួនក្រុមទោចនៅក្នុងតំបន់អភិរក្សជីវចំរុះសីម៉ាដែលចំនួនលើសពី៨០០ក្រុម។ ក្នុងចំណោមតំបន់ការពារទាំងអស់ ដែនជំរកសត្វព្រៃភ្នំព្រេចអាចជាតំបន់មានចំនួនទោចថ្ពាល់ឈ្វឹងទីពីរ បន្ទាប់ពីតំបន់អភិរក្សជីវចំរុះសីម៉ាដែលមានចំនួនច្រើនជាងគេនៅក្នុងពិភពលោក។ ការគំរាមកំហែងចំពោះសត្វទោចថ្ពាល់ឈ្វឹងនៅក្នុងដែនជំរកសត្វព្រៃភ្នំព្រេច រួមមានការបាត់បង់ទីជំរក និងការថយចុះនៃទីជំរកដោយសារសកម្មភាពមួយចំនួនដូចជា ការរុករករ៉ែ ការលួចកាប់ឈើ និងការអភិវឌ្ឍន៍ហេដ្ឋារចនាសម្ព័ន្ធសង្គម។ ទោះជាយ៉ាងណាក៏ដោយផ្អែកលើផែនការគ្រប់គ្រងតំបន់ច្បាស់លាស់កត្តាគំរាមកំហែងស្ថិតនៅក្នុងកំរិតដែលអាចទប់ស្កាត់បាន ព្រមទាំងមានប្រភេទព្រៃស្រោងជាទីជំរកសមស្របសំរាប់ការរស់នៅ ធ្វើអោយដែនជំរកសត្វព្រៃភ្នំព្រេចមានសក្តានុពលខ្ពស់សំរាប់ការអភិរក្សសត្វទោចថ្ពាល់ឈ្វឹង។

# Abstract

Yellow-cheeked crested gibbon *Nomascus gabriellae* is a Globally Threatened species (IUCN - Endangered) restricted to the east of the Mekong River in Cambodia, Vietnam and Laos. The conservation status of this taxon is however clouded by the uncertain taxonomic status of northern populations and the lack of accurate population estimates. Surveys were conducted in Phnom Prich Wildlife Sanctuary, Mondulkiri province, Cambodia to assess the status of the gibbon population around this protected area. Distribution and population size were obtained from auditory sampling undertaken between January and April 2008. The survey used single listening posts, visited on three consecutive mornings, to estimate the density of gibbon groups. Fifty-three listening posts were established across 866 $km^2$ of suitable habitat. These were used to obtain a gibbon population estimate. The estimated total population size within Phnom Prich WS was 149 (95% CI range: 15-273) gibbon groups; 89 groups in semi-evergreen forest; 18 groups in riparian semi-evergreen forest; 36 groups in evergreen forest and 6 groups in riparian evergreen forests. Suitable habitat in the north-west of the site, and within Lumphat Wildlife Sanctuary, Ratanakiri, were unoccupied by gibbon suggesting Phnom Prich Wildlife Sanctuary may represent the northern distributional limit of typical yellow-cheeked crested gibbon. Our population estimate compares to >800 groups within Seima Biodiversity Conservation Area, the only other site within the species' range with similarly robust population estimates. Among protected areas, Phnom Prich Wildlife Sanctuary may support the 2nd largest global population of taxonomically unambiguous *Nomascus gabriellae*. Threats to gibbon within Phnom Prich Wildlife Sanctuary largely derive from habitat loss and degradation driven by extractive activities (mining and logging) and associated infrastructure developments. However given strong future management the site has good potential conservation value for yellow-cheeked crested gibbon due to the current relatively manageable threat levels and a habitat mosaic that includes several large patches of suitable evergreen forest.

# The status and habitat of Yellow-cheeked Crested Gibbon *Nomascus gabriellae* in

# Phnom Prich Wildlife Sanctuary, Mondulkiri

**March 2009**

**Phan Channa and Tom Gray**

# Introduction

Crested Gibbons (*Nomascus*) are one of four main taxonomic groups within the Gibbon family (Hylobatidae) and are represented by 4-6 recognized species occurring in the tropical evergreen and semi-evergreen forests of Indochina east of the Mekong river (Brandon-Jones et al. 2004). All species are IUCN listed as globally threatened (IUCN 2008), making the genus a priority for primate conservation. Yellow-cheeked crested gibbon *Nomascus gabriellae* is traditionally regarded as occurring in northeastern Cambodia, southern Vietnam and southern Laos (Duckworth et al. 1995; Geissmann et al. 2000; Rawson et al. in press) and was listed in the 2000 IUCN Red List as Globally Threatened-Vulnerable. However the species listing has recently been uplisted to Endangered on the basis of accelerating declines in the extent of range occupied and perceived increases in the level of exploitation (Geissmann 2007; IUCN 2008). Therefore, as one of sixteen globally Endangered mammal species within Cambodia (IUCN 2008), yellow-cheeked crested gibbon must be regarded as of high conservation significance within the country.

Populations of yellow–cheeked crested gibbon are threatened due to the loss and fragmentation of their habitats (driven by illegal logging, shifting cultivation, and land encroachment), hunting for food or for use in traditional medicine, and for trade in the pet market (Duckworth et al. 1999; Geissmann et al. 2000; Traeholt et al. 2005). Additionally, harvest of non-timber forest products may drive the decline of food supply and disturb habitat (Pang 2005) whilst forest fires spreading from deciduous forest to adjacent patches of evergreen forest may also be a factor in habitat degradation (Traeholt et al. 2005). Traeholt et al (2005) regarded the species as more threatened than the second gibbon present in Cambodia, pileated gibbon *Hylobates pileatus*. Approximately 50% of prime habitat was regarded as lying outside the protected areas network with easy access to hunters from Vietnam and Laos further exacerbating threats. Basic population viability analysis suggested that, of the six populations analysed, three, including the largest within Virachey National Park, Ratanakiri, were likely to decline to critical levels within 20-30 years (Traeholt et al. 2005).

*Nomascus* gibbon are widely distributed in Cambodia east of the Mekong River, ranging from Snoul Wildlife Sanctuary in Kratie north to Virachey National Park in Stung Treng and Ratanakiri provinces (Fig. 1). However the taxonomic status of gibbon within northern Cambodia is unclear. The Virachey population, which is contiguous with areas in southern Laos, has been assigned, on the basis of vocalisations (Konrad & Geissmann 2006) and genetics (Van Ngoc Thinh in prep), to an ambiguous, possibly hybrid, taxon with closer affinities to *Nomascus siki* of central Vietnam and Laos than the more typical *N. gabriellae* of southern Mondullkiri and Kratie. Further studies have therefore been recommended to assess the genetic and taxonomic status of Nomascus species in north-eastern Cambodia (Geissmann 2007).

There are few data on the behaviour and ecology of yellow-cheeked crested gibbon. However, in recent years the species has received some study in Seima Biodiversity Conservation Area (SBCA), Voensei district, Ratanakiri, Cambodia, and Cat Tien National Park Vietnam (Dang &

Osborn 2004; Rawson 2004; Ouk 2005; Pang 2005; Phan Channa 2008; Rawson et al. in press). Yellow-cheeked crested gibbon prefer undisturbed evergreen forest with a tall broadleaf component (Dang & Osborn. 2004; Traeholt et al. 2005) though other habitat types such as semi-evergreen, mixed deciduous and bamboo forest are also used (Rawson et al. in press). The species seems tolerant of moderately disturbed forest, including selectively-logged habitat and areas close to human habitation and agricultural encroachment when hunting pressure is not high (Rawson et al. in press). Yellow-cheeked crested gibbon live in small groups that have an average size of two to six members including an adult pair and their immature offspring. They call in the early morning (Rawson 2004), and they may sing either solo songs or duets. The diet of yellow-cheeked crested gibbon is ripe fruits, young leaves, shoots, buds, stems, and insects (Ouk 2005). Social groups are headed by a male who defends the territory and forages for food. Ranging distance depends on resource availability and the weather (Ouk 2005); approximately 30 ha in evergreen forest but up to 100 ha in bamboo forest (Rawson et al. in press).

Although rapid reconnaissance surveys of most large blocks of suitable gibbon habitat across the species' Cambodian range were conducted in the early 2000s (Traeholt et al. 2005), population estimates using standard techniques, and representatively covering sites with sufficient sample size, have only been conducted at one site, Seima Biodiversity Conservation Area in southern Mondulkiri (Rawson et al. in press; Pollard et al. 2007). Additional surveys to clarify the status of yellow-cheeked crested gibbon within other Cambodian sites are therefore a priority. Previous surveys have documented the presence of yellow-cheeked crested gibbon, believed to be of the typical *N. gabriellae* form, within Phnom Prich Wildlife Sanctuary (PPWS) in the centre-west of Mondulkiri Province (Timmins & Ou 2001; Traeholt et al. 2005). Given the remoteness of this wildlife sanctuary, combined with manageable levels of threat including limited recent evidence of habitat loss or degradation and few reports of gibbon hunting, Traeholt et al. (2005) identified PPWS as being of high potential conservation value for the species. The aims of this study were to use single listening point count surveys (Brockelman & Srikosamatara 1993) to determine the distribution and population density of yellow-cheeked crested gibbon in Phnom Prich Wildlife Sanctuary.

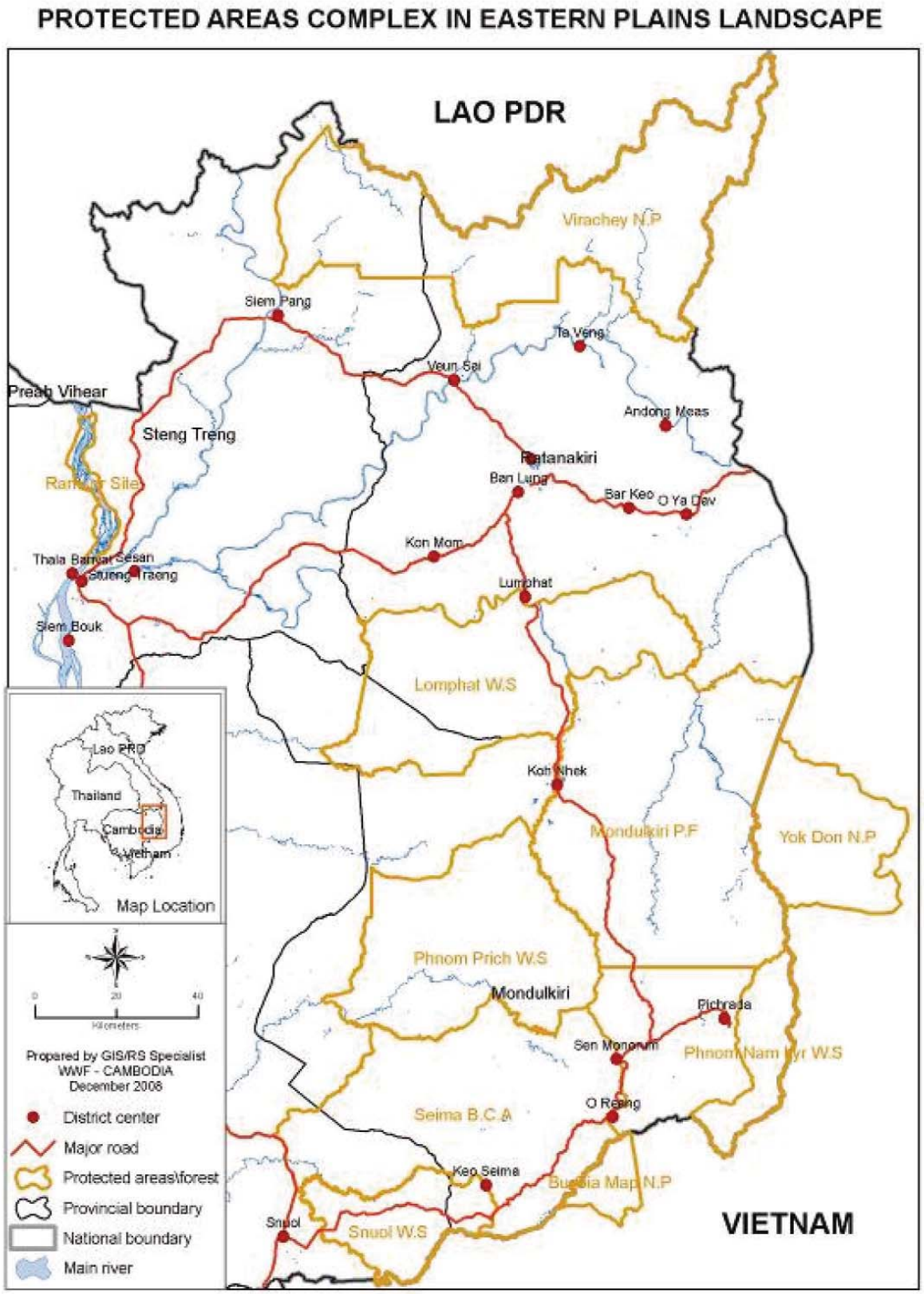


Figure 1) Protected Areas within the Eastern Plains Landscape of Cambodia.

# Study area

Phnom Prich Wildlife Sanctuary (PPWS) is located in the west of Mondulkiri Province, north-east Cambodia (centered on 12.8° N, 106.5° E) (Fig 1). Originally designated a reserve forest by Former King Sihanouk in 1962 as a refuge for Kouprey *Bos sauveli*, PPWS was established as a Wildlife Sanctuary by royal decree in 1993. PPWS covers 2,225 $km^2$ (>15 % of total area of Mondulkiri province) in two districts; Koh Nhek and Keo Seima. Terrain is characterized by higher elevation and relief (max. 640 m) in the southeastern Laoka Hills portion near the Mondulkiri plateau before sloping down towards the north and west to gently undulating lowlands with elevation ca. 80-200 m over most of the sanctuary. The lowlands have scattered, isolated hills, the most important being Phnom Kongshal (426 m) and Phnom Ngort (413 m).

The PPWS forest forms part of one of the largest remaining relatively undisturbed landscapes in mainland Southeast Asia and consists of an intricate mosaic of deciduous (or dry) dipterocarp forest and woodland (1027$km^2$), evergreen forest (262$km^2$) and semi-evergreen forest (808$km^2$). Although floristic compositions of these habitats are poorly defined, semi-evergreen forests appear dominated by *Lagerstroemia* spp. and are also notable for having extensive patches of short bamboo understory (WWF 2006). The open forest mosaics of north-east Cambodia support important faunal assemblages particularly of large mammals and waterbirds that have been extirpated from most other parts of south-east Asia. Although the flora and fauna of PPWS have not been adequately studied the sanctuary appears to contain irreplaceable globally significant populations of a number of key species including Banteng *Bos javanicus*, Jungle Cat *Felis chaus*, Giant Ibis *Thaumatibis gigantea* and White-shouldered Ibis *Pseudibis davisoni*, *Gyps* vulture spp. and Siamese Crocodile *Crocodylus siamensis* (WWF 2006). The central area of the sanctuary may also support the largest Asian Elephant *Elephas maximus* population in eastern Cambodia whilst an unknown number of Indochinese Tiger *Panthera tigris corbetti* are also present. Inventorying species groups and developing baseline population estimates for monitoring of key species are conservation priorities within PPWS (WWF 2006).

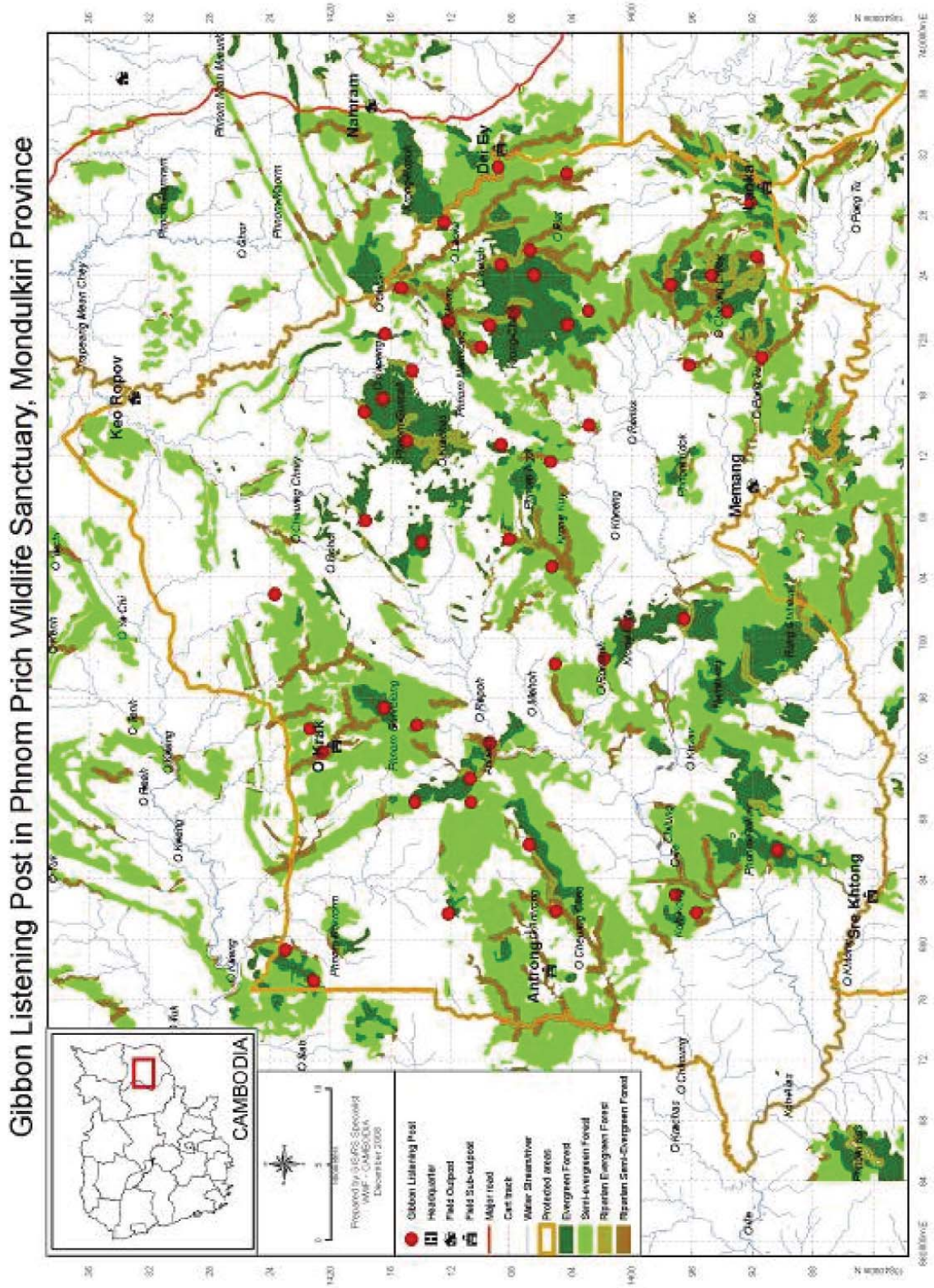


Figure 2) Distribution of evergreen and semi-evergreen forest and locations of surveyed gibbon listening posts within Phnom Prich Wildlife Sanctuary. Note seven listening posts in Sre Khitong range not analysed for population estimates are not indicated.

# Methods

### Listening posts

Gibbons typically live high in the thick canopy of evergreen and semi-evergreen forest and are very wary, with responses to detection of humans ranging from noisy flight to quiet hiding (O'Brien et al. 2004). However all gibbon species are known to produce loud, long and well patterned song bouts. In many species these are preferentially produced in the early morning, in the hours prior to, around, or after dawn (Geissmann 1993; Geissmann & Orgelginger, 2000; Rawson 2004; Geissmann & Nijman 2006). Song bouts have durations of 15-30 minutes and, depending on species and environmental conditions, can be audible over long distances (i.e. >2km) (Rawson 2004; O'Brien et al., 2004; Waller, 2005; Geissmann et al., 2005). Within yellow-cheeked crested gibbon, social groups sing regularly in the morning performing either solo (male/female or juvenile only) or duet (male and female) song bouts (Rawson 2004; Rawson et al. in press). Therefore to counter the problems associated with the limited visibility of gibbons in the canopy, and the variable response of gibbons to detection of humans, Brockelman and Ali (1987) pioneered the use of audio point counts for estimating gibbon density. This technique is now widely used for surveying gibbon populations (Nijman 2004; O'Brien et al. 2004; Traeholt et al. 2005; Whittaker 2005; Cheyne et al. 2008; Rawson et al. in press) and was the method used in this study.

### Survey design

This survey used single listening posts distributed randomly across PPWS within 4 habitat strata (2 major classes and 2 minor classes). Habitat classes were based on vegetation types generated by the MPW-JICA-2000 land cover data set (JICA 2000). Based on prior knowledge of gibbon habitat preferences within PPWS listening posts were restricted to evergreen and semi-evergreen forest patches and no surveys were conducted within the dipterocarp forest. The two initial major classes were evergreen and semi-evergreen forest (JICA, 2000 refers to the latter class as "mixed evergreen and deciduous forest"). Within each of these major classes a substratum for a riparian zone i.e. a buffering of the major streams by 250 meters on either side (total riparian zone width 500 m) was generated. This stratification resulted in 4 classes: evergreen forest, riparian evergreen forest, semi-evergreen forest and riparian semi-evergreen forest (Fig 2). From each of these four strata 15 survey sites were generated randomly across the whole of PPWS, using the x-tools extension in ArcGIS (ESRI 1999), with the restriction that no two listening posts be located closer than 3km from each other. A total of 60 listening post sites were identified (Fig 2), however accurate data was not collected from seven posts (2 in evergreen forest, 2 in semi-evergreen forest and 3 in riparian semi-evergreen forest) all within Sre Khtong range. Although presence/absence of singing gibbon was obtained from these posts the number of groups calling was not recorded, leaving data from 53 listening posts for the final analysis. The elevation of listening posts ranged from 107 to 626 m.

## Survey timing and methodology

Previous observations of yellow-cheeked crested gibbon in Cambodia and Vietnam suggest vocalisations are more frequent in the dry season (November-April), with heavy rainfall suppressing vocal activity (Rawson 2004; Rawson et al. in press). Consequently, to maximize the song bouts heard by surveyors, data collection was carried out during the dry season with surveys conducted between January and April 2008. Gibbon calling activity is, however, also dependant on a variety of additional factors (Cowlishaw 1996; Nijman 2004; Rawson 2004; Cheyne 2008), and Brockelman and Ali (1987) recommend, to reliably estimate density, that survey periods should be adequate to provide 90% probability of detection. Rawson et al. in press, based on observation of focal gibbon groups in SBCA over a variety of weather conditions, calculated the probability of detecting calls over three survey days in the dry season was 91.5%. Therefore all listening posts were surveyed for 3 consecutive mornings.

Six survey teams, each comprising two Ministry of Environment rangers, were used in data collection. In January 2008 rangers were trained in data collection protocols (e.g. use of compass for recording the direction of gibbon calls, how to listen to and estimate the distance of calling gibbons) during a field training session supervised by Phan Channa (Fig. 3). During data collection ranger teams navigated to pre-designated listening posts using hand-help GPS, and camped >1000m away from the listening posts. Listening post surveys were conducted on 3 consecutive mornings between 05:00 and 12:00, with all duet and solo songs recorded (Fig. 3). For all song bouts the following information was recorded: compass bearing direction to the group, estimated distance of calling, time of starting and ending of all song bouts, and type of song. As solo songs can be performed by non-mated individuals which are not resident within the area, data from solo songs were excluded from final analysis. In addition given that variation in topography and weather conditions between listening posts are both known to affect carrying distance of gibbon calls (Cheyne et al. 2008) it was assumed that song bouts >1.5 km from listening posts could not be recorded reliably and consistently. Therefore prior to data analysis all calling records estimated to be >1.5 km from listening posts were also excluded.


Figure 3) Training of Ministry of Environment rangers (top) and ranger team recording data at a listening post (bottom).

## Data analysis

The total number of gibbon groups within PPWS was estimated based on gibbon densities surrounding each listening post calculated using Jiang et al.'s (2006) modified version of the equations from Brockelman and Ali (1987).

Gibbon calling frequency (p) across PPWS was calculated by summing the vocalisations from all posts for the 1st day and dividing by the sum of the cumulative vocalisations of all posts over the three day period (Jiang et al. 2006). Across our listening posts this value was 0.77. The cumulative proportion of the total number of gibbon groups heard calling over 3 survey days at listening posts (calling probability p(m)) can subsequently by determined by the equation:
$p(m) = 1- [1- p]m$
where p = calling frequency and m = number of survey days i.e. 3
Across the listening posts surveyed this calling probability, over 3 consecutive survey days, was 0.988.

The total estimated number of gibbon groups at each listening post (Xi) was then estimated using the equation:
$Xi = ni / P(m)$
Where ni = cumulative number of gibbon groups heard in the three days period at listening post i, P(m) = calling probability over 3 survey days (i.e. 0.988).

The density of gibbon at each listening post (Di) was then calculated using the equation:
$Di = Xi / ai$
Where Xi = estimated number of gibbon groups at listening posti; ai = survey area at listening posti (i.e. 7.065 $km^2$; see below).

This estimate depends upon the effective survey area surrounding listening posts, and previous studies on yellow-cheeked crested gibbon, including Rawson's et al (in press) observation of focal individuals, have suggested 1.5km as a reasonable maximum carrying distance for vocalistations (Duckworth et al. 1995; Traeholt et al. 2005). Therefore gibbon densities were calculated within a 1.5km radius (7.065 $km^2$) of each listening post.

Mean gibbon density within each habitat stratum was subsequently calculated from densities at all listening posts within each habitat type. The total population of gibbon groups within each habitat stratum (Xy) was then calculated using the equation:
Xy= dy * Sy
Where dy= mean density of gibbon groups across all listening posts within habitat stratum y, Sy= total area of habitat stratum y.

The total gibbon population across PPWS was then calculated by summing the estimated total population of gibbon groups across the four habitat strata.

### Field surveys within Lomphat Wildlife Sanctuary and Prey Khieu

In order to clarify the distribution of yellow-cheeked crested gibbon north of PPWS, listening posts were established within suitable evergreen forest in Lumphat Wildlife Sanctuary (approximately 13.2° N, 106.3° E; 2 listening posts) and Prey Khieu (former Kingwood logging concession) on the Mondulkiri/Kratie provincial border (approximately 13.3° N, 106.4° E; 3 listening posts). Listening posts within Lomphat were located within Prey Thmon, an evergreen forest block of approximately 80km$^2$, close to the Mondulkiri/Ratanakiri provincial border (Fig. 4). Listening posts were surveyed on three consecutive mornings at each site during February and March 2008. During both surveys local villagers, particularly older people and former hunters, were interviewed by MoE rangers and questioned about the presence/absence of gibbon within the area.

# Results

### Population size of yellow-cheeked crested gibbon in Phnom Prich Wildlife Sanctuary

Yellow-cheeked crested gibbon were detected from all surveyed habitat strata and from four of the six management ranges of Phnom Prich Wildlife Sanctuary (Fig. 5). A total of 57 gibbon groups were heard with records from 17 (32%) of the 53 listening posts. The number of gibbon groups heard per listening post ranged from 0 to 7 groups, with a mean of 1.08 groups (± 1.875 SD). Density of gibbon groups varied between 0.12 and 0.19/km$^2$ across the four habitat strata with non-riparian forest apparently holding higher gibbon densities (Table 1). Semi-evergreen forest within the wildlife sanctuary is estimated to support 89 gibbon groups, with 36 in evergreen forest and a total of 24 between riparian evergreen and semi-evergreen forests (Table 1). The total gibbon population within PPWS was therefore estimated at 149 groups. Assuming an average group size of 4 individuals (an adult pair and 1-4 sub-adults; Geissmann et al. 2000), and ignoring non-mated individuals, gives a population estimate for the site of approximately 600 individuals.

| Habitat Type | Area ($km^2$) | Group density ($km^{-2}$) | Number of groups |
|---|---|---|---|
| Evergreen forest | 205 | 0.18 ± 0.19 | 36 (15-57) |
| Semi-evergreen forest | 469 | 0.19 ± 0.36 | 89 (0-183) |
| Riparian evergreen forest | 46 | 0.13 ± 0.25 | 6 (0-12) |
| Riparian semi-evergreen forest | 146 | 0.12 ± 0.28 | 18 (0-21) |
| **TOTAL** | | | 149 (15-273) |

Table 1) Mean density (± SEM) of yellow-cheeked crested gibbon groups surrounding listening posts within four habitat strata, and estimated total number of groups (95% CI range) within each habitat strata, in Phnom Prich Wildlife Sanctuary, Mondulkiri

### Distribution of yellow-cheeked crested gibbon in Phnom Prich Wildlife Sanctuary

Based on the distribution of occupied listening posts the yellow-cheeked crested gibbon population within PPWS is largely restricted to evergreen forest patches in the south and east of the wildlife sanctuary (Fig.5) with records from two distinct blocks: Phnom Kongshal /Kong Chilok/Laoka to the east and around Sre Khitong in the south-west. These strongly correspond to the largest blocks of evergreen forest within the wildlife sanctuary, highlighting the importance of medium-large fragments of such forest for the species (Fig. 5). Yellow-cheeked crested gibbon were not recorded from either Antrong management range, in the north-west of the site, or from the smaller Dei Ey range in the east.

### Status of yellow-cheeked crested gibbon within Lomphat WS and Prey Khieu

No gibbon were recorded from any of the listening posts within Lomphat Wildlife Sanctuary or Prey Khieu. Local people encountered around Prey Khieu reported gibbon had never been present within the area. Interviewees from villages surrounding Prey Thmon, Lumphat reported gibbon were present during the 1960s and 1970s but were heavily hunted and are no longer present.

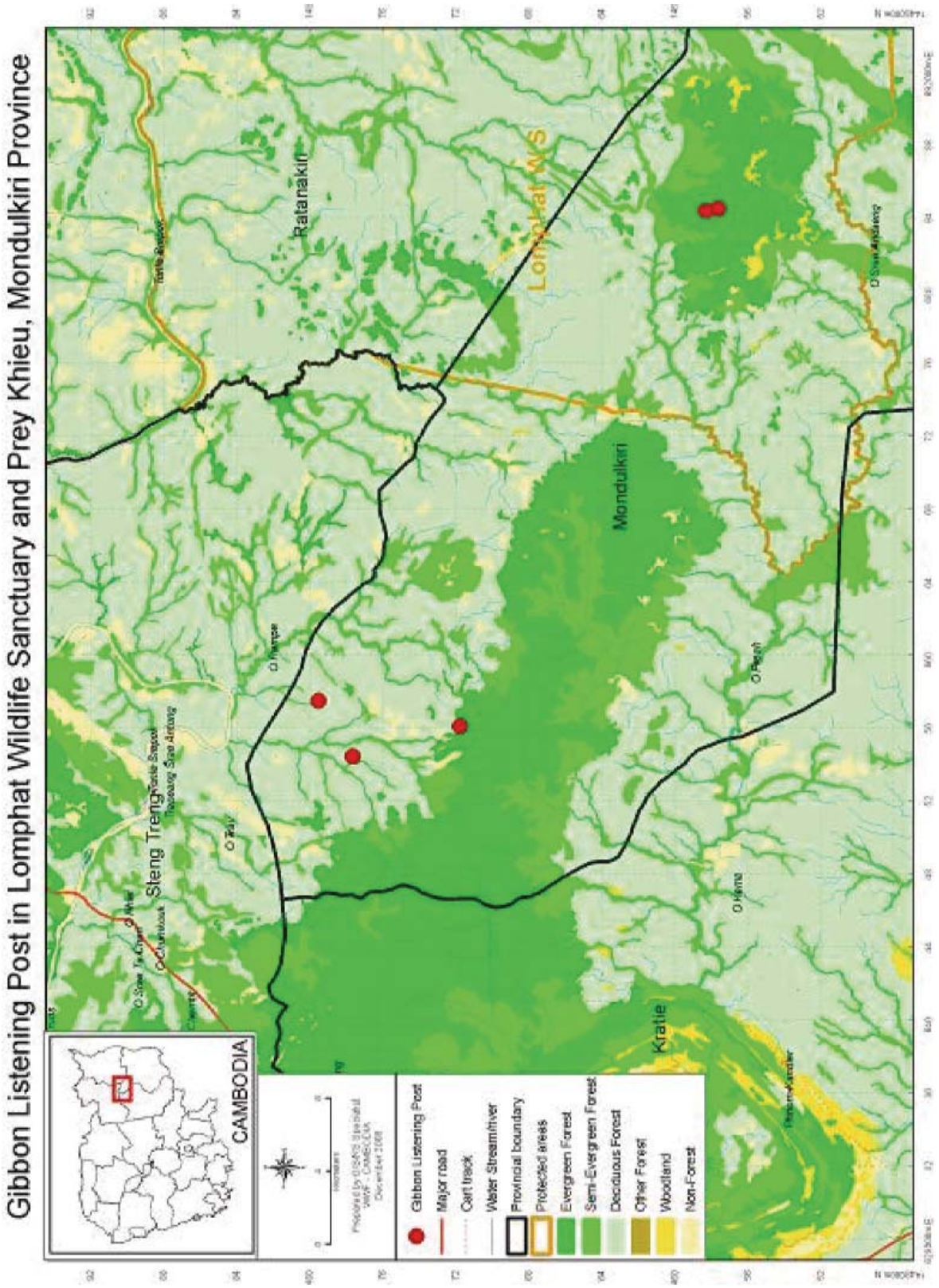


Figure 4) Locations of gibbon listening posts within Lomphat Wildlife Sanctuary and Prey Khieu, north-western Mondulkiri province, Gibbon were not recorded from any of these posts.

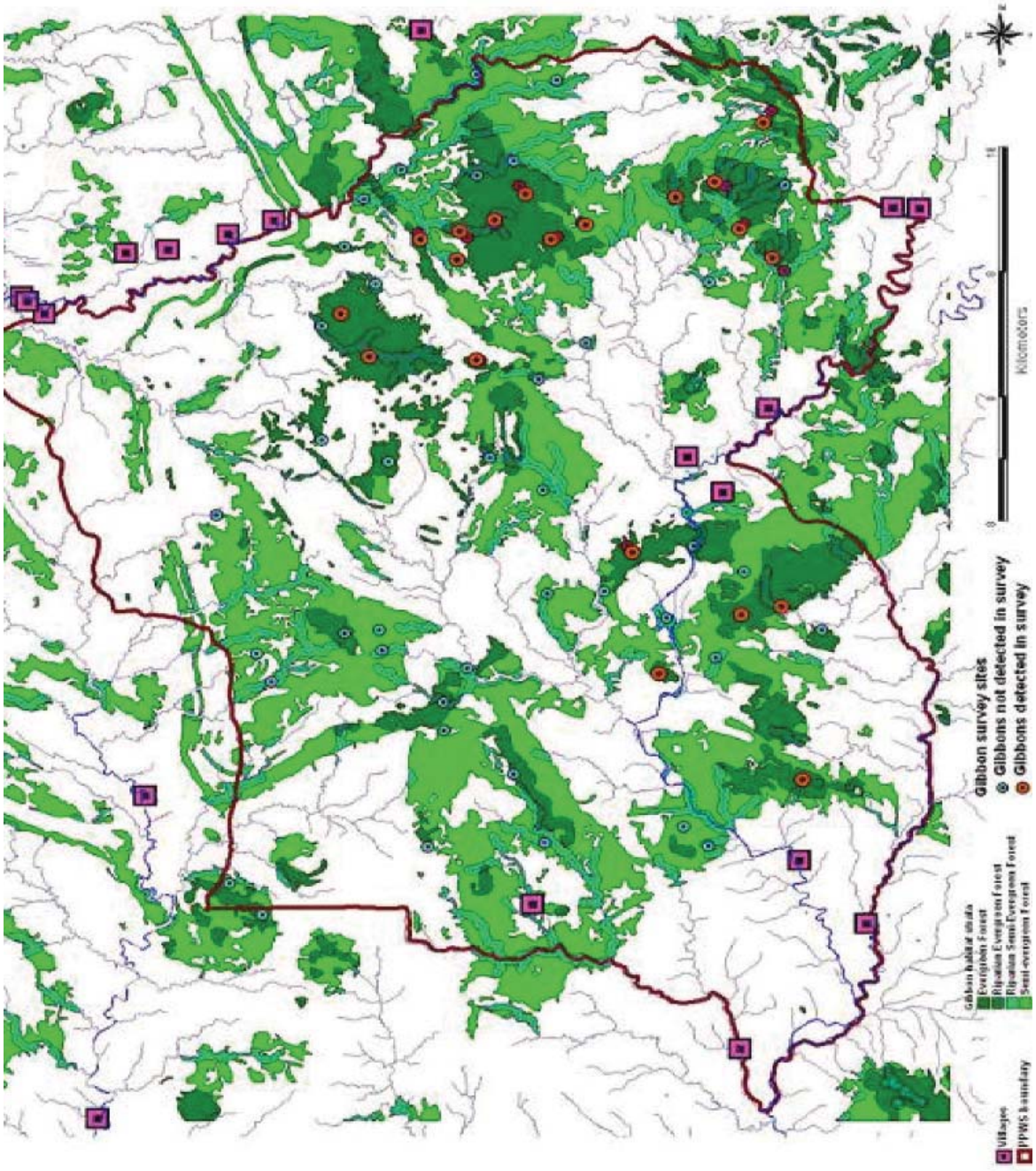


Figure 5) Presence and absence of gibbon from listening posts within Phnom Prich Wildlife Sanctuary. Note includes data from seven listening posts in Sre Khitong range not analysed for population estimate.

# Discussion

The yellow-cheeked crested gibbon population within Phnom Prich Wildlife Sanctuary (PPWS) is of global significance for the conservation of this Endangered species. We estimate 149 groups within the protected area which, assuming 4 individuals per group (Geissman et al. 2000; Pollard et al. 2007), gives an overall estimate of > 550 individuals. This represents the first robust population estimate for yellow-cheeked crested gibbon at this site and complements a similarly rigorous estimate of approximately 800 groups (>3,500 individuals) from the adjacent Seima Biodiversity Conservation Area (SBCA; Rawson et al. in press; Pollard et al. 2007). Assessing the global relevance of these populations is, however, clouded by uncertainties of the taxonomic status of *Nomascus* taxa within Laos and northern Cambodia, and the lack of rigorous population estimates from elsewhere within the species' range. Traeholt et al (2005) estimated in excess of 10,000 gibbon groups around Virachey National Park, Ratanakiri and whilst, as the authors acknowledged, this rapid survey may overestimate the population, Virachey is still likely to support the largest *Nomascus* population within Cambodia. Recent genetic (Van Ngoc Thinh in prep) and vocalisation studies (Konrad & Geissman 2006) however suggest this population more closely resembles N. siki of southern Laos and central Vietnam. Only limited evergreen forest remains between PPWS and Virachey and, with our surveys suggesting gibbon absence from Lumphat WS and Prey Khieu, PPWS may represent the current northern limit of typical N. gabriellae. Prey Khieu, in the former Kingwood logging concession, forms part of an apparently large block of evergreen forest (>1,000km2) east of the Mekong river in Stung Treng and Kratie provinces. This area was also partially surveyed by Traeholt et al. (2005) in 2003; again no gibbon were recorded.

In southern Vietnam substantial populations of yellow-cheeked crested gibbon are believed to be restricted to Cat Tien National Park (estimated <200 groups in two sub-populations) and possibly Bu Gia Map National Park to the south of SBCA (Geissmann et al. 2000; Rawson pers. comm.). Both populations may be severely targeted by hunters. Given apparent rapid and on-going habitat loss within two additional protected areas within the species' range (Snoul Wildlife Sanctuary, Kratie and Phnom Nam Lyr Wildlife Sanctuary, Mondulkiri) it seems likely that PPWS supports the second largest protected area population (after the adjacent SBCA) of yellow-cheeked crested gibbon. These two protected areas are therefore essential for the species' survival.

### Limitation of current survey

Although more rigorous than the previous estimate of 360 groups residing in PPWS, derived from the rapid surveys of Traeholt et al. (2005), this current study may inaccurately estimate the population of yellow-cheeked crested gibbon within PPWS for a number of reasons. As with the majority of surveys using audio-sampling to calculate gibbon densities information is only provided on the number of gibbon groups; non-mated solo individuals, who make up an unknown proportion of gibbon populations, are excluded. Therefore data from line transect surveys, or other methodologies in which all individuals are recorded, may not be comparable. However a number of studies (including Rawson et al. in press on yellow-cheeked gibbon in

SBCA) have shown at least limited congruence between population estimates based on listening posts and line-transects (Nijman and Menken 2005).

Variation in effective survey area around listening posts may also affect the precision of our final population estimates. Carrying distances of gibbon calls can be affected by terrain (Cheyne et al. 2008). Therefore variation in topography surrounding the randomly distributed listening posts within PPWS could have caused non consistent survey areas between listening posts. As with previous studies on yellow-cheeked crested gibbon (Duckworth et al. 1995; Traeholt et al. 2005; Rawson et al. in press) we calculated gibbon density assuming a maximum carrying distance of song bouts of 1.5km. However under some circumstances, for example if listening posts are located within valleys, carrying distance may be reduced, which could lead to an underestimation of the total gibbon population. For example, using the more conservative value of 1km gives a total estimate of >300 gibbon groups within PPWS.

The survey methodology may also have failed to detect gibbon groups in areas where they occur at low population density. Surveys did not record gibbon from within the Dei Ey or Antrach ranges of PPWS despite local people and field rangers reporting small numbers (i.e. <5 groups) present at both sites. It is possible therefore that either the sample size of listening posts within these areas was not sufficient to detect gibbon, or that density-dependant variation in calling frequency confounded results. Calling frequency by gibbon groups can be affected by factors as varied as season (Rawson 2004), ambient weather (O'Brien et al 2004), environmental conditions (Cheyne 2008), habitat disruption (Johns 1985), food availability (Cowlishaw 1997; Rawson 2004) and, possibly, population density (Nijman 2004). Brockelman and Ali (1987) presented some evidence that song bouts in Hylobates gibbons were stimulated by those of neighbours; low density populations could therefore be stimulated to sing less often. Nijman (2004) also presented limited evidence that low (<2 groups/km$^2$) density populations of Javan Gibbon Hylobates moloch call less often than higher (>2 groups/km$^2$) density populations and speculated that this variation could affect population estimates. Although Rawson et al. (in press), based on data from SBCA, suggested 3 subsequent days at each listening post is sufficient to detect >90% of gibbon groups within detection range, this may possibly be insufficient in some low density areas of PPWS. However the effect of density on calling frequency in primates appears to be surprisingly poorly studied given the high profile of these species in conservation and research; future study into how population densities affect calling probability, and thus detection, in gibbons seems essential.

Population estimates may also be affected by inaccurate identification of the extent of available habitat from remotely sensed data sets. Within SBCA Rawson et al. (in press), also using the 2000 JICA data-set, found no significant differences in gibbon density between evergreen, semi-evergreen and mixed deciduous forests dominated by *Lagerstroemia* spp.. It was concluded that the resolution of JICA was insufficient to represent the heterogeneous nature of deciduous forests within SBCA with many gibbon groups in these areas utilising small patches of evergreen forest located on hills or along rivers. Ad-hoc ground-truthing of the JICA data set during 2008 around PPWS (e.g. near Dei Ey) has also found some areas classified as deciduous dipterocarp forest strongly resemble semi-evergreen forest and may thus be suitable for gibbon (T Gray pers obs).

Conversely assuming that all of the habitat classified by JICA as evergreen/semi-evergreen forest is suitable for gibbons may over-estimate the population. These forest types are often patchily distributed within the deciduous forest matrix of PPWS (Fig. 2) and many fragments may be too small or isolated to support gibbon. The preliminary results of a logistic regression model of gibbon habitat preferences and distribution within PPWS, based on gibbon presence/absence from the listening posts, indicates a potential threshold fragment size of >15 $km^2$; smaller fragments, representing greater than 50% of the evergreen forest cover within PPWS, were predicted as unsuitable for the species (Gray et al in prep). Restricting the extent of suitable habitat to that predicted by the model gives an estimate of <100 gibbon groups within PPWS (Gray et al in prep). Further work exploring the minimum fragment size of evergreen/ semi-evergreen forest capable of supporting gibbon is clearly necessary for accurate assessment of gibbon population size for monitoring purposes.

### Habitat preferences of yellow-cheeked crested gibbon in Phnom Prich Wildlife Sanctuary

Within PPWS yellow-cheeked crested gibbon were detected within all four habitat types surveyed: evergreen forest, semi-evergreen forest, riparian evergreen forest and riparian semi-evergreen forest type. These findings confirm that the species may be quite flexible in its habitat usage (Rawson. et al. in press) and is not restricted to one specific habitat type. Mean density of gibbon groups did not differ greatly between habitat types although densities appeared lower in riparian than non-riparian habitats. Rawson et al. (in press) provide a number of references indicating that, traditionally, riparian forest habitats have been regarded as less suitable for gibbon species and our findings may provide some support for this hypothesis.

Highest gibbon densities were apparently found within semi-evergreen forest (0.19 groups/$km^2$) with an estimated population within this habitat type of 89 groups; two-thirds of the total within PPWS. Previous gibbon studies, other than Rawson et al. (in press) in SBCA, have however suggested that evergreen forest is the preferred habitat for gibbon. In contrast our results indicate that semi-evergreen forest in PPWS supports a higher population density than evergreen forest. It is possible however that this conclusion is misleading as the boundary between semi-evergreen and evergreen forest can be gradual and thus difficult to define precisely. Therefore the remote sensing-generated classification used here may not be precise. There is also the distinct possibility that some listening posts located in semi-evergreen forest allowed detection of gibbon groups that actually were occurring in evergreen forest. The habitat preference model (Gray et al in prep) and the distribution of occupied listening posts across PPWS (Fig. 5) strongly suggest that evergreen forest is the preferred habitat yellow-cheeked crested gibbon with a high proportion of listening posts within semi-evergreen forest unoccupied. Within PPWS gibbon presence within semi-evergreen forest may be highly dependant upon the proximity to large blocks of evergreen forest. The variety of resources present year-round within these evergreen forests may be essential for maintaining gibbon populations in this habitat type even during periods of low-resource availability.

Gibbon densities within PPWS (<0.2 groups/$km^2$) are lower than the adjacent SBCA (>0.7 groups/$km^2$). This probably reflects the more patchy and fragmented distribution of suitable habitat within the deciduous diptero-

carp (DDF) matrix with a number of evergreen/semi-evergreen forest patches within PPWS too small or isolated to support gibbon groups. Despite the presence of considerable evergreen and semi-evergreen forest (c. 200 km$^2$) yellow-cheeked crested gibbon were not recorded within the north-west of PPWS e.g. Antrong range and north-west Keo Ropov. These areas are separated from other, occupied areas of PPWS, by considerable DDF containing only small fragments of semi-evergreen forest and evergreen forest (Fig 4). This DDF may act as a barrier to gibbon dispersal (Srikosamatara & Doungkhae 1982) preventing the colonisation of northwestern PPWS.

## Threats to yellow-cheeked crested gibbon in Phnom Prich Wildlife Sanctuary

Globally, primate populations are threatened by habitat loss, hunting and the wildlife trade. A recent IUCN re-assessment of the conservation status of primates classified 70% of Asian species as globally threatened. The situation is particularly dire in Indochina with 90% of Cambodian, 86% of Vietnamese and 83% of Laotian primates IUCN-classified (Schipper et al. 2008). Habitat loss, fragmentation and hunting are regarded as major threats to gibbon species; the recent re-assessment classified 88% of the 25 recognised Hylobatidae taxa (species and subspecies) as Endangered or Critical (Geissmann 2007; IUCN 2008).

The main threats to yellow-cheeked crested gibbon within PPWS appear to be habitat loss and degradation caused by legal and illegal extractive activities (primarily gold mining and selective logging) and associated activities within the wildlife sanctuary. Yellow-cheeked crested gibbon are, however, regarded as generally tolerant to, at least, minor habitat alterations (Geissmann et al. 2000; Rawson et al. in press). Indeed wider studies into the long-term affects of commercial logging on primates have largely demonstrated a surprising resilience to habitat alteration particularly among species with high dietary flexibility (Plumtree 1994; Chapman et al. 2000; Guo et al. 2008). However Infrastructure developments associated with logging and other extractive activities are well documented to ease access to remote forest areas thereby facilitating hunting, permanent settlements and further habitat degradation (Schwartzman et al. 2000; Laurance et al. 2008).

As with much of Mondulkiri poorly regulated mining operations appear likely to have the biggest impact on the conservation value of PPWS in the near future. Gold mining activities were recorded during field surveys in the vicinity of four listening posts. Habitat degradation associated with gold mining includes harvesting of wood, for fuel in mineral processing and for the construction of stairs and supports for underground mines (Claassen & Ou, 2007). Human population density can also increase around gold mines with outsider laborers coming in to work the mines, and clearing forest for settlement and subsistence agriculture. Indeed a semi-permanent settlement within the boundaries of PPWS featuring temples, schools and karaoke parlors has recently been developed adjacent to a gold mine (Phan Channa pers.obs.).This in-migration into PPWS may also increase the demand for wildlife products.
Survey teams also recorded evidence of illegal logging and associated infrastructure within PPWS. Most loggers appeared to be from outside Mondulkiri, and were targeting *Afzelia xylocarpa*, a globally threatened (IUCN Endangered; IUCN 2008) and valuable tree. As noted earlier logging

is associated with the development of roads in order to extract timber, whilst loggers also spend at least several days within the forest often subsisting on natural resources, including primate meat. Although gibbons are widely hunted across Indochina hunting activity of gibbon was not recorded in PPWS during this survey. However hunting is likely to remain at least a background threat, and enforcement patrols, particularly targeting core gibbon areas and around mining and logging camps, are necessary (see recommendations).

Although the gibbon population within PPWS seems relatively large and may therefore be resilient to extinction in the short-term, increased enforcement, through patrols to limit hunting and, more importantly, prevent further land-use change within the wildlife sanctuary are essential, Local extinctions of gibbon associated with habitat clearance and intensive hunting are widely reported in the literature (Geissmann et al. 2003; Zhou et al. 2005; Jiang et al. 2006) and our interviews suggest extinction from Lumphat Wildlife Sanctuary during the Khmer Rouge-era (see results). It seems possible therefore that, despite some tolerance to habitat degradation, gibbon may be amongst the species most rapidly lost from poorly protected habitat.

Yellow-cheeked crested gibbon within PPWS and SBCA also appear to exist at lower densities than those reported for the majority of other gibbon species (Table 2). Brockelman and Srikosamatara (1993) considered gibbon densities of less than two groups/km$^2$ as low and, whilst it may be questionable to compare densities between genera and between Sundaic forests and Indochina, all reported Nomascus densities fall below this number. In comparison with Hylobates gibbon, it is possible Nomascus may occur at naturally low densities, perhaps related to more specialisation within this genus. This could lead to lower populations, more susceptible to stochastic extinction events, even when considerable habitat remains.

# Recommendations

### Research and monitoring

| Species | Location | Density (groups/km$^2$) | Reference |
|---|---|---|---|
| *Symphalangus syndactylus* | Sumatra, Indonesia | 2.23 | O'Brien et al. 2004 |
| *Hylobates albibarbis* | Kalimantan, Indonesia | 2.59 | Cheyne et al. 2008 |
| *Hylobates muelleri* | Kalimantan, Indonesia | 2.1-2.9 | Nijman & Menken 2005 |
| *Hylobates agilis* | Sumatra, Indonesia | 0.67 | O'Brien et al. 2004 |
| *Nomascus siki* | Central Vietnam | 1.3 | Geissmann 2007 |
| *Nomascus concolor* | Yunan, China | 0.67 | Jiang et al. 2006 |
| *Nomascus gabriellae* | SBCA, Cambodia | 0.71 | Rawson et al. in press |
| *Nomascus gabriellae* | PPWS, Cambodia | 0.15 | This study |

Table 2) Mean estimates of gibbon density (groups/km$^2$) from the literature. All estimates based on listening post surveys

- Repeat listening surveys every 2-3 years to assess changes in the population and distribution of yellow-cheeked crested gibbon with in PPWS. Given recent concerns about data from listening post surveys distance sampling techniques may be more suitable (O'Kelly pers. com.) however gibbon densities within PPWS may be too low to generate sufficient data (Rawson pers. com). Future surveys how ever must:
  1. Ensure sufficient sampling within Sre Khtong range in south-west PPWS as extent of gibbon occurrence within this portion of the reserve is unclear
  2. Identify a more accurate GIS data set to differentiate habitat types within the wildlife sanctuary and exclude habitat fragments likely to be too small for gibbon

- Assess the taxonomic status of *Nomascus* gibbon within PPWS – this can involve collaborative work with researcher Van Ngoc Thinh from WWF-Vietnam.

### Protection and enforcement

The results of this survey can be used to identify important areas of PPWS for yellow-cheeked crested gibbon. These should be targets for increased enforcement activities and must be included within the core areas of the wildlife sanctuary. The essentially continuous block of evergreen and semi-

evergreen forest within Laoka range between Phnom Kongshal and O Cheung Chrey appears to be particularly important for gibbon and all habitat encroachment here should be halted particularly as this area also holds significant numbers of Asian Elephant (MoE rangers pers. comm; WWF unpublished data). The connectivity of gibbon habitat within Laoka and Memang ranges to the extensive evergreen forests of SBCA and its associated large yellow-cheeked crested gibbon population, is unclear. Forest either side of the road between the provincial capital Sen Monorum and Memang village may be essential for dispersing gibbon. Maintaining continuous forest cover, and preventing further encroachment, in this area is essential. Key recommendations are therefore to:

- Increase frequency of enforcement patrols in and around key gibbon areas, particularly Krong Chilok, Phnom Kongshall, and Phnom Rohav to limit hunting. Particularly target loggers and gold miners.
- Work with provincial and national authorities to prevent further habitat degradation associated with gold mines and limit any new mining activities within the wildlife sanctuary.
- Work with provincial and national authorities to limit habitat encroachment and degradation particularly on road between Sen Monorum and Memang.

# Conclusions

Despite acute threats to its potential biodiversity value, primarily from mining and illegal logging, Phnom Prich Wildlife Sanctuary has the potential to be crucial for conservation and the ecological integrity of the Eastern Plains Landscape of Cambodia. Estimating population size for focal species, and assessing their distribution within PPWS, is essential. This study establishes a baseline population estimate for yellow-cheeked crested gibbon and highlights the global significance of PPWS for this endangered primate, and suggests the site represents the northern limit of the species' distribution within Cambodia. The study provides further support to WWFs commitment to conservation within the sanctuary and highlights the global conservation value of evergreen forest patches within the deciduous dipterocarp matrix of the Eastern Plains Landscape.

# Acknowledgments

This study was conducted as part of WWF Greater Mekong Cambodia Program's Eastern Plains Landscape project. Major funding was provided by USFWS-Great Apes Conservation Fund grant no. 94210-7-G183. . Work in PPWS was supported by His Excellency Chay Samith of the MoE and Chak Sokhavicheaboth the Director of PPWS. Data collection was undertaken by the dedicated ranger teams of PPWS including Ou Dorn, Heng Dout, Prenh Vanna, Yan Sania, Touch Sovandy, Chat Khve, Prouch Khve, Sab Treo, Sim Samon, Ngoeum Kean, Meas Channy, and Yet Sron. We thank Andy Maxwell for project conceptualization and planning, and are grateful for significant input from Ben Rawson of Conservation International-Indo-Burma, and Tom Clements and Edward Pollard of WCS Cambodia. We also thank Khou Eang Hourt, Craig Bruce, Huy Keavuth, and Lim Kannitha for help throughout the project.


Figure 6) Field ranger teams in Phnom Prich Wildlife Sanctuary January 2008.

# References

Brandon-Jones, D., Eudey, A.A., Geissmann, T., Groves, C.P., Melnick, D.J., Morales, J.C., Shekelle, M. and Stuart, C.B. 2004. Asian primate classification. International Journal of Primatology 25: 97-164

Brockelman, W. Y. and R. Ali. 1987. Methods of surveying and sampling forest primate populations. pp 23-62 in: Marsh, C.W. and Mittermeier, R.A. eds. Primate Conservation in the Tropical Rainforest Alan R. Liss, Inc, New York.

Brockelman, W.Y. and Srikosamatara, S. 1993. Estimating density of gibbon groups by use of the loud songs. American Journal of Primatology. 29:93–108

Champan, C.A, Balcomb, S.R., Gillespie, T.R., Skrupa, J.P. and Struhsaker, T.T. 2000. Long-term effects of logging on African primate communities: a 28-year comparison from Kibale National Park, Uganda. Conservation Biology 14: 202-217

Cheyne, S.M. 2008. Effects of meteorology, astronomical variables, location and human disturbance on the singing apes: Hylobates albibarbis. American Journal of Primatology. 70: 386-392

Cheyne, S.M., Thompson, C.J.H., Phillips, A.C., Hill, R.M.C. and Limin, S.H. 2008. Density and population estimate of gibbons (Hylobates albibarbis\0 in the Sabangau catchment, Central Kalimantan, Indonesia. Primates 49: 50-56.

Claassen, A.H. and Ou R. 2007. A stream and wetland survey of southwestern Phnom Prich Wildlife Sanctuary and adjacent areas, with a focus on large waterbirds. WWF Greater Mekong, Cambodia Country Programme, Phnom Penh

Cowlishaw, G. 1996. Sexual selection and information content in gibbon song bouts. Ethology 102: 272-284.

Dang K.X. and Osborn, T. 2004. Biodiversity and Socio-economic Assessment of Loc Bac State Forest Enterprise, Lam Dong Province, Vietnam. Cat Tien National Park, World Wide Fund for Nature and Koninkrijker Nederlanden, Hanoi.

Duckworth, J. W., Timmins, R., Anderson, G. Q. A., Thewlis, R. M., Nemeth, E., Evans, T. D., Dvorak, M. and Cozza, K. E. A. 1995. Notes on the status and conservation of the gibbon Hylobates (Nomascus) gabriellae in Laos. Tropical Biodiversity 3: 15-27.

Duckworth, J.W., Salter, R.E. and Khamkhoun Khounboline. 1999. Wildlife in Lao PDR: 1999 Status Report. IUCN/WCS/Centre for Protected Areas and Watershed Management, Vientiane.

ESRI. 1999. ArcView GIS 3.2a. Environmental Systems Research Inc, Redlands, California, USA.

Geissmann, T. 1993. Evolution of communication in gibbons (Hylobatidae). PhD thesis, Zürich University, Switzerland.

Geissmann, T. 2007. Status reassessment of the gibbons: Results of the Asian Primate Red List Workshop 2006. Gibbon Journal 3: 5-15

Geissmann, T. and Nijman, V. 2006. Calling in Wild Silvery Gibbons (Hylobates moloch) in Java (Indonesia) Behavior, Phylogeny, and Conservation. American Journal of Primatology 68: 1–19.

Geissmann, T. and Orgeldinger, M. 2000. The relationship between duet songs and pair bonds in siamangs, Hylobates syndactylus. Animal Behaviour 60: 805–809

Geissmann, T., Nguyeen Xuan Dang, Lormee, N. and Momberg, F. 2000. Vietnam Primate Conservation Review 2000. Part 1: Gibbons. Flora and Fauna International – Indochina Programme, Hanoi.

Geissmann, T., Nguyen Xuan Dang, Lormée, N. and Momberg, F. 2003: Status review of gibbons in Vietnam. Asian Primates 8: 10-12.

Geissmann, T., Bohlen-Eyring, S. and Heuck, A. 2005. The male song of the Javan silvery gibbon (Hylobates moloch). Contributions to Zoology 74: 1-2.

Guo S.T., Ji W.H., Li B.G. and Li M. 2008. Responses of a group of Sichuan snub-nosed monkeys to commercial logging in the Qinling Mountains, China. Conservation Biology 22: 1055-1064

IUCN 2008. IUCN red-list 2008. http://www.iucnredlist.org/.

Jiang X.L., Luo Z.H. and Zhao S.Y. 2006. Status and distribution patterns of black crested gibbon (Nomascus concolor jingdongensis) in Wulian Mountains, Yunnan, China: implications for conservation. Primates 47: 264-271.

JICA. 2000. Cambodia Reconnaissance Survey Digital Data Project. Ministry of Public Works and Transportation. Phnom Penh, Cambodia.

Johns, A.D. 1995. Behavioural responses of two Malaysian primates (Hylobates lar and Presbytis melalophus) to selective logging: vocal behaviour, territoriality and nonemigration. International Journal of Primatology 6: 423-433

Konrad, R., and Geissmann, T. 2006. Vocal diversity and taxonomy of Nomascus in Cambodia. International Journal of Primatology 27: 713-745.

Laurance, W.F., Croaes, B.M., Guissouegou, N., Buih, R., Dethier, M. and Alonso, A. 2008. Impacts of Roads, Hunting, and Habitat Alteration on Nocturnal Mammals in African Rainforests. Conservation Biology 22: 721-732

Nijman, V. 2004. Conservation of the Javan Gibbon Hylobates moloch: population estimates, local extinctions and conservation priorities. The Raffles Bulletin of Zoology 52: 271-280.

Nijman, V. and Menken, S.B.J. Assessment of census techniques for

estimating density and biomass of gibbons (Primates: Hylobatidae. The Raffles Bulletin of Zoology 53: 169-179

O'Brien, T. G., Kinnaird, M. F., Nurcahyo, A., Iqbal, M. and Rusmanto, M. 2004. Abundance and distribution of sympatric gibbons in a threatened Sumatran rain forest. International Journal of Primatology 25: 267-284.

Ouk P. 2005. Study on Natural Habitat of Yellow-Cheeked Crested Gibbon at Virachey National Park, Ratanakiri Province. Bachelors Thesis, Royal University of Agriculture, Faculty of Forestry Science, Phnom Penh.
Pang P. 2005. Study on the Foods Preference of Yellow-Cheeked Crested Gibbons in Virachey National Park, Ratanakiri Province. Bachelors Thesis, Royal University of Agriculture, Faculty of Forestry Science, Phnom Penh,.

Phan Channa. 2008. Habitat utilisation of yellow-cheeked crested gibbon in Rattanakiri province, Cambodia. MSc Thesis. The Royal University of Phnom Penh, Cambodia.

Plumptree, A.J. 1994. The effect of selective logging on the primate populations in the Budongo Forest Reserve, Uganda. Journal of Applied Ecology 31: 631-641.

Pollard, E., Clements, T., Nut Meng Hor, Sok Ko and Rawson,B. 2007. Status and conservation of globally threatened primates in the Seima Biodiversity Conservation Area, Cambodia. WCS, Phnom Penh.

Rawson, B. M. 2004. Vocalisation Patterns in the Yellow-cheeked Crested Gibbon (Nomascus gabriellae). pp. 130-136 in: Nadler, T., Streicher, U. and Ha Thanh Long (eds). Conservation of Primates in Vietnam. Haki Publishing, Hanoi..

Rawson, B. M., Clements, T. J. and Nut Meng Hor (In press). Status and Conservation of Yellow-cheeked Crested Gibbons in Seima Biodiversity Conservation Area, Mondulkiri Province, Cambodia. In The Gibbons: New Perspectives on Small Ape Socioecology and Population Biology (Eds, Lappan, S. and Whitaker, D. M.). Springer, New York

Schipper, J. et al. 2008. The status of the world's land and marine mammals: diversity, threat and knowledge. Science 322: 225-230.

Schwartzman, S., Moreira. A. and Nepstad, D. 2000. Rethinking tropical forest conservation: Perils in Parks. Conservation Biology 14: 1351-1357

Srikosamatara, S. and Doungkhae, S. 1982. Dry dipterocarp forest as a barrier to gibbon dispersal: A survey in Phu Phan National Park, northeast Thailand. Natural History Bulletin of the Siam Society 30: 25–32.

Timmins, R.J. and Ou R. 2001. The Importance of Phnom Prich Wildlife Sanctuary and Adjacent Areas for the Conservation of Tigers and Other Biodiversity. WWF Cambodia Conservation Program, Phnom Penh, Cambodia.

Traeholt, C., Bunthoeun, R., Rawson, B., Samuth, M., Virak, C. and Vuthin, S. 2005. Status review of pileated gibbon, Hylobates pileatus and

yellow cheeked crested gibbon, Nomascus gabriellae, in Cambodia. FFI Cambodia Programme, Phnom Penh,

Waller, M. 2005. Vocal diversity of the male Kloss's gibbon (Hylobates klossii) in the Mentawai Islands, Indonesia. MScThesis, Oxford Brookes University, Oxford.

Whittaker, D.J. 2005. New population estimates for the endemic Kloss's gibbon Hylobates hlossii on the Mentawai Islands, Indonesia. Oryx 39: 458-461

WWF. 2006. Draft Phnom Prich Wildlife Sanctuary Management Plan 2006-2009. WWF Cambodia Conservation Programme and Phnom Penh, Cambodia.

Zhou J., Wei F. and Li M. 2005. Hainan black-crested gibbon is headed for extinction. International Journal of Primatology 26: 453-465

This photo: © Nick Cox / WWF

WWF's mission is to stop the degradation of the planet's natural environment and to build a future in which humans live in harmony with nature, by:

- conserving the world's biological diversity
- ensuring that the use of renewable natural resources is sustainable
- promoting the reduction of pollution and wasteful consumption.

WWF Greater Mekong
Cambodia Country Programme

#54, Street 352, Boeung Keng Kang I,
Chamkar Morn, Phnom Penh.
Tel: +855 23 218 034
www.panda.org/greatermekong

WWF

*for a living planet®*