MONITORING OF KEY WILDLIFE POPULATIONS IN SEIMA PROTECTION FOREST, CAMBODIA, 2005 - 2010

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WCS WILDLIFE CONSERVATION SOCIETY

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Hannah O'Kelly and Nut Meng Hor
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Cover photograph by Eleanor Briggs

SUMMARY

Statistically rigorous surveys of primate and ungulate populations have been conducted in the Seima Protection Forest on an annual or biennial basis since 2005. These species are important conservation targets in their own right and also act as indicators of broader ecosystem health, since they face similar threats to many other, harder to survey species.

Sampling effort was greatly increased in 2008 and spatial coverage was expanded in 2010. These adjustments resulted in the first statistically robust estimates of ungulate densities for the site (and indeed for any site in Indochina, as far as we are aware) and also improved estimator precision and accuracy in measurement of primate numbers. In 2010 Green Peafowl was added as a target species and a preliminary population estimate, the first of its kind for the site, was obtained. The high conservation value of the site for Black-shanked Douc, Yellow-cheeked Crested Gibbon, wild cattle (Gaur and Banteng) and Green Peafowl has been reinforced by these results. The current population estimates suggest that the Seima Protection Forest is one of the most important remaining strongholds in Indochina for these species and underscores the necessity of increased protection if these valuable populations are to be retained. Densities of all ungulate species are depressed compared to natural densities in habitat of this kind and so there is considerable potential for recovery.

Preliminary trend data can be examined. No statistically significant trends were found, but this is perhaps not surprising since the lower-intensity surveys prior to 2008 gave relatively imprecise estimates. Estimates for wild cattle and Sambar suggest that these species might have declined from 2008 to 2010, and there is certainly evidence from other sources of continuing heavy hunting of these species, which gives serious cause for concern given their already low numbers. Numbers of wild pig and Red Muntjac appear to be broadly stable, possibly with fluctuations from year to year. As the precision of the estimates for doucs and gibbons has improved, estimated densities have converged around the lower end of the confidence intervals for earlier estimates. This is most likely due to sampling variation. If densities have decreased natural causes are the most probable cause, since these populations are not known to be experiencing any significant hunting pressure.

2010 is a milestone year in the development of the monitoring program. Additional temporal data are required before population trends can be reliably inferred for all target species in Seima, but if effort and data quality can be maintained at the levels now attained it is clear that each successive survey will add greatly to our understanding of this key indicator of project success. These results emphasise the importance of undertaking biological monitoring at biologically meaningful temporal and spatial scales, and also highlight the need for a substantial investment of both time and resources over several years in the development of a functional monitoring regime.

សេចក្ដីសង្ខេប

ចាប់តាំងពីឆ្នាំ២០០៥មក ការសិក្សាស្រាវជ្រាវសត្វព្រៃតាមបែបស្ថិតិយ៉ាងហ្មត់ចត់ នៃប្រភេទសត្វព្រៃអំបូរពានរ និងអំបូរសត្វរំពារដែលជាចំណីរបស់ខ្លាធំដែលមានក្រចកជើងគូ (ពពួកសត្វអំបូរ គោសាទិស់ ប្រើស ឈ្លូស និងជ្រូកព្រៃ) ត្រូវបានធ្វើឡើងជារៀងរាល់១ឆ្នាំ រឺ២ឆ្នាំម្ដងនៅក្នុង**តំបន់ព្រៃការពារ និងអភិរក្សជីវចម្រុះ "សីមា"**។ ប្រភេទសត្វព្រៃទាំង នេះគឺជាប្រភេទសត្វដ៏មារសារៈសំខាន់ សំរាប់គោលដៅអភិរក្សដើម្បីជៀសផុតពីការវិនាសផុតពូជ។ ហើយវត្តមាននៃការ រស់រានមានជីវិតរបស់ប្រភេទសត្វព្រៃសំខាន់៧ទាំងនេះ នឹងអាចបញ្ជាក់ឱ្យយើងដឹងពីស្ថានភាពទូទៅនៃលក្ខណៈប្រព័ន្ធអេកូ ឡូស៊ី និងប្រភេទទីជម្រករស់នៅរបស់ពួកវា។

នៅក្នុងឆ្នាំ២០០៨ មានកិច្ចខិតខំប្រឹងប្រែងនៃការសិក្សាស្រាវជ្រាវដែលមានលក្ខណៈជាប្រព័ន្ធគំរូត្រូវបានបង្កើតឡើងគួរឱ្យកត់សម្គាល់និងឆ្នាំ ២០១០ ផ្ទៃដីគ្របដណ្ដប់នៃតំបន់សិក្សាស្រាវជ្រាវត្រូវបានពង្រីកបន្ថែមទៀត។ លទ្ធផលដែលគួរឱ្យកត់សម្គាល់ទាំងនេះគឺជាលទ្ធផលបានមកពីការសិក្សាស្រាវជ្រាវលើកដំបូង ដែលបានប៉ាន់ប្រមាណចំនួនជាក់លាក់នៃដង់ស៊ីតេរបស់ប្រភេទសត្វរំពារដែលមានក្រចកជើងគូ ដែលកំពុងមានវត្តមាននៅក្នុងតំបន់សិក្សាស្រាវជ្រាវ (ប្រាកដណាស់នូវអ្វីដែលយើងបានដឹងនេះ គឺជាលទ្ធផលលើកដំបូងដែលទទួលបានល្អជាងតំបន់ដទៃទៀត នៅក្នុងតំបន់ភូមិភាគឥណ្ឌូចិន)។ ហើយលទ្ធផលនេះក៏បានបង្ហាញឱ្យដឹងពីភាពកាន់តែល្អប្រ សើរនិងកាន់តែជាក់ច្បាស់នៃការវាស់វែងប៉ាន់ប្រមាណចំនួនសត្វអំបូរពានរដែលមានវត្តមាននៅក្នុងតំបន់សិក្សាផងដែរ។ នៅក្នុងឆ្នាំ២០១០ ប្រភេទ សត្វក្ងោក ត្រូវបានដាក់បញ្ចូលបន្ថែមជាប្រភេទសត្វគោលដៅអភិរក្សបន្ទាប់ ពីធ្វើការប៉ាន់ប្រមាណលើកដំបូងអំពីចំនួនរបស់ពួកវាត្រូវបានគេសិក្សាស្រាវជ្រាវ។ ដូច្នេះតម្លៃនៃការអភិរក្សសំរាប់តំបន់ព្រៃការពារ និងអភិរក្សជីវចម្រុះ"សីមា" បាននិងកំពុងតែត្រូវបានពង្រឹងឱ្យកាន់តែមានសារៈសំខាន់ថែមទៀត ដោយសារលទ្ធផលនៃការសិក្សាទាំងអស់នេះបានបង្ហាញពីវត្តមានដ៏សំខាន់នៃប្រភេទសត្វស្វាកន្ទុយស ទោចថ្គាល់លឿង គោសាទិស (ខ្ទីង និងទន្សោង) និងសត្វក្ងោក។ បច្ចុប្បន្នការសិក្សាប៉ាន់ប្រមាណចំនួនសត្វព្រៃបានបង្ហាញថា តំបន់ព្រៃការពារ និងអភិរក្សជីវចម្រុះ "សីមា" គឺជាតំបន់ទីជម្រកដ៏មានសារៈសំខាន់បំផុតមួយក្នុងចំណោមតំបន់សំខាន់៧ដទៃទៀតនៅក្នុងភូមិភាគឥណ្ឌូចិន សំរាប់ការរស់រានមានជីវិតបន្តពូជពង្សនៃប្រភេទសត្វព្រៃសំខាន់៧ទាំងនេះ។ ហើយកិច្ចការពារប្រភេទសត្វទាំងនេះ ចាំបាច់ត្រូវតែខិតខំពង្រឹងឱ្យកាន់តែមានប្រ សិទ្ធភាពថែមទៀតដើម្បីរក្សាបាននូវចំនួនសត្វព្រៃដ៏សំខាន់ទាំងនេះឱ្យស្ថិតនៅគង់វង្ស។ ចំនួនដង់ស៊ីតេនៃប្រភេទ សត្វរំពារដែលមានក្រចកជើងគូទាំងអស់ត្រូវបានធ្លាក់ចុះ ប្រសិនបើយើងធ្វើការប្រៀបធៀបជាមួយចំនួនដង់ស៊ីតេសរុបនៃចំនួនពិតប្រាកដ នៅក្នុងធម្មជាតិនៃប្រភេទទីជម្រកនៅក្នុងតំបន់សិក្សានេះ។ ដូច្នេះការស្តារឡើងវិញនៃចំនួនប្រភេទសត្វទាំងនេះត្រូវតែគិតគូជាអាទិភាពចម្បងក្នុងសកម្មភាពការងារអភិរក្ស។

ទិន្នន័យបម្រែបម្រួលបឋមនៃចំនួនសត្វព្រៃទាំងនេះ អាចត្រូវបានគេដឹងរួចមកហើយ។ ក្នុងនោះពុំមាន បម្រែបម្រួលទិន្នន័យស្ថិតិអ្វីមួយគួរឱ្យកត់សម្គាល់ឡើយ។ ប៉ុន្តែនេះប្រហែលមកពីការសិក្សាស្រាវជ្រាវនាឆ្នាំកន្លងមកទទួលបាន

ទិន្នន័យចំនួនដង់ស៊ីតេទាបជាងលទ្ធផលដែលទទួលបានក្នុងឆ្នាំ២០០៨។ ការប៉ាន់ប្រមាណចំនួនសត្វ ខ្ទីង ទន្សោង និងប្រើស បានឱ្យដឹងថាចំនួនប្រភេទសត្វទាំងនេះអាចត្រូវបានធ្លាក់ចុះក្នុងចន្លោះពីឆ្នាំ២០០៨ ដល់ ២០១០។ មូលហេតុនៃការធ្លាក់ចុះនេះត្រូវបានគេដឹងប្រាកដថាបណ្ដាលមកពីសកម្មភាពបរបាញ់យ៉ាងធ្ងន់ធ្ងរលើ ប្រភេទសត្វព្រៃទាំងនេះដែលធ្វើឱ្យស្ថានភាពនៃចំនួនដង់ស៊ីតេកំពុងតែមានទាបស្រាប់របស់ពួកវា កាន់តែបន្ដថយចុះគួរឱ្យព្រួយបារម្ភបំផុត។ រីឯចំនួនរបស់សត្វជ្រូកព្រៃ និងឈ្លូស បានបង្ហាញឱ្យដឹងថាហាក់បីដូចជាកំពុងស្ថិតនៅ ក្នុងចំនួនថេរនៅឡើយ។ នៅពេលដែលភាពជាក់លាក់នៃការសិក្សាប៉ាន់ប្រមាណចំនួនសត្វស្វាកន្ទុយស និងទោច ថ្ពាល់លឿង ទទួលបានលទ្ធផលកាន់តែប្រសើរឡើងហើយការប៉ាន់ស្មានចំនួនដង់ស៊ីតេបានខិតទៅរកចំណុចទាប បំផុតនៃកំរិតលំអៀងនៃភាពជឿជាក់ដែលបានប៉ាន់ប្រមាណនាពេលកន្លងមក។ នេះជាមូលហេតុភាគច្រើនបណ្ដាលមកពី ភាពខុសៗគ្នានៃគំរូតាងនៃការរាប់។ ប្រសិនបើចំនួនដង់ស៊ីតេមានការថយចុះដូច្នេះកត្តាធម្មជាតិប្រហែលជាមូលហេតុចម្បង។ ប៉ុន្តែទោះបីជាណាក៏ដោយចំនួនសត្វព្រៃទាំងនេះ គឺមិនទាន់ត្រូវបានដឹងច្បាស់នៅឡើយថាមានការកើនឡើងក្រោមសំពាធនៃការបរបាញ់។

ឆ្នាំ២០១០ គឺជាឆ្នាំគោលដៅដែលបានកំណត់នៅក្នុងដំណើរការកម្មវិធីត្រួតពិនិត្យតាមដានចំនួនសត្វព្រៃ។ ពេលវេលានៃការប្រមូលទិន្នន័យបន្ថែម គឺចាំបាច់ត្រូវរៀបចំផែនការទុកជាមុនដើម្បីអាចឈានដល់ការដឹងកាន់តែច្បាស់ពីចំនួនពិតប្រាកដនៃប្រភេទសត្វគោលដៅអភិរក្សសំខាន់ៗទាំងនេះនៅក្នុងតំបន់ព្រៃការពារ និងអភិរក្សជីវចម្រុះ"សីមា"។ ប៉ុន្តែប្រសិនបើកិច្ចខិតខំប្រឹងប្រែង និងការប្រមូល ទិន្នន័យប្រកបដោយគុណភាពល្អដូចសម្រេច បាននាពេលបច្ចុប្បន្នជាក់ច្បាស់ណាស់លទ្ធភាពជោគជ័យទាំងនេះ នឹងផ្ដល់នូវការយល់ដឹងកាន់តែទូលំទូលាយពីស្ថានភាពនៃប្រភេទសត្វគោលដៅសំខាន់ៗទាំងនេះហើយក៏អាចធ្វើឱ្យគេដឹងច្បាស់ពីភាពជោគជ័យរបស់គំរោងអភិរក្សផងដែរ។ លទ្ធភាពទាំងនេះបានបញ្ជាក់កាន់តែច្បាស់ឡើងថែមទៀតស្ដីពីសារៈសំខាន់នៃការសិក្សាស្រាវជ្រាវត្រួតពិនិត្យតាមដានធនធានជីវចម្រុះ ស្របពេលដែលពិភពលោកទាំងមូលកំពុងយកចិត្តទុកដាក់ថែរក្សាការ ពារនូវធនធានជីវចម្រុះដ៏សម្បូរបែប និងមានតម្លៃដូចនៅក្នុងតំបន់ព្រៃការពារ និងអភិរក្សជីវចម្រុះ"សីមា"នេះ។ ហើយលទ្ធផលនេះក៏បង្ហាញឱ្យដឹងផងដែរអំពីតម្រូវការចាំបាច់នៃការប្ដេជ្ញាចូលរួមចំណែកទាំងពេលវេលា និងធន ធានផ្សេងៗទៀតក្នុងកិច្ច ដំណើរការសិក្សាស្រាវជ្រាវនេះជាច្រើនឆ្នាំបន្តទៅមុខទៀតដើម្បីឈានដល់ការបង្កើតបែបផែនច្បាស់លាស់មួយ នៃការងារត្រួតពិនិត្យតាមដានស្ថានភាពធនធានជីវចម្រុះប្រកបដោយសមត្ថភាព និងគុណភាពខ្ពស់។

INTRODUCTION

Biological monitoring is a vital component of any conservation project if the effects of management are to be assessed (Green *et al.* 2005). There is increasing recognition that conservationists need to provide empirical evidence to back up claims of conservation success (Sutherland *et al.* 2004; Ferraro & Pattanayak 2006) but in many projects in developing countries even rudimentary baseline information is not available for species of conservation concern (Milner-Gulland & Bennett 2003; Sodhi *et al.* 2009). This makes it difficult to evaluate the biological impacts of conservation efforts (Robinson 2006; Steinmetz *et al.* 2010).

Data collection is often impeded by demanding field conditions, severe resource constraints and limited local capacity (Danielsen et al. 2003). Nevertheless, it is still possible to employ rigorous methods to assess the status of target populations, even those, which have been subject to dramatic declines and persist at extremely low densities (Nichols & Williams 2006).

This has been demonstrated in the case of the Seima Protection Forest (SPF) where biological monitoring activities have been underway since 2002. Since 2005 these activities have focused primarily on the estimation of primate and ungulate densities within the Core Area of the site. In 2010 green peafowl was also added as a target species. The SPF populations of a number of these species, such as Black-Shanked Douc, Yellow-cheeked Crested Gibbon, Banteng and Green Peafowl, are of particular conservation significance in their own right (see Table 1). In addition, ungulate, primate and peafowl species can be used as indicators of general ecosystem health. All are vulnerable to hunting, habitat loss and other anthropogenic pressures and all of these species are suitable for monitoring using rigorous population estimation methods. These target species are part of a wider suite of species selected to represent the site in its ecological entirety and it is anticipated that by developing strategies to conserve these few species, all the biodiversity values of the site will be conserved (WCS/FA 2010).

Density estimation is achieved through the use of distance sampling methods (Buckland *et al.* 2001), implemented in SPF in the form of line transect surveys. The Distance software package was used for the design of the survey and the analysis of the data (Thomas *et al.* 2010). Line transect distance sampling has been used widely in tropical forests in South Asia and Africa to estimate absolute densities of ungulates and primates (Karanth & Nichols 2002; Buckland *et al.* 2010a). A number of alternative survey techniques have also been utilised in SPF including camera-trap surveys and listening-post surveys. However, it was not possible in this context to generate absolute estimates using either of these methods and so listening-post surveys were discontinued after 2008 and camera-trapping was continued only in a low-intensity ad-hoc manner, rather than for the purposes of population estimation. Thus, the main focus of monitoring activities, and consequently of this report, rests upon line transects surveys. Species covered by the line transects and the significance of their populations in SPF are listed in Table 1.

A distance sampling approach facilitates the generation of absolute density and abundance estimates and, if implemented appropriately, can produce precise and accurate results. However, in order for this potentially powerful approach to be valid, a number of key theoretical assumptions must be met. In contexts where multiple biological and logistical constraints apply it can often be challenging to satisfy these theoretical requirements. As a consequence line transect surveys in SPF have necessitated a significant investment of time and resources, but ultimately this effort has been vindicated by the success of the surveys and the quality of the results yielded.

Table 1 Species surveyed on the line transects

English Name	Scientific Name	Status*	SPF importance
Primary target species			
Black-Shanked Douc	*Pygathrix nigripes*	EN	Global
Yellow-cheeked Crested Gibbon	*Nomascus gabriellae*	EN	Global
Banteng	*Bos javanicus*	EN	Global
Gaur	*Bos gaurus*	VU	Regional
Sambar	*Rusa unicolor*	VU	Possibly regional
Eld's Deer	*Rucervus eldii*	EN	Regional
Green Peafowl	*Pavo muticus*	EN	Global
Other species surveyed			
Northern Pig-Tailed Macaque	*Macaca leonina*	VU	National
Stump-Tailed Macaque	*Macaca arctoides*	VU	Possibly regional
Long-Tailed Macaque	*Macaca fascicularis*	lc	National
Germain's Silvered Langur	*Trachypithecus germaini*	EN	Possibly global
Red Muntjac	*Muntiacus muntiacus*	lc	-
Wild Pig	*Sus scrofa*	lc	-

* = Status from the 2010 IUCN Red List of Globally Threatened Species
En = Endangered VU = Vulnerable lc = Least Concern (i.e. not Globally Threatened)

METHODOLOGY

Distance Sampling

Distance sampling comprises a family of methods which are characterised by the measurement of distances between a fixed point or line and the location where an object is detected. This information is used to estimate the density and/or abundance of objects. Objects in this case are individual or groups of animals and detections are visual observations of these animals (animal sounds or signs are not recorded). Line transect sampling is the most widely used form of distance sampling for large-bodied mammals and involves the placement of a fixed set of survey routes, or line transects, across the survey area. The line transects are walked by observers who record all target species detected and take measurements to calculate the perpendicular distance of animals from the line. Distance sampling uses these measured perpendicular distances from the line to estimate the detection function; that is the proportion of animals present within each distance category that are detected. The detection function can effectively be used to estimate the area covered by the survey, which is combined with the encounter rate of animals on the transects to estimate the density of animals. For clustered animals (a group of animals) the density of individuals is a function of the cluster encounter rate, the detection function for clusters and the mean cluster size. Ideally, 60 to 80 observations of each target species or group of target species are required to accurately estimate the shape of the detection function. However, it is sometime possible to pool data over several years or to “borrow” detection functions from appropriate sources to use in analysis.

Survey Protocols

Using coordinates from the prescribed survey design, the start, end and middle points (corner points in 2010) of each transect are marked and a line connecting each point along a given bearing is marked with paint. Marking with paint allows observers to focus on detecting and recording wildlife rather than on navigation. Vegetation along the transects is cut but only to such an extent that observers can walk quietly along them. If the transects are cut too wide they may become used as trails either by wildlife or people which in turn can affect survey results. Transects are cleared and re-marked each year, at least one month before the start of surveys.

A standard protocol for surveys is developed to ensure that all teams collect comparable information and that the method is implemented correctly. There are three key assumptions underlying distance sampling which must be incorporated into the protocol (Buckland *et al.* 2001). These assumptions are;

1. Animals on the line are detected with certainty, i.e. no animals on the line are missed by observers.
2. Animals are detected and their location recorded before they move, i.e. observers must see an animal before it sees them and flees.
3. Measurements are exact. Training and appropriate equipment must be used to ensure accuracy of distance measurements.

Well trained, experienced field teams are an integral part of successful distance sampling. Training takes place annually to maintain observer proficiency and data quality is monitored continually.

Transects are walked twice daily in the hours just after sunrise and those just preceding sunset, when animals are most active and easy to observe. Survey teams consist of two people only. For each animal (or animal group) encountered the following information is recorded: location (UTM co-ordinates), number of animals, distance between the animal or centre of a group of animals and the observers on the line (with a laser rangefinder), compass bearing to the animal or to the centre of a group of animals, and compass bearing of the transect line. The latter three pieces of information are required to calculate the perpendicular distance of the observed animal(s) from the line.

Sampling Design & Effort

Between 2005 and 2008 surveys took place on 14 transects 3-5 km in length located within a 1086 km^2 survey area (Table 2, Figure 1). This area represents the most important habitat for large-bodied mammals within the site, as identified in the 2002 preliminary surveys (Clements 2002). Transects were placed randomly, with stratification by broad forest type (evergreen forest, semi-evergreen forest, deciduous dipterocarp forest) and location (approximately southern, central and northern SPF). Each transect was walked twice in 2005 and 2006 resulting in approximately 113 km of survey effort. In 2007 each transect was surveyed three times giving 170 km of effort. This level of sampling effort resulted in a sufficient number of observations to produce annual density estimates for Black-shanked Doucs but for other target species encounter rates were extremely low and variable, precluding consistent population estimation at a species- and year- specific level.

Table 1 Survey effort over time.

Year	2005	2006	2007	2008	2010
Effort (km)	113	113	170	1359	1600
No. Transects	14	14	14	14	40
Survey Area (km2)	1068	1068	1068	1068	1807

Despite the low number of detections there were several reasons to continue with annual line transect surveys. Firstly; distance sampling can accommodate the pooling of data across multiple years and, when sufficient observations are obtained cumulatively, an average detection function can be derived. This detection function can subsequently be used to produce estimates from a smaller number of observations. Such an approach is limited, however, in that it assumes that detectability (i.e. the probability than an observer will see a given animal when it is present) does not change over time. In reality, detectability can be subject to multiple sources of temporal variation, for example due to changes in species behaviour, in observers, or in environmental conditions, none of which are necessarily related to underlying patterns of abundance. Thus, where possible, it is always preferable to use a season specific detection function.

Secondly; the success of line transect surveys in this context depends heavily on having skilled observers who can detect cryptic species and adhere to the strict protocols required for distance methods. Repeating surveys annually is beneficial in this regard as it provides a training opportunity and ensures high levels of skill are maintained.

Thirdly; the presence of survey teams within these key areas for wildlife fulfils a protective function to some extent. Hunters are deterred by active wildlife monitoring teams and anecdotal information relating to the general conditions within these areas can also be collected during the line transect surveys.

To obtain a sufficient number of animal observations for population estimates across all target species a substantial increase in sampling effort was required. Sampling effort can be increased by either increasing the number of temporal replicates (i.e. the number of times a given transect is walked) or spatial replicates (i.e. the number of transects), both of which should lead to a higher number of animal encounters. Increasing temporal replication is logistically easier to achieve as existing transects can be re-surveyed on multiple occasions, whereas increasing spatial replication requires extra transects to be cut and surveyed. However, all walks on a given transect within a season are combined during analysis and so a greater number of spatial replicates is more useful than multiple temporal replicates. Temporal replication serves to add precision to the estimation of effective half strip width and cluster size, but a minimum of 10-20 spatial replicates is required for an adequate estimation of variance of the encounter rate (Buckland *et al.* 2001). Beyond this requirement, the greater the number of lines surveyed, the smaller the variance of the density or abundance estimate will be (Karanth & Nichols 2002).

Such modifications to the survey design entailed a major investment of resources and posed significant logistical challenges. With this in mind it was decided in 2008 to focus on increasing sampling effort through temporal replication only, which allowed initial population estimates to be generated, and to redesign the entire system in 2010, in order to improve and refine subsequent estimates.

In 2008 each of the original 14 line transects was walked between 32 and 34 times resulting in a total effort of 1359 km. This level of effort represented an eight-fold increase from that invested in previous years. In 2010 40 new transects, each 4 km, in length were established across an expanded 1807 km^2 survey area (Figure 2). Transect placement was systematic, with a random starting point, which ensures optimal spatial coverage and appropriate representation of the entire Core Area. Transects are now closed circuits, square-shaped, which allows greater logistical ease as the start and end points are equivalent and can be situated at any point on the circuit. Each of the 40 transects was walked a total of ten times, over five consecutive days, which resulted in a total sampling effort of 1600 km. This represents one of the most extensive and ambitious surveys undertaken for large mammals in Indochina to date.

Green Peafowl had been previously monitored using listening posts, which were presumed to provide an approximate relative index of abundance. However, with the increase in survey effort from 2008 onwards it became feasible to generate absolute measures of abundance for these species from the line transect surveys, and so this species was included for the first time as a target species during the 2010 surveys.

Figure 1 Transect Layout 2005-2008

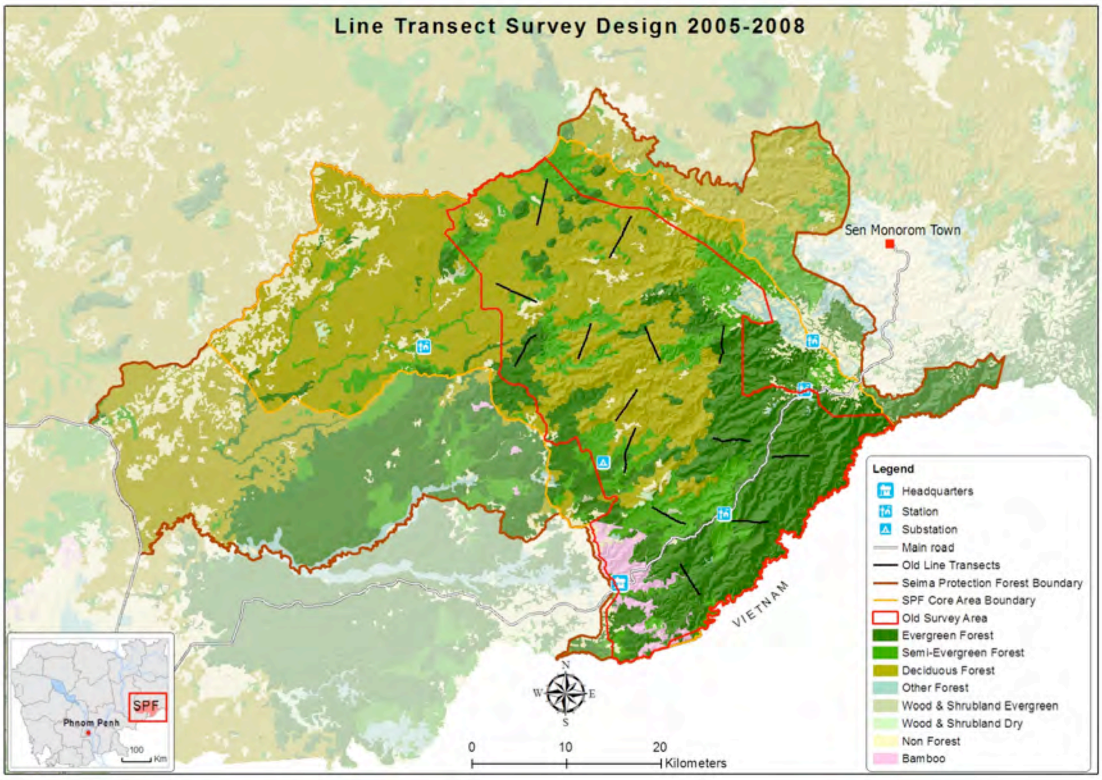
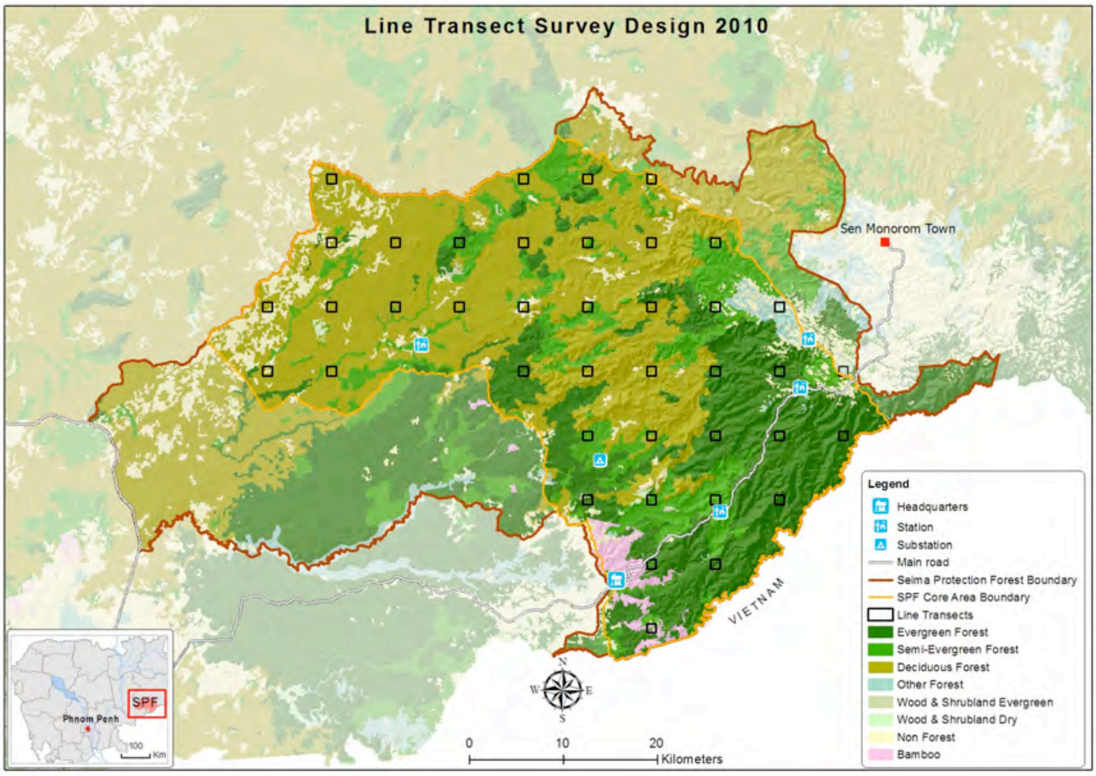


Figure 2 Transect Layout 2010



RESULTS

The data collected during the 2010 survey season allowed density and abundance estimates to be generated for the majority of target species. As a consequence of the modified sampling design these 2010 estimates are representative of the entire Core Area of SPF. The 2010 survey area encompasses both optimal and sub-optimal areas for wildlife and these estimates reflect, to as great an extent as possible, the varying environmental and anthropogenic factors which affect the spatial patterns of abundance of target species throughout SPF.

Table 3 summarises the results from 2010 for 8 of the 13 surveyed species. There were no observations of Eld's Deer on the transects and analysis of the remaining four primate species is still under way.

Table 3. Density and abundance of selected species across the entire SPF Core Area in 2010.

Species	Observations	Density (individs /km^2)	95% CI lower	95% CI higher	Approximate no. individuals in expanded survey area 2010 ***
Black-shanked Douc*	330	12.81	8.39	19.55	23400 (17000-32100)
Yellow-cheeked Crested Gibbon*	18	0.43	0.20	0.95	800 (400-1700)
Red Muntjac	169	1.75	1.22	2.51	3200 (2200-4500)
Wild Pig	52	2.04	1.19	3.49	3700 (2200-6300)
Wild Cattle**	19	0.29	0.11	0.77	500 (200-1400)
Sambar	6	0.09	0.04	0.23	200 (100-400)
Green Peafowl	25	0.17	0.08	0.34	300 (200-700)

* For primate species density and abundance estimates are given for area of suitable habitat only, i.e. evergreen and semi-evergreen forest within the expanded survey area.
** Gaur and Banteng combined.
*** Figures are rounded to nearest 100.

Due to the difference in survey area between 2010 and previous years, a simple comparison of results is not appropriate. Surveys in 2005 – 2008 focused only areas where the abundance of target species was expected to be highest, whereas in 2010 additional areas of both high and low abundance were sampled with the aim of producing a more representative estimate of the current status of target species in the whole SPF core area. In order to make the numbers comparable over time the 2010 data can be truncated to include only an area corresponding to that which was sampled in earlier years. These data can then be compared with data from previous years to investigate the existence of trends. In future years, as repeated estimates for the new survey area become available, trends in density over the entire 1807 km^2 Core Area will also be examined.

Tables 4 & 5 present summary results for eight target species across the original 2005-2008 survey area, including those from the truncated 2010 data set. Note the low number of encounters in some of the earlier years. Figures 3a-c & 4a-d present the same data graphically for those species where more than one year of suitable data is available. Again, note the long error bars in earlier years for most species. For both primate species density and abundance estimates are presented for evergreen and semi-evergreen forest only[1]. This is because these species are primarily restricted to these forest types (although they may pass through all other habitat typesand virtually all observations are recorded therein. Sufficient data exists to stratify by habitat for these two species and the precision of the resulting estimate is improved in doing so (See Appendix 2B for further details of the results the stratification process.

[1] Note that some figures differ from those in (Pollard *et al.* 2007) as estimates have been refined as more data has been collected.

Table 5 Time-series density estimates for selected primate species within suitable habitat across the original 2005-2008 survey area.

Year	Effort (km)	No. of Obs	Indiv D	cv	Group D	cv	Encounter Rate	Mean Group Size	Approximate no. Groups in Survey Area	Approximate no. Indivs in Survey Area
Yellow-cheeked Crested Gibbons										
2005	89	6	2.25	46.20	0.96	33.88	0.067	3.00	800 (400-1500)	1800 (700-4600)
2006	89	5	1.53	61.07	0.55	58.54	0.056	2.75	400 (100-1400)	1200 (400-4000)
2007	133	9	2.00	37.81	0.90	32.38	0.068	2.22	700 (400-1400)	1600 (700-3400)
2008	1017	42	1.83	18.72	0.81	16.20	0.041	2.27	600 (500-900)	1400 (1000-2100)
2010	648	16	1.01	35.64	0.46	33.83	0.025	2.19	400 (200-700)	800 (400-1600)
Black-shanked Doucs										
2005	89	42	47.05	24.62	6.72	19.68	0.472	7.76	5300 (3500-7900)	37100 (22800-60400)
2006	89	54	64.63	28.70	7.30	25.18	0.607	8.85	5800 (3400-9700)	51000 (28600-90900)
2007	133	65	35.30	26.65	6.83	24.12	0.489	5.17	5400 (3300-8800)	27900 (16300-47600)
2008	1017	395	29.32	14.68	7.62	14.13	0.388	4.05	6000 (4500-8100)	23100 (17100-31400)
2010	648	241	27.64	15.16	6.84	14.43	0.372	4.04	5400(4000-7200)	21800(16100-29500)

Figure 3a

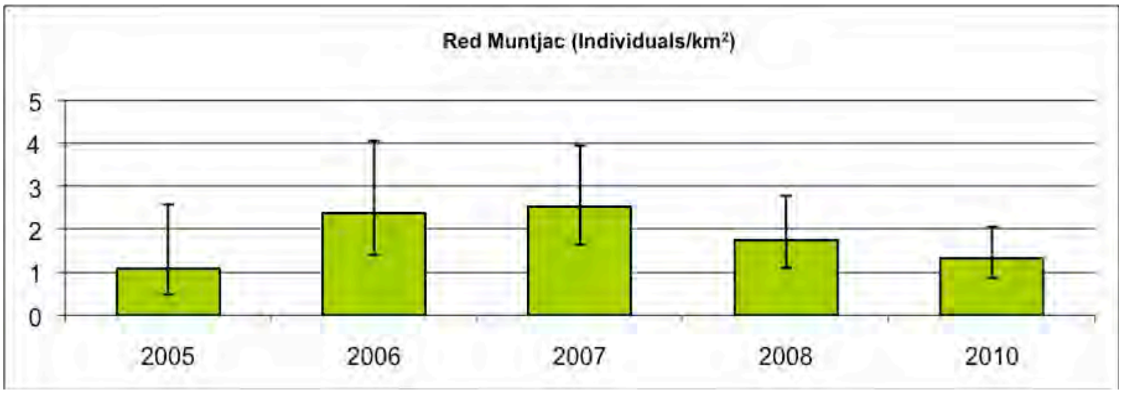


Figure 3b

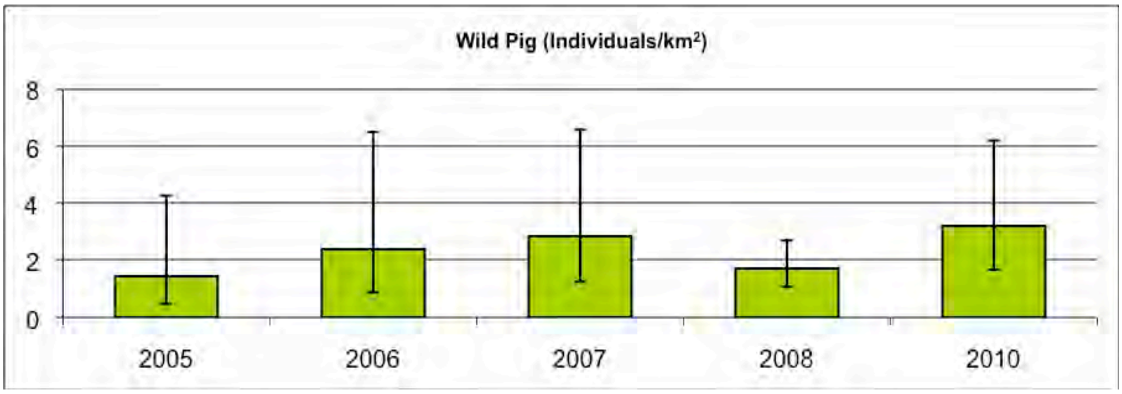
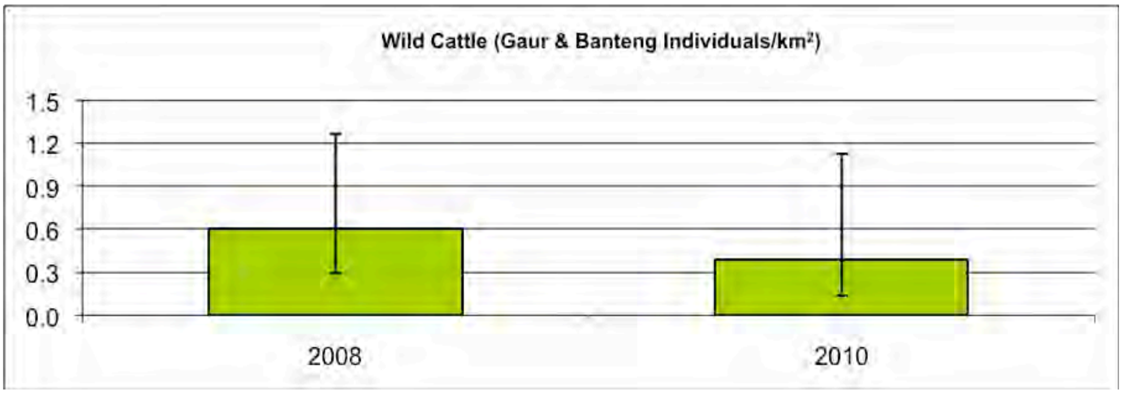


Figure 3c



Figures 3 a, b & c: Trends in ungulate density across all habitat types in the 2005-2008 survey area.

Figure 4a

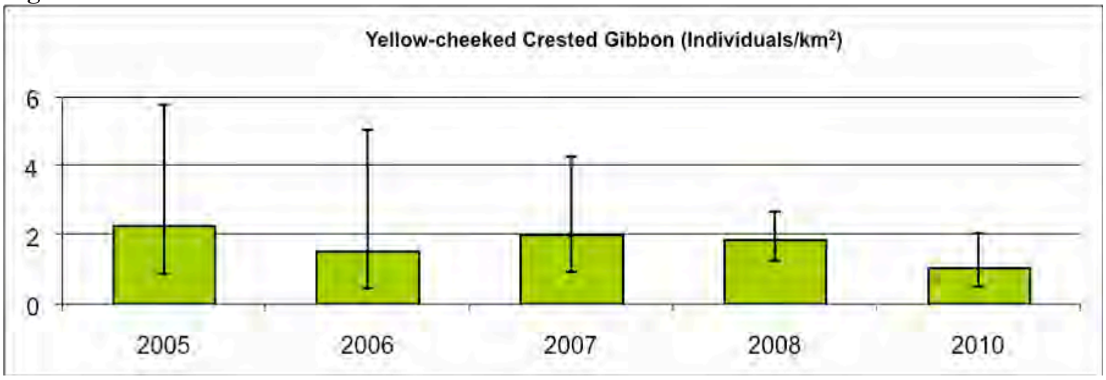


Figure 4b

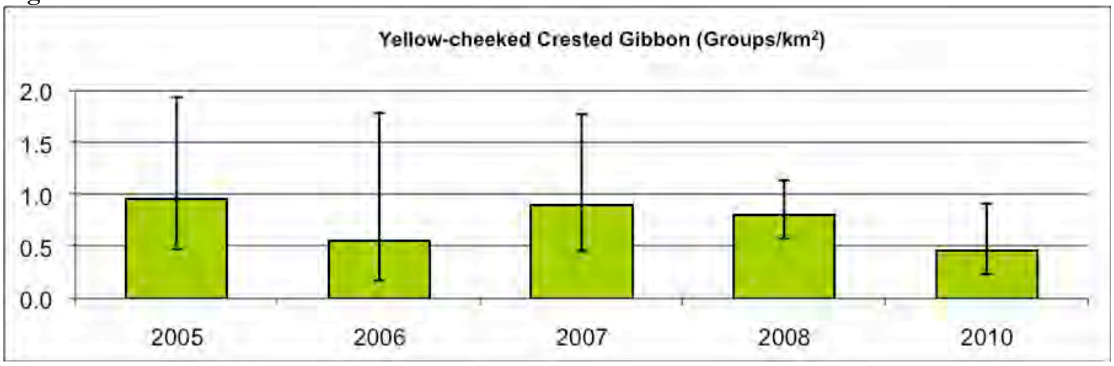


Figure 4c

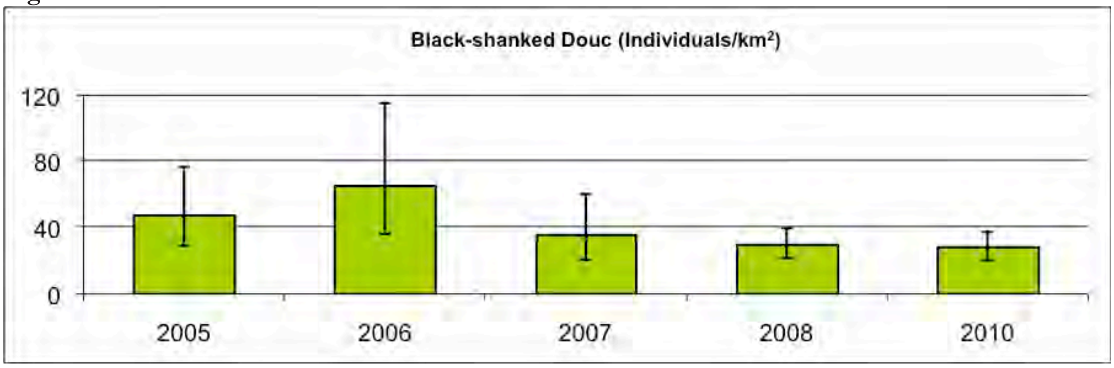
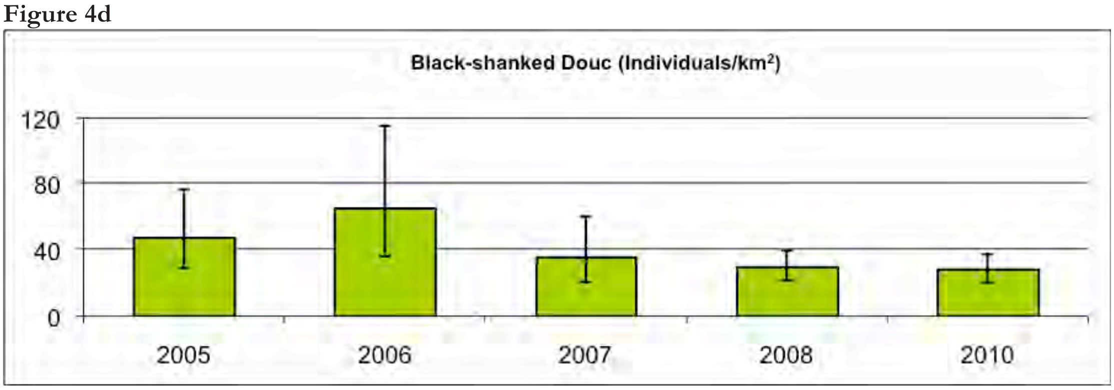


Figure 4d



Figures 4 a, b, c & d: Trends in primate density in suitable habitat in the 2005-2008 survey area.

Figure 8 is an interpolated density map which provides a visual representation of the relative distribution of wild cattle throughout the entire Core Area. Darker areas represent concentrations of animals based on the results from the 40 line transects in 2010.

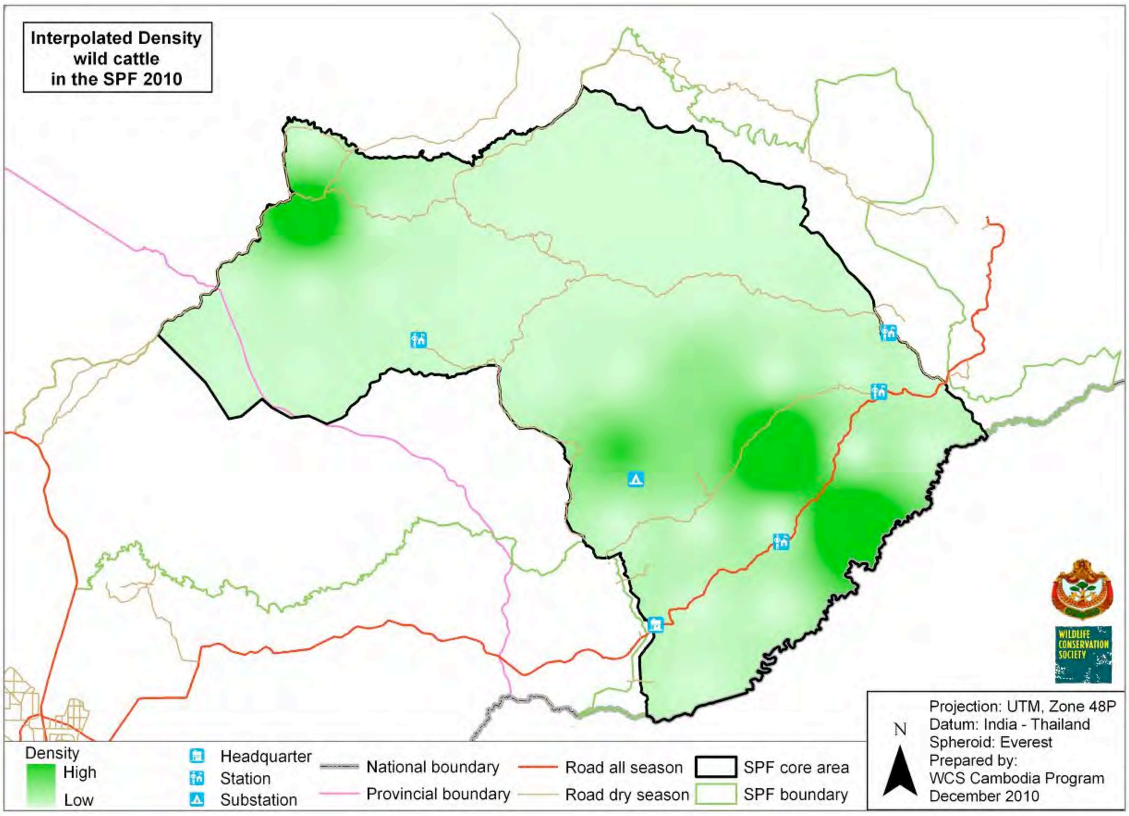


Figure 5. Interpolated density map of wild cattle across the SPF Core Area, from 40 transects, 1600km of effort.

DISCUSSION

Larger ungulates:

Population estimates were obtained within the Core Area for Gaur, Banteng and Sambar, indicating the presence of approximately 400 head of wild cattle (most likely composed of roughly equal numbers of each species) and around 200 Sambar. Sample sizes for all large ungulates were small, a result of low underlying densities which yields low encounter rates on transects and wide confidence intervals for the resulting population estimates. It was necessary to combine Gaur and Banteng observations during analysis in order to obtain an appropriate number of encounters, an approach that assumes the detection probability for each species is similar. Allowing for these uncertainties, the populations of wild cattle at the site are clearly of high conservation importance, especially for Banteng which has an estimated global population of only 5000-8000 (IUCN 2010).

Estimates exist only for 2008 and 2010 and, consequently, it is not yet possible to examine trends over time for any of the large ungulate species. Furthermore, the relative imprecision of these initial estimates must be taken into account when making comparisons over time.

The 2010 density estimate for wild cattle was lower that that obtained in 2008 but the high variance surrounding the estimates precluded statistical testing for a significant difference between years. Nevertheless, this lower estimate does provide some cause for concern, especially as a number of incidents of hunting of wild cattle were observed or reported during the year (FA/WCS unpublished law enforcement patrol monitoring data). In coming years surveys will be repeated on an annual or biennial basis and data will continue to accumulate. This will allow us to distinguish between real population fluctuations and changes which are simply a reflection of inherent sampling variation.

The number of Sambar observations has so far been extremely low on the line transects and there is some evidence in the data of evasive movement in the moments prior to detection. Sambar in SPF are a particularly timorous species, highly sensitive to the presence of humans and it is possible they are repelled by anything resembling a trail. It may be that they are actively avoiding the transects or simply evading detection by fleeing before survey teams sight them. These behaviours constitute a violation of the underlying assumptions of distance sampling and may result in under-estimates of density and abundance. Until sufficient data are available to generate a reliable detection function, the figures presented remain provisional for Sambar.

Appendices 1A, 1B and 1C shows the known distribution of wild cattle and Sambar in the SPF and Figure 5 is an interpolation map which provides a visual representation of the distance sampling results for wild cattle[2]. All sources of information, including the line transect surveys, observations collected during other types of monitoring activity, and anecdotal reports, concur broadly with respect to distribution patterns for large ungulates within the site. It is further supposed that seasonal movement of populations occurs within the site but the data available to date have precluded any detailed investigation into this phenomenon.

Observations of these three large ungulates have typically tended to be concentrated within the central and southern parts of the site, with a new hotspot for Banteng identified in the north-west of the Core Area during the 2010 surveys. Gaur and Sambar observations tend to be most frequent in evergreen and semi-evergreen habitat while Banteng are typically observed in semi-evergreen and deciduous forest. Areas comprised of a mosaic of different habitat types are apparently favoured by all three species over large blocks of uniform habitat type, and there may also be a predilection for areas with multiple water sources and mineral licks. These apparent patterns are consistent with recorded habitat preferences elsewhere in the range of these species (Nguyen 2009; Steinmetz 2004). However, not all areas of suitable vegetation in SPF are occupied, and this is likely to be due to variation in human pressure and levels of active law enforcement.

[2] This map does not represent a statistical spatial model and should not be confused with density surface models.

The prevalence of hunting in SPF is variable across space and time, and is influenced by a range of potentially interacting factors. Ease of access, vegetation density, proximity to roads and settlements, and presence and intensity of anti-poaching patrols all appear to be important determinants in the nature and extent of hunting. There are extensive tracts of apparently suitable habitat in which abundances are very low, a situation which we attribute primarily to over-hunting. Thus, large ungulates have generally persisted in areas characterised by good quality habitat together with some level of protection from hunting, either by virtue of their inaccessibility, or a result of anti-poaching efforts, or both.

With adequate protection it is likely that this landscape could support considerably higher numbers of these species as densities appear to be well below habitat carrying capacity. In comparable habitat in Huai Kha Khaeng Wildlife Sanctuary in Western Thailand combined density of Gaur and Banteng was estimated to be 1.8km² (compared to 0.29/km² in SPF) while density of Sambar in the wet season was 4.2 km² (compared to 0.09/km² in SPF) and these numbers were also thought to be depressed due to poaching (Srikosamatara 1993). This indicates that there is significant potential for recovery of large ungulates within SPF.

Smaller ungulates

Wild Pig and Red Muntjac populations were each estimated at over 3,000 animals in the Core Area. Sample sizes were relatively large in comparison to the larger ungulates, particularly for the later years (2008 and 2010). Estimates were not possible at the time of the 2005 – 2007 surveys for any ungulate species but one of the advantages of using distance sampling methods is that as data accrue over time they can be used to retrospectively generate population estimates. Year- and species-specific detection functions were estimated in 2008 and 2010 for both Red Muntjac and Wild Pig and showed detection probability to be reasonably consistent across time (See Appendix 2A). Data were subsequently pooled across all years to generate a global detection function which was used to estimate yearly densities from 2005 to 2007 for both species. The resulting time series data facilitate a preliminary examination of potential trends in species density and abundance. Populations of both species appear to have undergone fluctuations but there are no sustained declines or increases apparent from the data. Red Muntjacs in particular appear to have increased and then decreased quite markedly during the study period. The difference between the 2010 estimate and that of 2007 is statistically significant ($z=-2.008$ $p < .05$) but there are no statistically significant differences between 2010 and any other year (2005 $z=0.416$ $p > .05$, 2006 $z=-1.576$ $p > .05$, 2008 $z=0.861$ $p > .05$), suggesting that the 2007 estimate was exceptionally high.

The known distribution of Wild Pig and Red Muntjac is shown in Appendices 1D and 1E. During the line transect surveys these species were recorded more uniformly across all habitats than the three large ungulates. Observations were moderately common even in areas subject to high levels of human disturbance, which suggests that they are more tolerant of anthropogenic pressures. Both species are known to experience high hunting pressure at the site and whilst other studies have suggested that they may be comparatively resilient to some level of hunting off-take (e.g. (Steinmetz et al. 2010), densities nevertheless remain considerably lower than would be expected in unhunted sites. For example, densities of Red Muntjac and Wild Pig in Taman Negara in Malaysia were estimated at 3.2 per km² and 4.17 per km² respectively (Kawanishi & Sunquist 2004) compared to 1.75 and 2.04/km² respectively in SPF.

Primates

The 2010 population estimates were over 23,000 individuals (7,000 groups) for Black-shanked Douc and over 800 individuals (400 groups) for Yellow-Cheeked Crested Gibbon. These represent the most reliable estimates to date for either of these species, from anywhere, and they confirm the status of SPF as a global stronghold for these primates.

Obtaining accurate and precise estimates for arboreal mammals such as primates is notoriously difficult (Buckland *et al.* 2010b). The ecology and behavioural characteristics of both species present a number of challenges to data collection and analysis.

Doucs occur at high densities and observations are frequent and numerous.

However, doucs typically occur in groups of variable size and it is extremely difficult to count every individual within a potentially large and highly mobile group of animals in dense evergreen forest. Accordingly, estimates of group size may not be exact and obtaining an accurate assessment of group spread and identification of group center is often highly problematic. These issues are compounded by the fact that distance sampling protocols require observers to distinguish between social groups and geometric clusters, and to record the number of individuals in the latter rather than the former.

Cluster size for gibbons is generally smaller and more consistent, and hence easier to record. However, gibbons are scarcer than doucs and encounter rates are much lower. In addition, gibbons are an exceptionally cryptic species; they are wary of observers and typically move silently and at considerable speed through the canopy. Particular vigilance is required to ensure that no gibbons on or close to the transect line are missed by observers, as this would constitute a failure to meet one of the key assumptions of distance sampling. The level of skill and experience of observer teams is crucial in this regard.

During the earlier surveys (2005-2007) sample sizes were too low to obtain a gibbon-specific detection function, but it was possible to calculate a year-specific detection function for doucs and gibbons combined. In 2008 it was possible to produce a time- and species-specific detection function for both species which allowed for a comparison (see Appendix 2B). Estimates were reasonably similar using both types of detection function which appears to validate the use of a combined-species detection function for earlier years. As data accumulate in future years for both species, the accuracy of the detection function estimation will improve, and this can then be applied retrospectively to population estimates in all years, thus increasing the precision of these estimates further.

Figure 4c and Table 5 suggest that the mean density of doucs is declining, but on closer examination the difference between 2005 and 2010 densities (individuals) is not statistically significant ($z = 1.12$, $p > .05$) and there was no evidence of a statistically significant negative trend (linear regression on log-density, $r^2 = 0.649$, 3 d.f., $P = 0.100$). Although the 2008 and 2010 estimates exhibit reassuringly high levels of precision, earlier estimates are less precise and additional data points from future surveys are required before trends can be established with any great certainty. Nevertheless, the annual estimates do suggest that douc numbers may be declining and this warrants further analysis.

In contrast to individual density, group density has remained remarkably stable between 2005 and 2010 which indicates that the apparent decline in overall abundance is primarily attributable to a decline in recorded group sizes. During the 2005 and 2006 surveys the average cluster size recorded for doucs was approximately eight individuals per group, but as the number of observations increased in 2007 the average cluster size recorded dropped to around five. In both 2008 and 2010 the cluster size averaged four. Three possible explanations are discussed here - hunting, natural causes and methodological issues. On balance the most likely explanation is methodological issues.

Hunting might be expected to reduce group sizes without necessarily obliterating entire groups, which would result in patterns of population change similar to those implied by these results. However, there has never been any evidence that doucs are targeted by hunters in SPF. In six years of law enforcement records only one case of douc hunting has been reported, when an animal was confiscated alive and subsequently released. Doucs constitute one of the few large-bodied mammal species within SPF for which hunting pressure is believed to be negligible. It is highly improbable that hunter-prey preferences would undergo such a radical change without coming to the attention of law enforcement, community engagement or biological monitoring personnel. To support this argument, there have been manifest increases in hunting intensity for a sympatric primate species, the long-tailed macaque, and also for East Asian Porcupine *Hystrix brachyura*. These increases, driven by a spike in market demand, rapidly became common knowledge amongst all staff and local community members and were readily apparent from threat monitoring data.

If human factors such as hunting are to be discounted, environmental conditions may represent an alternative explanation for a reduction in group size. Natural fluctuations in populations are an ecological reality for many species, and what appear to be dramatic changes in populations over the short-term may in fact be within the normal range of the population when viewed over a greater temporal scale. These changes can be driven by factors such the cyclical nature of resource availability or by disease. Doucs are an under-studied species and much of their ecology, including mechanisms of population regulation, remain poorly understood.

Finally, there is a strong possibility that the apparent declines suggested by results are an artefact of sampling or observer variation. The 2005-2007 estimates lack the precision of the 2008 and 2010 estimates, and true densities during earlier surveys may have lain at the lower end of the confidence interval. Additionally, survey protocols have to some degree evolved over time, and observer accuracy may have improved as more experience was gained. This could account for discrepancies in group size between earlier and later years. In this scenario it would be expected that estimated group size will stabilise at the level determined during the 2008 and 2010 surveys, a supposition which will be put to the test in future surveys.

Similar considerations can be applied to the gibbon results. Both mean group and mean individual densities appear to be declining (Figures 4a and 4b, Table 5) but the difference between 2005 and 2010 individual densities is not statistically significant ($z = 1.123$, $p > 0.05$) and a regression of the logarithms of the annual estimates on time provided no support for the hypothesis of a statistically significant negative trend ($r^2 = 0.634$, 3 d.f., $P=0.107$).

Due to the existence of a market for young gibbons to supply the pet trade this species is targeted by hunters to a greater extent than doucs. However, hunting pressure is still believed to be low for this species at this site and there is no evidence of any recent increase, as discussed above for doucs. As with doucs it is possible that environmental or ecological factors are causing a real decline in gibbon numbers but it is also possible that the lower estimates in later years are a result of sampling and/or observer variation. Small samples sizes in earlier surveys may have led to sampling error in the estimation of cluster size which has declined from 3 in 2005 to 2 in 2010. The precision of the estimates for gibbons was greatly improved in later years but a considerable amount of uncertainty surrounds the earlier estimates due to the limited number of observations they are based upon. More data are required to build up a more comprehensive picture of gibbon status within SPF. During the 2011 monitoring season teams will exercise increased vigilance with respect to this species and will conduct informal surveys with local people in and around the SPF in order to further assess the situation.

Both Yellow-cheeked Crested Gibbon and Black-shanked Douc are most frequently observed in the evergreen and semi-evergreen forests and it is likely that densities are highest in these habitat types. They have also been observed in *Lagerstroemia* dominated mixed-deciduous forest, and riparian forest corridors through deciduous dipterocarp forest. The known distributions of both species are shown in Appendix 1F and 1G.

Green Peafowl

Green Peafowl were included as a target species for the first time during 2010 surveys. A relatively low sample size was achieved (<30) and the 2010 estimate lacks precision, but is indicative of a large population, numbering hundreds of birds. In future years it is likely this will be greatly improved upon and some of the first reliable estimates from the region will become possible.

Although historically it may have occurred across a wider range of habitats, peafowl populations throughout its remaining range are now mostly limited to dry deciduous forest, in areas with access to water and low levels of human disturbance (Brickle 2002). This pattern appears to be followed in SPF, although there are also records from mixed deciduous and semi-evergreen forest. Hunting and egg collection, together with habitat modification and human disturbance, are believed to present the greatest threats to peafowl in SPF, as is the case elsewhere (Brickle 2002). The known distribution of Green Peafowl in SPF is shown in Appendix 1H.

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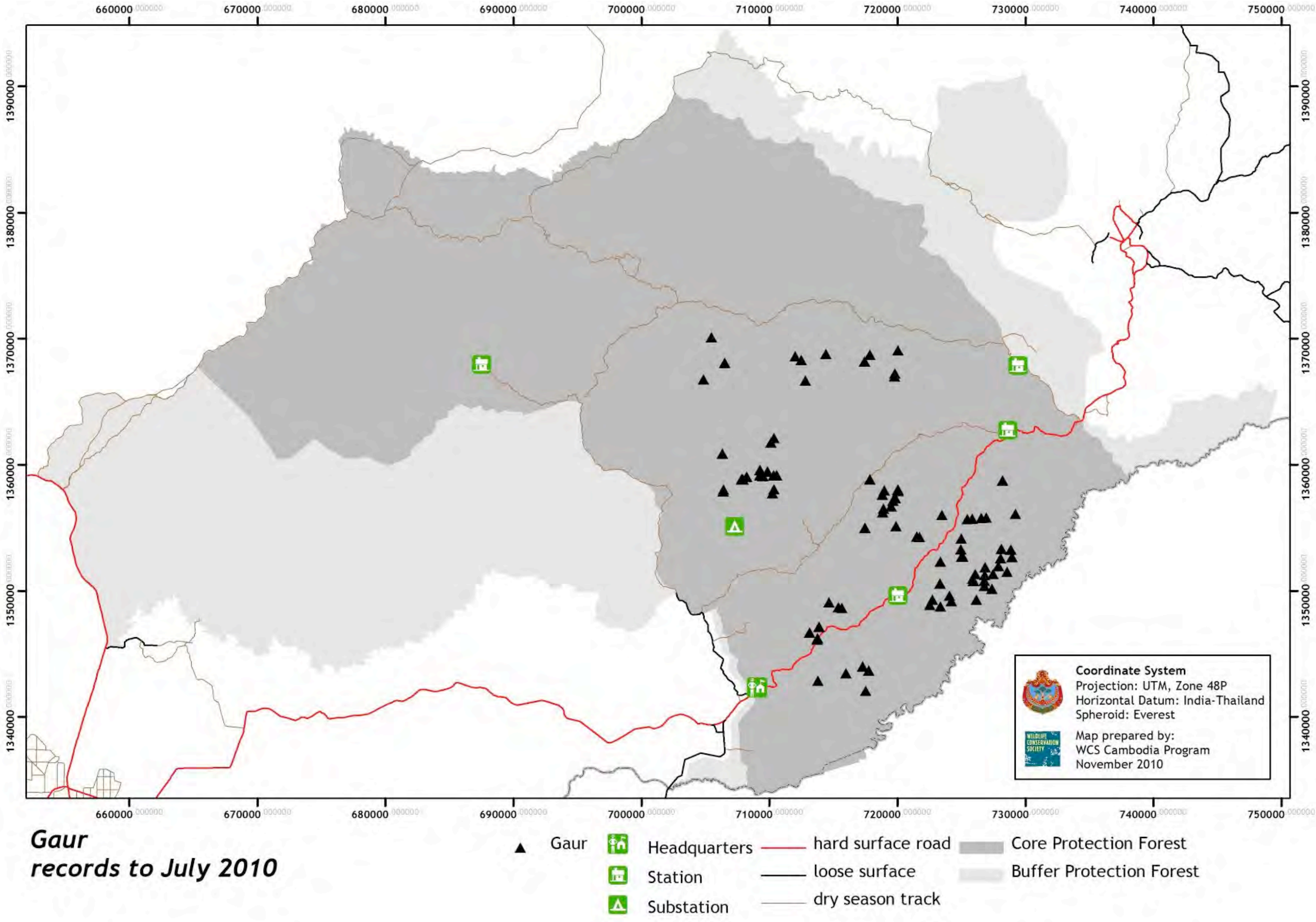
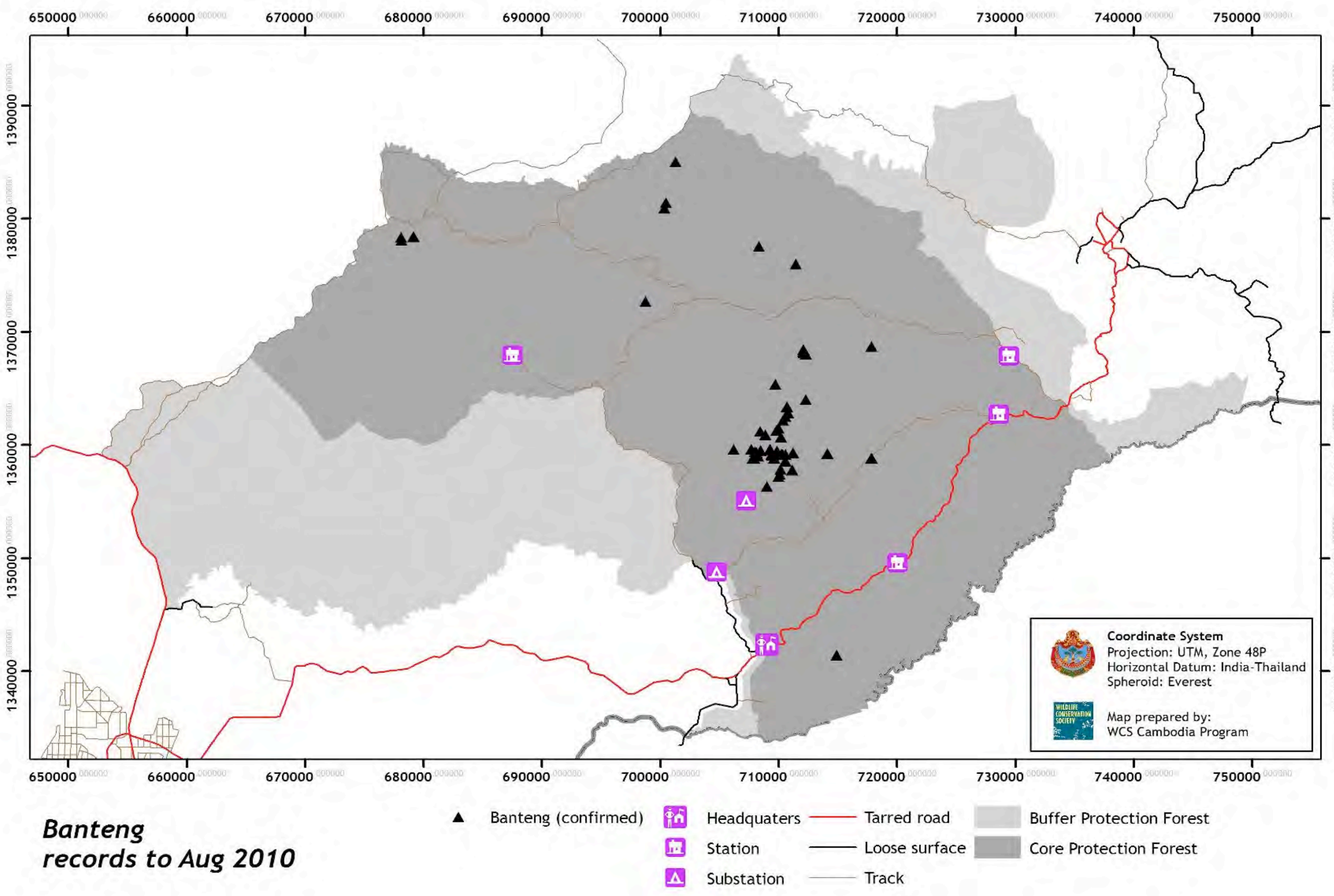
APPENDICES

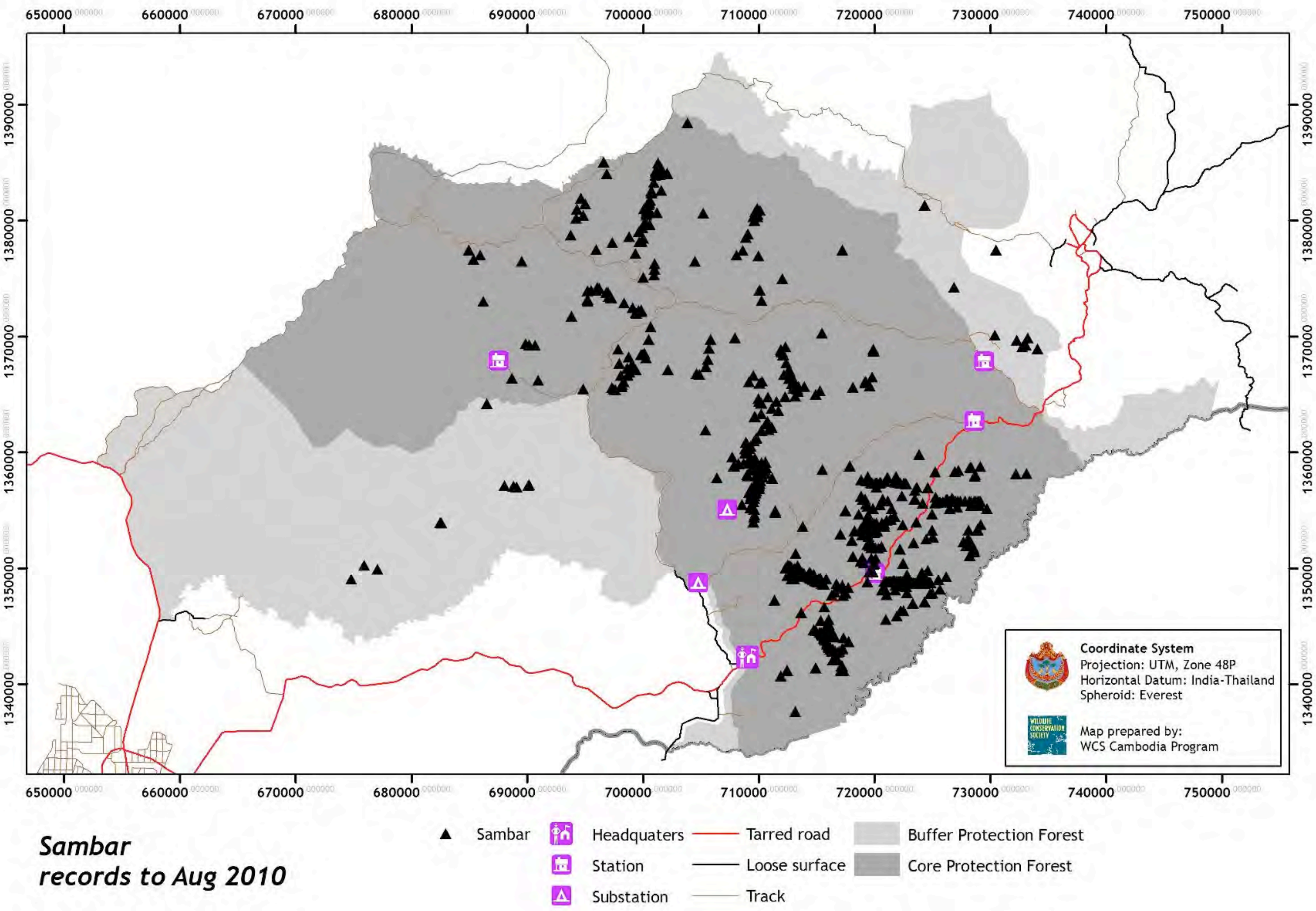
APPENDIX 1A Known distribution of Gaur



APPENDIX 1B Known distribution of Banteng

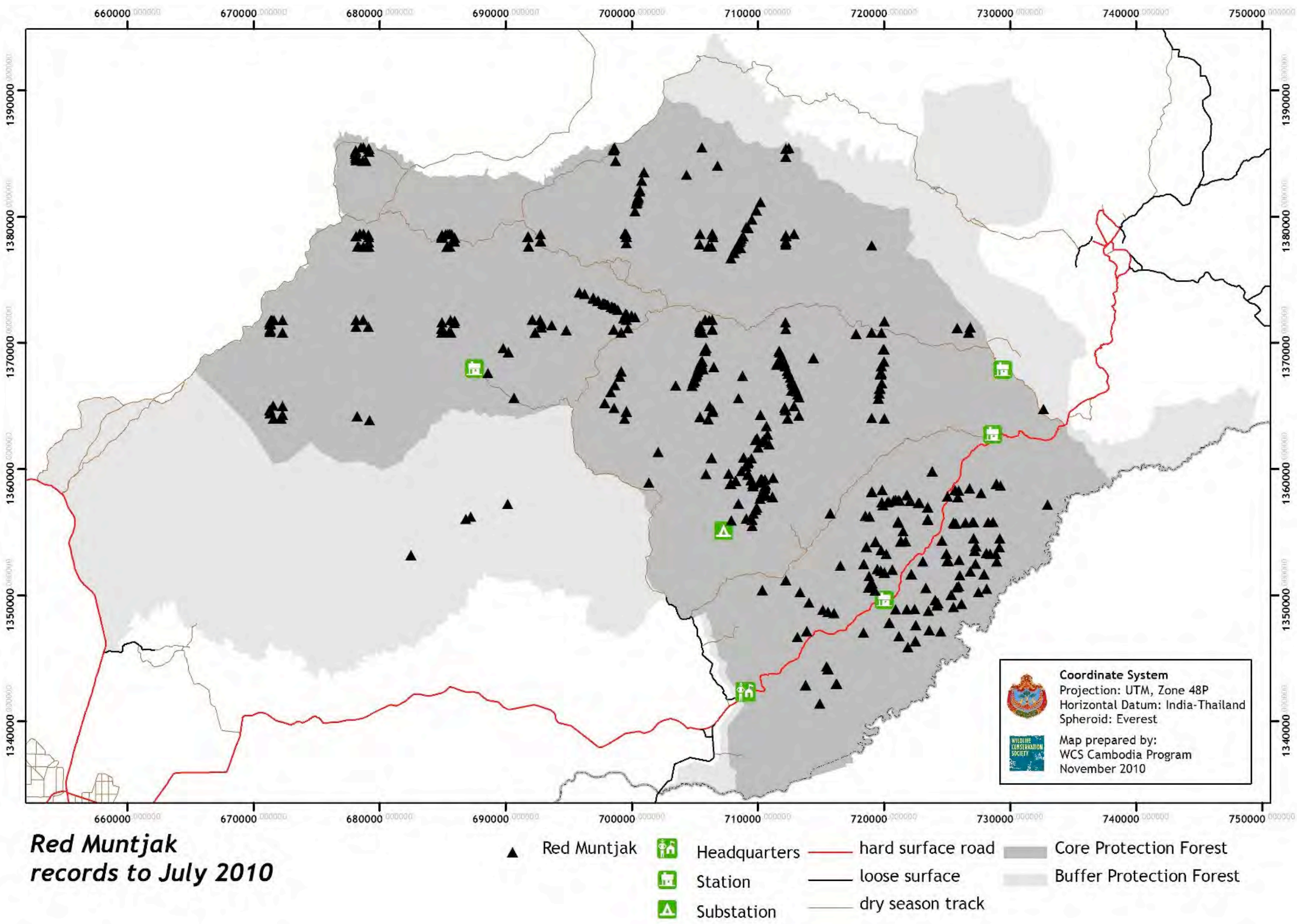


APPENDIX 1C Known distribution of Sambar

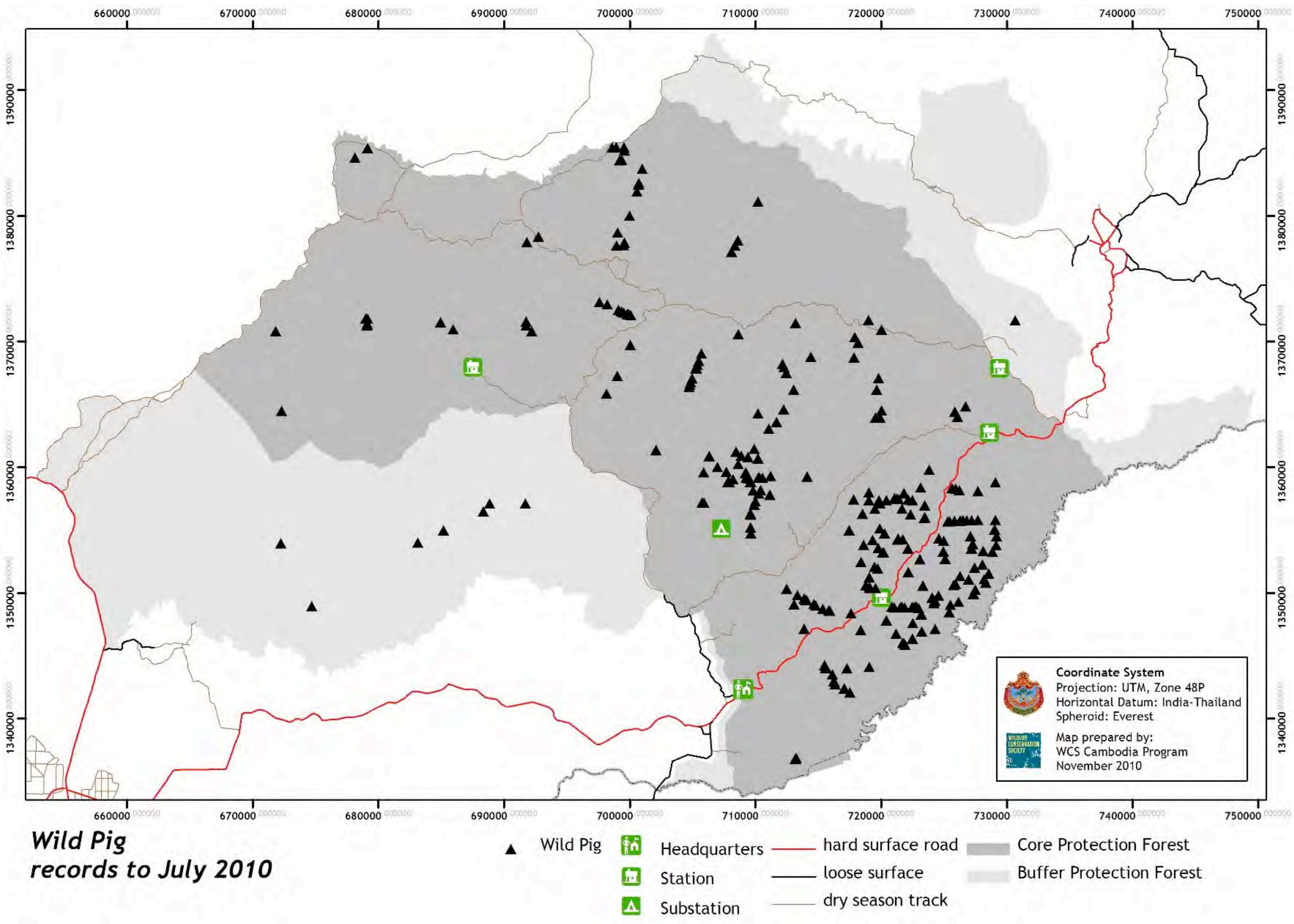


Sambar records to Aug 2010

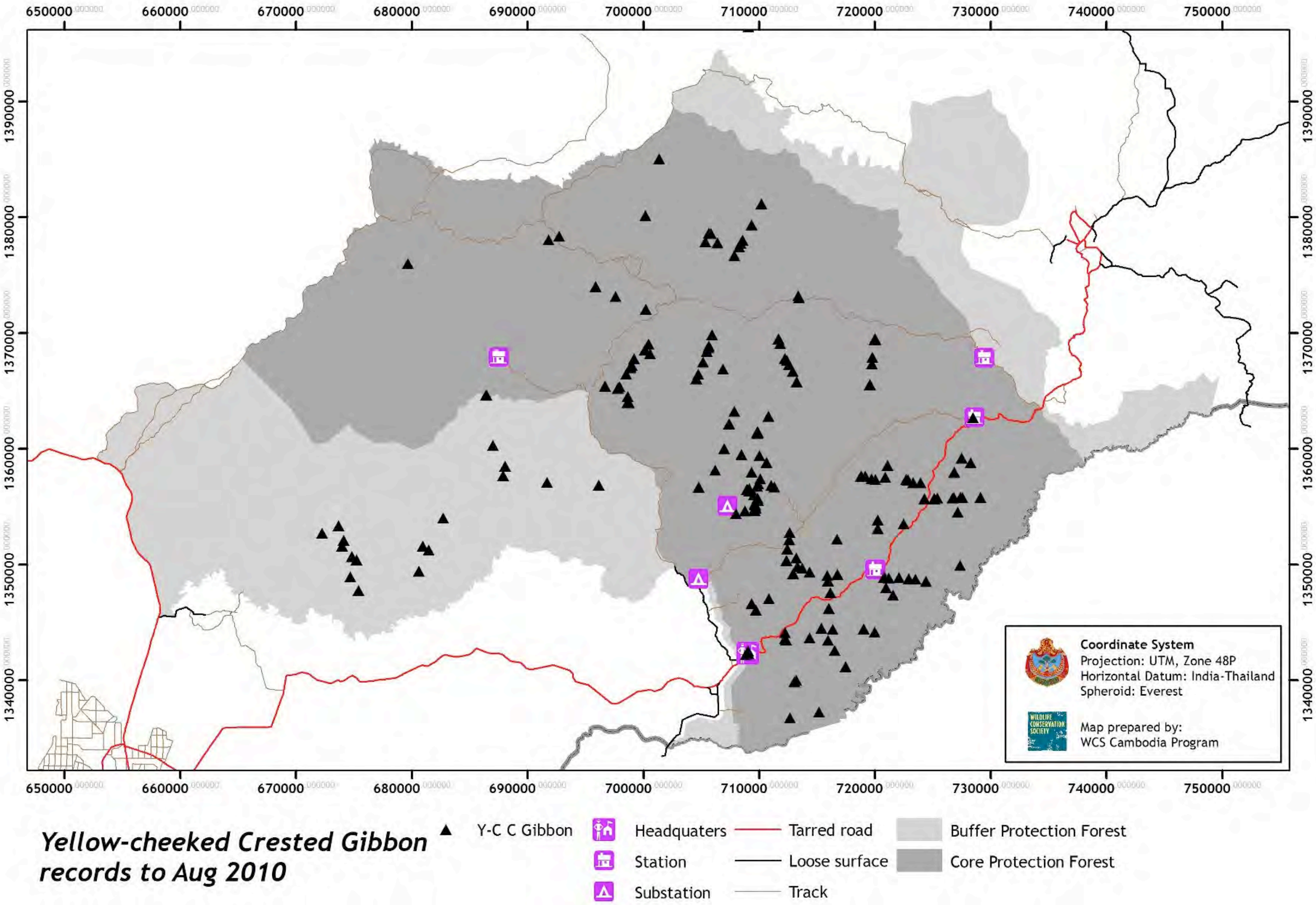
APPENDIX 1D Known distribution of Red Muntjac



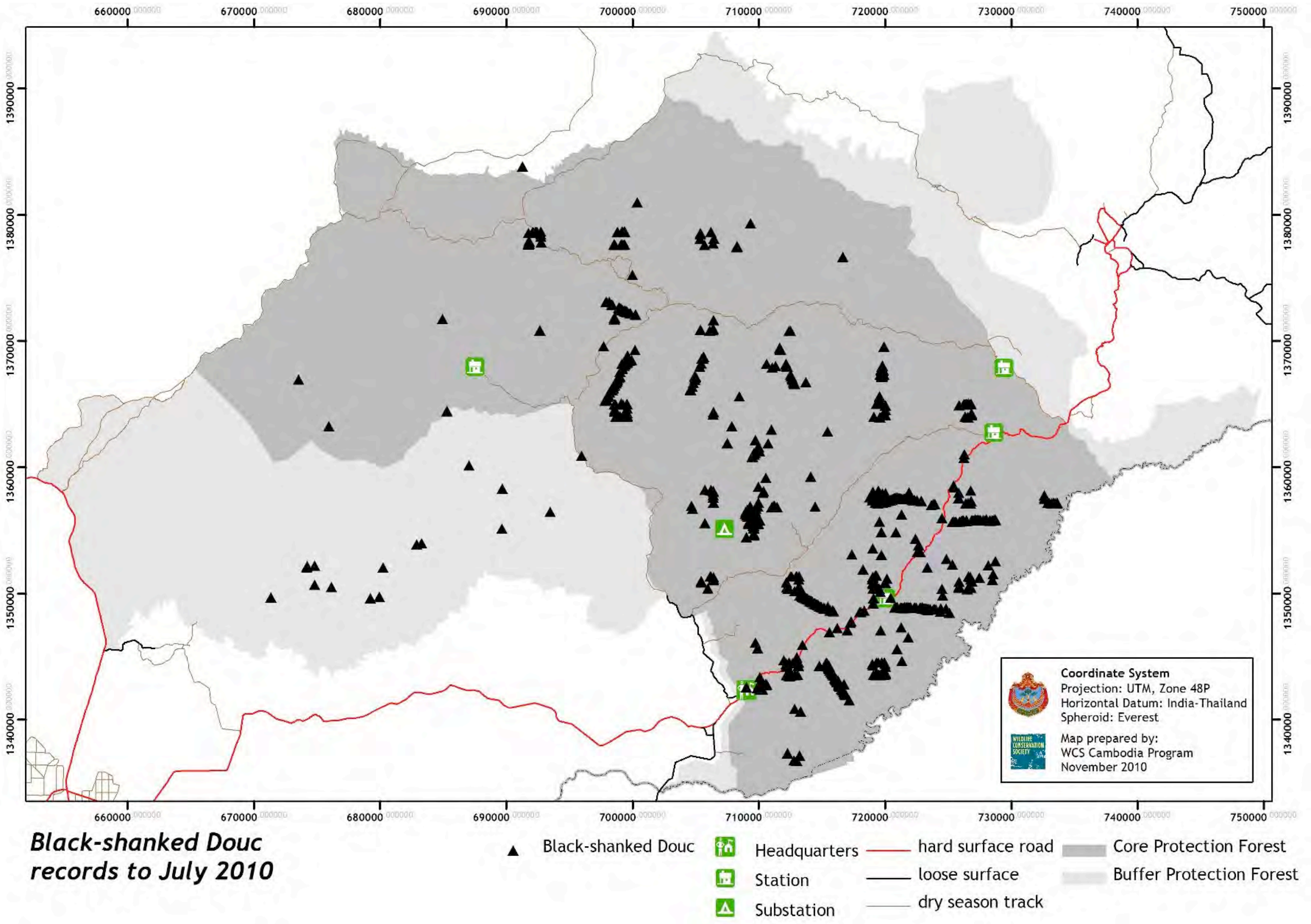
APPENDIX 1E Known distribution of Wild pig



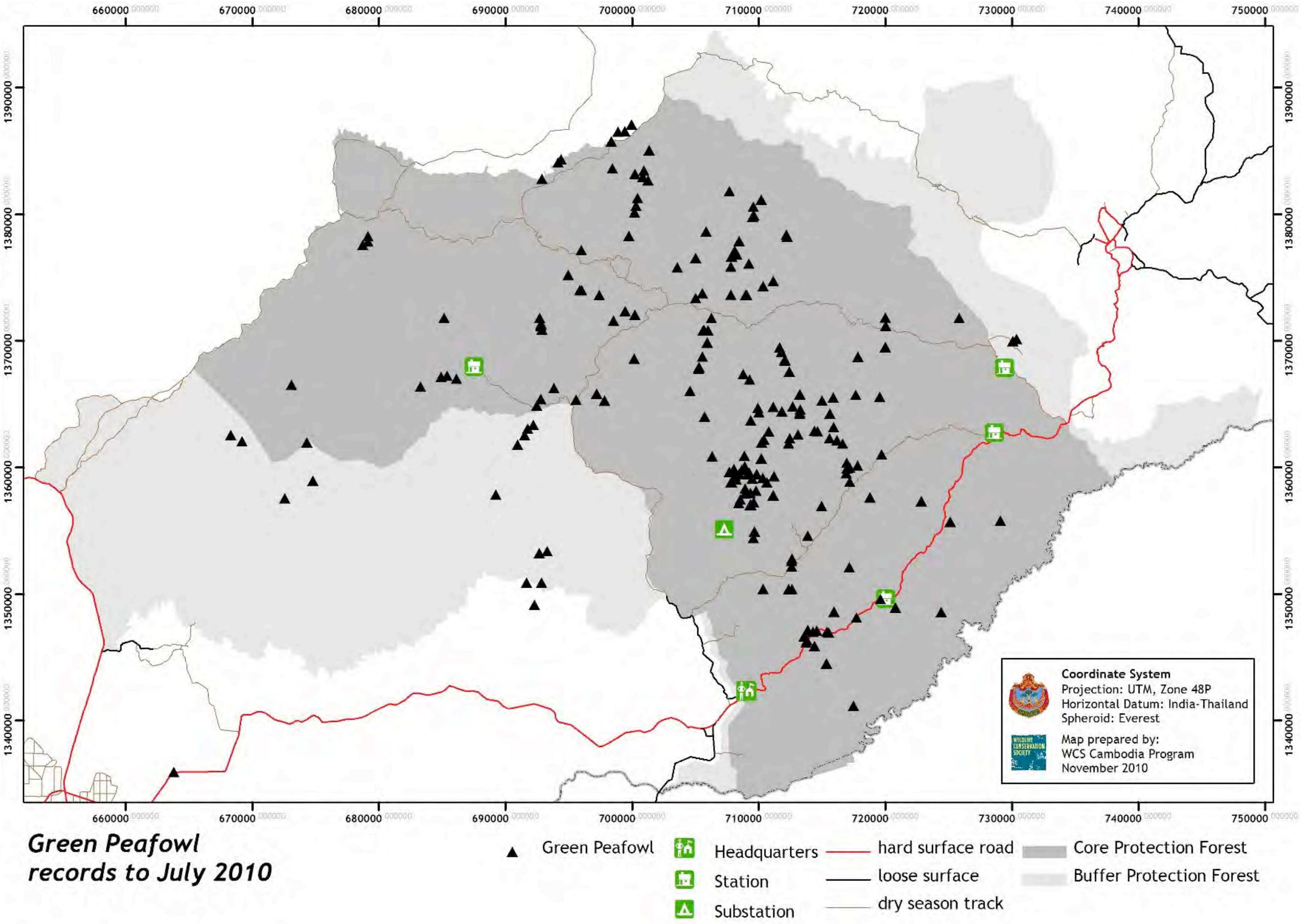
APPENDIX 1F Known distribution of Yellow-cheeked Crested Gibbon



APPENDIX 1G Known distribution of Black-shanked Douc



APPENDIX 1H Known distribution of Green Peafowl



APPENDIX 2A Summary of Distance results for Ungulates & Peafowl

Analysis	*year*	*survey area (km^2)*	*LT effort (km)*	*n**	*Model*	*RT (m)*	*D*	*CV(D)*	*95% lower*	*95% upper*	*σ (D)*	*DS*	*N*	*ER*	*P*	*ESW*
Wild Cattle																
Year specific df	2008	1086	1344	28	HRCos	100	0.54	42.62	0.23	1.23	0.23	0.24	572(245-1314)	0.021	0.40	40.1
Pooled df all data	2008	1086	1359	28	HRCos	90	0.50	37.45	0.24	1.06	0.19	0.28	545(259-1147)	0.021	0.38	34.6
	2010	1807	1600	19	HRCos	90	0.29	50.80	0.11	0.77	0.15	0.16	533(204-1392)	0.012	0.38	34.6
Pooled df old survey area only	2008	1086	1359	28	HRCos	90	0.61	36.59	0.29	1.27	0.22	0.35	663(319-1378)	0.021	0.30	27.1
	2010	1086	960	15	HRCos	90	0.40	54.82	0.14	1.13	0.22	0.29	429(150-1225)	0.016	0.30	27.1
Wild Pig																
Pooled df old survey area	2005	1086	113	3	HnCos	70	1.44	54.47	0.48	4.28	0.78	0.60	1561(524-4645)	0.027	0.31	22.0
	2006	1086	113	5	HnCos	70	2.40	49.47	0.88	6.51	1.18	1.00	2601(958-7065)	0.044	0.31	22.0
	2007	1086	170	9	HnCos	70	2.87	40.55	1.25	6.58	1.17	1.20	3121(1363-7149)	0.053	0.31	22.0
	2008	1086	1359	61	HnCos	70	2.39	21.21	1.56	3.67	0.51	1.00	2596(1689-3990)	0.045	0.31	22.0
	2010	1086	920	35	HnCos	70	2.00	28.16	1.14	3.51	0.56	0.84	2173(1238-3813)	0.038	0.31	22.0
Year specific df old survey area	2008	1086	1344	61	HnCos	70	1.71	22.91	1.08	2.70	1.71	0.85	1855(1173-2935)	0.045	0.37	25.9
	2010	1086	920	35	UnCos	60	3.23	33.54	1.68	6.21	1.08	0.97	3504(1821-6741)	0.038	0.32	19.1
Year specific df new survey area	2010	1807	1560	53	HnCos	70	2.04	27.69	1.19	3.49	0.56	0.71	3676(2144-6303)	0.034	0.33	23.4
Red Muntjac																
Pooled df old survey area only	2005	1086	113	9	HnCos	60	1.11	40.50	0.48	2.58	0.45	1.04	1210(523-2802)	0.080	0.50	29.7
	2006	1086	113	15	HnCos	60	2.39	25.21	1.40	4.07	0.60	1.49	2593(1524-4415)	0.133	0.50	29.7
	2007	1086	170	25	HnCos	60	2.55	20.81	1.64	3.95	0.53	2.38	2766(1782-42940	0.147	0.50	29.7
	2008	1086	1359	134	HnCos	60	1.72	21.59	1.09	2.72	0.37	1.63	1869(1185-2950)	0.099	0.50	29.7
	2010	1086	920	71	HnCos	60	1.37	20.18	0.91	2.07	0.28	1.28	1487(985-2244)	0.077	0.50	29.7

Year specific df old survey	2008	1086	1344	134	HnCos	80	1.75	22.12	1.10	2.79	0.39	1.59	1903(1197-3025)	0.100	0.50	30.2
	2010	1086	920	71	HnCos	60	1.34	21.45	0.87	2.06	0.29	1.32	1452(943-2237)	0.077	0.48	28.9
Year specific df new survey	2010	1807	1560	169	HnCos	80	1.75	18.14	1.22	2.51	0.38	1.69	3163(2207-4532)	0.108	0.38	30.4
Sambar																
Year specifc df	2008	1086	1344	22	HnCos	65	0.39	70.87	0.10	1.53	0.28	0.30	428(110-1667)	0.016	0.42	27.4
Pooled df all data	2008	1086	1359	22	HnCos	0	0.40	70.54	0.10	1.56	0.28	0.31	436(112-1694)	0.016	0.50	26.0
	2010	1807	1600	6	HnCos	0	0.09	48.32	0.04	0.23	0.04	0.07	167(67-420)	0.004	0.50	26.0
Pooled df old survey area only	2008	1086	1359	22	HnCos	55	0.41	70.10	0.11	1.57	0.29	0.32	442(14-1709)	0.016	0.47	25.7
	2010	1086	960	6	HnCos	55	0.16	46.20	0.06	0.38	0.07	0.12	170(69-418)	0.006	0.47	25.7
Green Peafowl																
Year specifc df	2010	1807	1600	26	HnCos	120	0.18	38.68	0.09	0.39	0.07	0.17	333(158-700)	0.016	0.39	47.3

* In appropriate survey area before truncation

APPENDIX 2B Summary of Distance results for primate individuals

Year	*n*	*Survey Area Description*	*Survey Area (km2)*	*Walk Effort (km)*	*Forest Type Included**	*RT*	*Model*	*Detection Function*	*p*	*ESW*	*ER*	*Density Indivs*	*CV*	*95%CI*	*95%CI*	**σ**	*N*	*N LCL*	*N UCL*
Gibbons																			
2008	42	Old	789	1017	EG/SE	70	HnCos	YrSppSp	0.47	33.2	0.041	1.38	21.08	0.90	2.10	0.29	1087	713	1656
2005	6	Old	789	89	EG/SE	70	UnCos	Pooled spp	0.50	35.0	0.067	2.25	46.20	0.87	5.78	1.04	1774	690	4563
2006	5	Old	789	89	EG/SE	70	UnCos	Pooled spp	0.58	40.4	0.056	1.53	61.07	0.46	5.05	0.93	1204	364	3986
2007	9	Old	789	133	EG/SE	70	UnCos	Pooled spp	0.53	37.4	0.068	2.00	37.81	0.93	4.28	0.76	1577	737	3375
2008	42	Old	789	1017	EG/SE	70	HnCos	Pooled spp	0.36	24.9	0.041	1.83	18.72	1.25	2.68	0.34	1447	989	2117
2010	16	Old	789	648	EG/SE	70	HnCos	Pooled spp	0.38	26.6	0.025	1.01	35.64	0.50	2.06	0.36	800	394	1622
2010	17	New	1069	872	EG/SE	65	HnCos	Pooled spp	0.40	25.9	0.019	0.77	36.25	0.38	1.57	0.28	827	408	1676
2010	18	New	1807	1560	All Hab	65	HnCos	Pooled spp	0.40	26.2	0.012	0.43	39.97	0.20	0.93	0.17	774	357	1679
Doucs																			
2005	42	Old	789	89	EG/SE	70	UnCos	YrSppSp	0.50	35.0	0.472	47.05	24.62	28.91	76.57	11.58	37121	22809	60412
2006	54	Old	789	89	EG/SE	70	UnCos	YrSppSp	0.58	40.6	0.607	64.63	28.70	36.27	115.16	18.55	50994	28619	90861
2007	65	Old	789	133	EG/SE	70	UnCos	YrSppSp	0.50	35.0	0.489	35.30	26.65	20.67	60.29	9.41	27854	16310	47567
2008	395	Old	789	1017	EG/SE	70	UnCos	YrSppSp	0.36	25.3	0.388	29.32	14.68	21.62	39.77	4.30	23133	17054	31379
2010	241	Old	789	648	EG/SE	70	UnCos	YrSppSp	0.39	27.0	0.372	27.64	15.16	20.41	37.43	4.19	21805	16101	29530
2010	283	New	1807	1560	All Hab	65	HnCos	YrSppSp	0.45	29.1	0.181	11.83	20.96	7.79	17.95	2.48	21373	14081	32443
2010	330	New	1807	1561	All Hab	65	HnCos	YrSppSp	0.41	26.6	0.211	12.81	21.30	8.39	19.55	2.73	23144	15161	35332
2010	314	New	1069	872	EG/SE	65	HnCos	Pooled habitat	0.41	26.6	0.023	21.87	15.92	15.94	30.01	3.48	23383	17043	32082
2010	16	New	738	687	DEC	65	HnCos	Pooled habitat	0.41	26.6	0.360	1.34	51.89	0.49	3.65	0.69	987	362	2693

* EG=evergreen forest, SE=semi-evergreen Forest, All Hab= all forest types

** YrSppSp = Year and species specific detection function, Pooled spp=Douc and Gibbon combined, Pooled Habitat=all forest types combined

APPENDIX 2C Summary of Distance results for primate groups

Year	*n*	*Survey Area (km2)*	*Survey Area Description*	*Walk Effort (km)*	*Forest Type Included*	*RT*	*Model*	*Detection Function*	*Density Groups*	*CV*	*95% CI*	*95% CI*	*σ grps*	*Cluster Type**	*Exp. Cluster size*	*Mean cluster size*	*Cluster Used**	*Grp*	*Grp LCL*	*Grp UCL*
Gibbons																				
2008	42	789	Old	1017	EG/SE	70	HnCos	YrSppSp	0.61	18.89	0.41	0.89	0.11	GC	2.19	2.27	mean	479	326	704
2005	6	789	Old	89	EG/SE	70	UnCos	Pooled species	0.96	33.88	0.48	1.94	0.33	GC	2.34	3.00	exp	757	375	1529
2006	5	789	Old	89	EG/SE	70	UnCos	Pooled species	0.55	58.54	0.17	1.79	0.32	GC	2.90	2.75	mean	438	136	1409
2007	9	789	Old	133	EG/SE	70	UnCos	Pooled species	0.90	32.38	0.46	1.77	0.29	GC	2.27	2.22	mean	710	360	1399
2008	42	789	Old	1017	EG/SE	70	HnCos	Pooled species	0.81	16.20	0.57	1.14	0.13	GC	2.21	2.27	mean	638	453	898
2010	16	789	Old	648	EG/SE	70	HnCos	Pooled species	0.46	33.83	0.23	0.91	0.16	GC	2.29	2.19	mean	366	185	721
2010	17	1069	New	872	EG/SE	65	HnCos	Pooled species	0.38	34.17	0.19	0.74	0.13	TC	2.07	2.06	mean	402	205	786
2010	18	1807	New	1560	All Hab	65	HnCos	Pooled species	0.21	38.09	0.10	0.44	0.08	GC	2.07	2.06	mean	376	179	791
Doucs																				
2005	42	789	Old	89	EG/SE	70	UnCos	YrSppSp	6.72	19.68	4.50	10.04	1.32	GC	7.00	7.76	exp	5302	3549	7920
2006	54	789	Old	89	EG/SE	70	UnCos	YrSppSp	7.30	25.18	4.32	12.35	1.84	GC	8.31	8.85	mean	5763	3408	9743
2007	65	789	Old	133	EG/SE	70	UnCos	YrSppSp	6.83	24.12	4.16	11.21	1.65	GC	6.04	5.17	mean	5386	3281	8841
2008	395	789	Old	1017	EG/SE	70	UnCos	YrSppSp	7.62	14.13	5.67	10.26	1.08	GC	3.85	4.05	exp	6014	4470	8092
2010	241	789	Old	648	EG/SE	70	UnCos	YrSppSp	6.84	14.43	5.12	9.15	0.99	GC	3.93	4.04	mean	5401	4039	7221
2010	283	1807	New	1560	All Hab	65	HnCos	YrSppSp	3.07	20.38	2.04	4.61	0.63	GC	3.85	4.07	exp	5545	3690	8332
2010	330	1807	New	1561	All Hab	65	HnCos	YrSppSp	3.92	20.89	2.59	5.94	0.82	TC	3.27	3.47	exp	7085	4675	10738
2010	314	1069	New	872	EG/SE	65	HnCos	Pooled habitat	6.70	15.36	4.93	9.09	1.03	TC	3.27	3.47	exp	7157	5269	9722
2010	16	738	New	687	DEC	65	HnCos	Pooled habitat	0.41	51.72	0.15	1.11	0.21	TC	3.27	3.47	exp	302	111	823

* GC=geometric cluster (30m radius), TC=tree cluster (all animals on one tree)
** If test p-value is non significant average cluster size is used, but if significant expected value used (expected value of cluster size computed by regression)