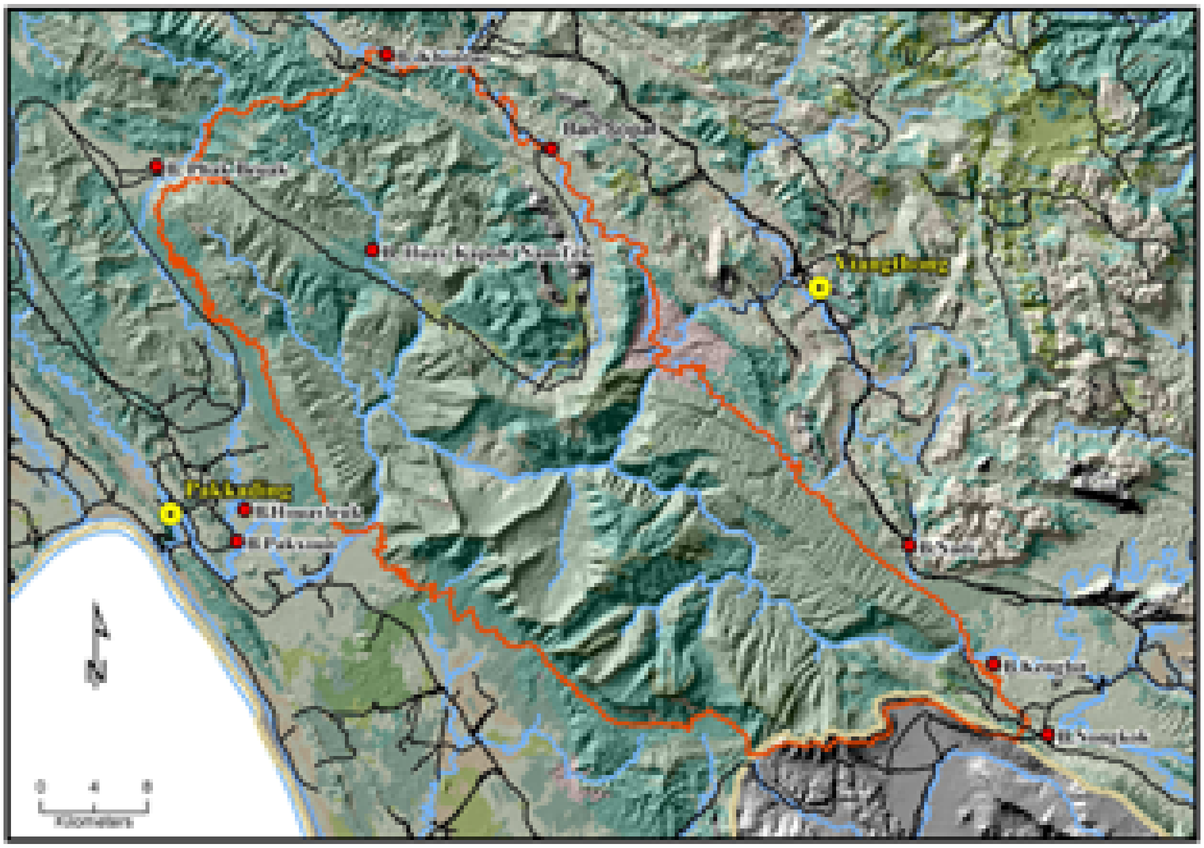
Lao PDR Program

Recommendations for Monitoring Landscape Species in the Nam Kading National Protected Area, Bolikhamxay Province, Lao PDR



A report to the *Integrated Ecosystem and Wildlife Management Project*

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Cover Illustration: A digital elevation model of the Nam Kading National Protected Area and surrounding landscape. GIS analysis by Ms. Akchousanh Rasphone (WCS Lao Program).

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Table of Contents

Figures and Tables

Introduction

The Integrated Ecosystem and Wildlife Management Project (IEWMP) is a cooperative project between the Bolikhamxay Provincial Agriculture and Forestry Office, the Department of Forestry and the Wildlife Conservation Society. It is a five year project that received major funding from the MacArthur Foundation in September 2003 and the Global Environment Facility in January 2005. The project officially began in April 2005 with signing of Memorandums of Understanding between the Government of Lao PDR (GoL) and the Wildlife Conservation Society (WCS) and the World Bank and WCS.

The stated goal of the IEWMP is to conserve the globally important biodiversity of Bolikhamxay Province (Johnson *et al.* 2006) (Figure 1). To achieve this goal, the objectives of the project are to increase the capacity of Lao conservation professionals working in the Nam Kading National Protected Area (NPA) and at least one Bolikhamxay provincial protected area[1] and to provide them with an opportunity to practice their conservation planning and management skills. A secondary objective is to demonstrate a model for conservation planning and implementation that can be replicated in other protected areas in Lao PDR.

Bolikhamxay province is renowned for its globally significant biodiversity. The predominant habitat in the province is dry evergreen forest. The largest block of this habitat is found in the Nam Kading NPA (Figure 2) and represents the highest quality dry evergreen forest remaining in Indochina (Duckworth et al., 1999). Many of the important species in the province depend on this forest type and some, such as the large hornbills, cannot survive without very large areas of this forest type. The NPA, covering 1570 km^2, also contains areas of mixed deciduous forest, grasslands, wetlands and limestone karst and is bisected by the Nam Kading River. The areas of wet evergreen forest in the mountains along the Vietnam border, such as Nam Chat-Nam Pan Provincial Protected Area, are a refuge for plants and animals that survive from the last ice age, including several newly described endemic species such as Saola (*Pseudoryx nghetinhensis*) and Annamite Striped Rabbit (*Nesolagus timminsi*).

To achieve the goal and objectives of the IEWMP, the project adopted the WCS Landscapes Species Approach (LSA) to conservation planning. The LSA is a strategic planning process that guides wildlife management within large landscapes of human influence (Sanderson *et al*., 2002). The conservation targets used within the LSA are referred to as “Landscape Species” and these have five characteristics: they range over large areas, use a variety of habitat types, are especially vulnerable to threats in the landscape (such as over harvest or habitat loss), are socio-economically important, and have a strong ecological function in the natural ecosystem (e.g., seed disperser, top predator) (Coppolillo *et al*., 2004). The seven species identified as Landscape Species for Bolikhamxay by the IEWMP in March 2006 are Asian elephant (*Elephas maximus*), tiger (*Panther tigris*), southern serow (*Naemorhedus sumatraensis*), Eurasian wild pig (*Sus scrofa*), white-cheeked crested gibbon (*Nomascus leucogenys*), great hornbill (*Buceros bicornis*) and a catfish called “Pakheung” in Lao language (*Hemibagrus wyckoides*)(Strindberg, 2006). From March to November 2006, IEWMP government staff worked with WCS to, i) identify the best habitat for each Landscape Species (called Biological Landscapes), ii) to show where the important human-caused threats are occurring and how strongly they impact the species (called Threats Landscapes), and, iii) to use the Biological and Threats Landscapes to create Conservation Landscapes. The Conservation Landscapes for Bolikhamxay Province identify the areas of the landscape that are a management priority for the species (Bryja, 2006a).

In November 2006, maps of the conservation landscapes where used by the IEWMP to build conceptual models that define a population target for six of the landscape species and management interventions (reduction of hunting, wildlife trade and habitat loss) to reach these targets in the Nam Kading NPA (Johnson, et al., 2006). The population targets set by the IEWMP for the landscape species of the NPA by the end of 2010 are:

- A 10% increase in the white-cheeked crested gibbon population
- A 35% increase in the great hornbill population

[1] National Protected Areas (NPAs) are designated and supervised by the central government in Vientiane while Provincial Protected Areas (PPAs) are designated and supervised by the provincial government in Bolikhamxay Province.

- A 20% increase in the tiger population
- A 50% increase in the southern serow population
- A 100% increase in the Eurasian wild pig population
- No decline in the Asian elephant population

In advance of designing a monitoring program to detect change in the populations of landscape species, the IEWMP conducted baseline reconnaissance surveys in the NPA from January to April 2007 to, i) determine encounter rates and estimate distribution of landscape species and anthropogenic threats and, ii) map access routes (Van Der Helm and Johnson, 2007).

This document summarizes recommendations for the design and implementation of a Landscape Species monitoring program for the Nam Kading Protected Area. The monitoring program was designed from October 29-November 2 by a team of WCS and IEWMP staff. The design team included Dr. Arlyne Johnson (WCS Lao Program; Team Leader); Dr. Samantha Strindberg (WCS Living Landscapes Program; Biostatistician); Mr. Chris Hallam (WCS Lao Program; IEWMP Site Coordinator); Ms. Fiona Van Der Helm (WCS Lao Program; Trainer), Mr. Phienxay Xiongyiadang (WCS Lao Program; IEWMP Project Officer) and Mr. Phouthong Sisavath (WCS Lao Program, IEWMP Project Officer). The GIS analysis was conducted by Ms. Akchousanh Rasphone (WCS Lao Program, GIS Officer), with the assistance of Mr. Souksavath (WCS Lao Program; GIS Assistant).

This report includes three sections:

Section 1. Wildlife Monitoring Design.

Section 2. Field Protocol for Camera Trapping of Ground Dwelling Mammals in the Nam Kading National Protected Area.

Section 3. Field Protocol for Monitoring Forest Hornbills and Arboreal Mammals along Line Transects in the Nam Kading National Protected Area.

Acknowledgements

We would like to acknowledge and thank the following agencies for their assistance:

- The Integrated Ecosystem and Wildlife Management Project, a cooperative project between the Bolikhamxay Provincial Agriculture and Forestry Office, the Department of Forestry, and the Wildlife Conservation Society.
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- Local communities of the Nam Kading National Protected Area.

Figure 1: Map of Bolikhamxay Province, Lao PDR

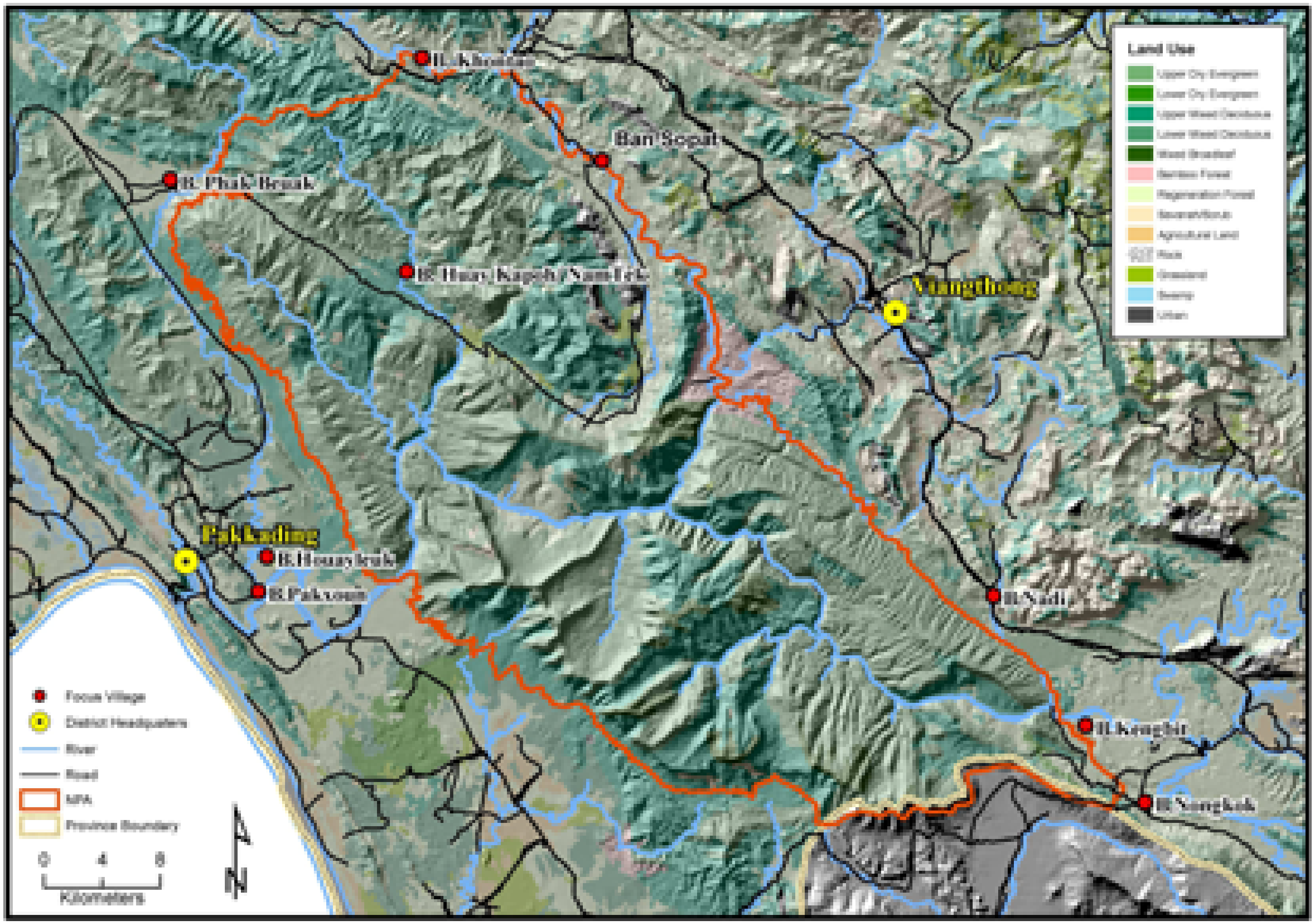

Figure 2: A digital elevation model of the Nam Kading National Protected Area and surrounding landscape.

Section 1. Wildlife Monitoring Design

1. Strategic Conservation Planning

In this section we will introduce wildlife monitoring in the context of strategic conservation planning and briefly explain where it falls within the conservation management cycle. We will also describe the characteristics of the Landscape Species Approach and how this particular framework for strategic conservation planning moves through the various steps in the conservation management cycle.

1.1 The Conservation Management Cycle

We believe that successful conservation projects should broadly speaking apply the following adaptive management steps (as illustrated in Figure 3):

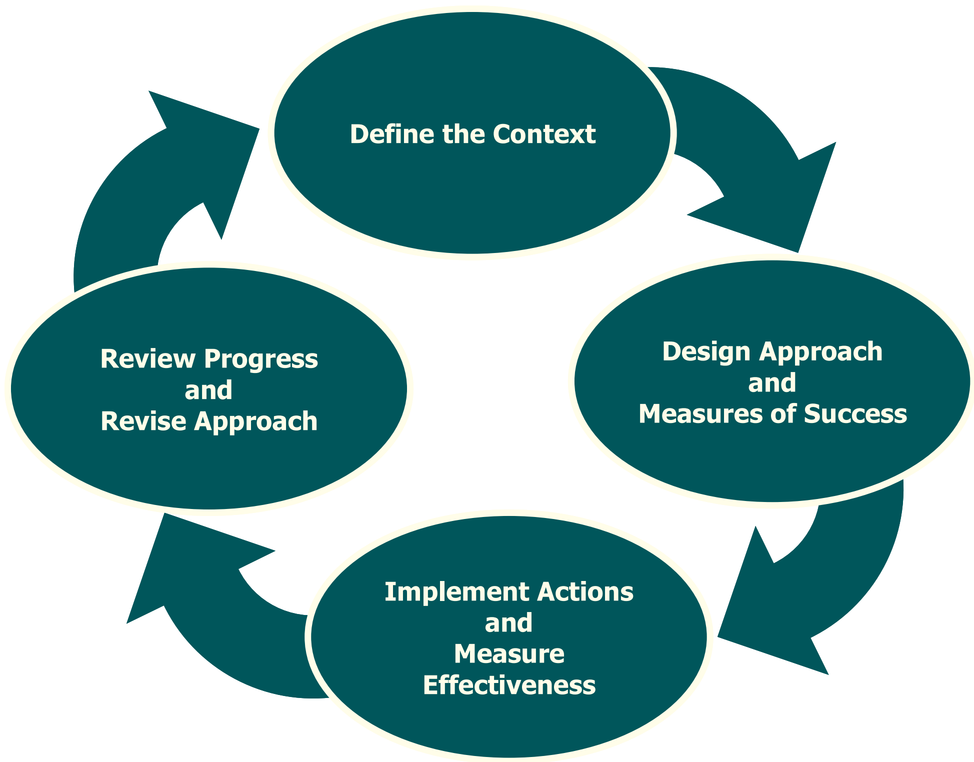

Figure 3: The Wildlife Conservation Society's interpretation of the conservation management cycle as developed by the Living Landscapes Program.

Define the Context: We explicitly define where we want to work and what we want to conserve, also identifying the most important threats and where they occur within the landscape of interest. Developing conceptual models for the project or completing a participatory threats assessment can be useful tools for successfully completing this step.

Design Approach and Measures of Success: We strategically plan our interventions so we are confident that they will help abate the most critical threats, while putting in place a process for measuring the effectiveness of our conservation actions, and using this information to guide our decisions. The latter involves the formulation of a monitoring design and generally benefits from the development of a formal monitoring framework.

Implement Actions and Measure Effectiveness: Develop and implement work plans taking account the available resources and capacity. Collect and analyze the data to assess how well the interventions are being implemented, to what degree the threats are being successfully mitigated and whether the wildlife populations of interest are doing as well as we hope.

Review Progress and Revise Approach: Based on the monitoring results, adapt the interventions and refine the monitoring design.

1.2 The Landscape Species Approach

Effective wildlife conservation requires that we consider the complex mix of biological, social and economic factors that influence the ecological integrity of landscapes, and then focus our conservation efforts on activities that will have the most positive impact on wildlife populations and their habitat. This requires that we clearly understand the ecological needs of species and the human activities that impinge on them.

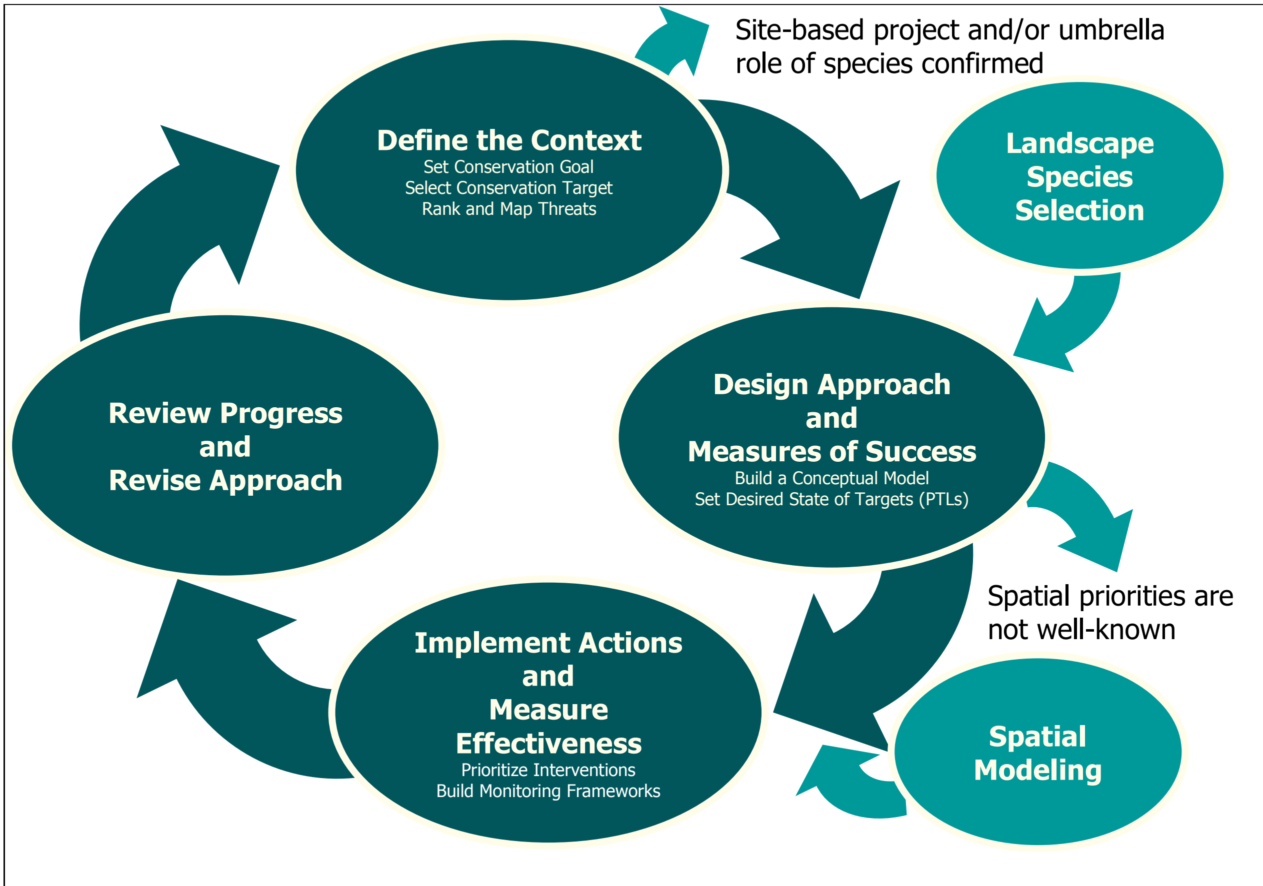

Figure 4: An illustration of how the Landscape Species Approach is applied at different points (highlighted in light blue) within the general conservation management cycle shown in Figure 1.

The Landscape Species Approach (LSA), developed by WCS' Living Landscapes Program, provides the coherent framework and practical tools needed to guide site-based conservation based on the needs of wildlife within large landscapes of human influence. This step-by-step process for planning and implementing conservation actions includes the following (Figure 4), which also follows the general conservation management cycle:

(1) Building conceptual models for clearly defining a program's goals and objectives, (Wilkie *et al*., 2002a & 2004b),

(2) Engaging in a participatory approach for prioritizing and mapping human activities that threaten landscapes and the wildlife within them (Wilkie *et al*., 2004a),

(3) Applying an objective and transparent process for selecting a complementary suite of target species that if conserved, will help protect all biodiversity under their collective conservation canopy (i.e., Landscape Species; see Coppolillo *et al*. 2004, Strindberg, 2004 and Strindberg *et al*., 2006b),

(4) Mapping habitat quality of Landscape Species and the human activities which affect Landscape Species (Didier *et al*., 2006),

(5) Creating a "Conservation Landscape" to map areas of the greatest conservation impact,

(6) Following a process for prioritizing and strategically planning interventions, and

(7) Developing effective monitoring designs and frameworks (Wilkie *et al*., 2002b & 2006a).

All the Bulletins and technical manuals developed by the Living Landscapes Program that give an overview of the approach and more detailed guidance in the use of some of the tools are available online at http://www.wcslivinglandscapes.org.

The components of the LSA that distinguish it from strategic conservation planning more generally are their special relevance to planning at the landscape scale, the systematic and transparent selection of conservation targets using specially designed software and according to clearly defined criteria, and the development of biological, human and conservation landscape models, which is appropriate if little is know about how to spatially prioritize interventions (Figure 4).

As briefly described in the introduction, the Nam Kading Landscape has followed all the steps that comprise the Landscape Species Approach and this report details the formulation of a monitoring design for the Nam Kading NPA that constitutes part of step 7 listed above.

2. Monitoring Overview

In this section we review some key monitoring concepts and then go on to introduce a general sampling framework and issues that need to be considered in terms of accuracy and precision of an estimator and how to achieve both. We briefly review the factors that influence our ability to detect a trend in a short section on power analysis. State variables such as abundance and extent of occurrence can be used to estimate the status of the population for monitoring purposes. We give a brief overview of line transect distance sampling and patch occupancy methods that will be used in the context of the Nam Kading NPA monitoring design.

2.1 Introduction

Monitoring tracks progress over time towards a clearly defined target or objective. We can only monitor if we have a clear idea of what we hope to achieve, thus setting explicit targets lies at the core of effective monitoring. Monitoring assumes sufficient knowledge of the system of interest to allow us to set explicit targets in contrast to research that gathers information about the unknown.

As described above, as part of the LSA and effective conservation planning more generally, we have been developing conceptual models that 1) explicitly define what it is that we want to influence or change as a result of project interventions (i.e., the conservation targets); 2) characterize and prioritize the factors that directly or indirectly result in undesirable impacts on the species or lands we want to conserve (i.e., the threats); 3) graphically represent how these threats, individually or in combination, cause the undesirable changes in the species or lands that we want to conserve; 4) demonstrate that the interventions we choose are clearly focused on reducing key threats and attaining our conservation targets; 5) provide a strategic framework for determining what to monitor to assess project effectiveness and to adapt project actions; and 6) offer a structure for reviewing and revising project assumptions and activities as conditions change over time (Wilkie *et al*., 2002a & 2004b).

Monitoring is a crucial component of good conservation management (Salafsky *et al*., 2001). It allows us to assess whether or not threats are decreasing, and/or wildlife populations increasing or remaining stable. Through monitoring we can test our assumptions as to whether our interventions actually lead to what we want to achieve, or are they wasted effort (Kremen *et al*. 1994).

Ideally we would want to monitor the interventions, the threats and the conservation targets themselves to get the most information about the effectiveness of our actions. We would monitor our interventions to make sure that they are being implemented as we planned (e.g., Are trained guards getting out on patrol?). Since our interventions are chosen to reduce levels of threat to wildlife and their habitat, we monitor our success in reducing threats to assess whether or not our interventions were worthwhile (e.g., Is there a reduction in the number of arms & cartridge shells in the area being patrolled?). Lastly, we look at the status of the wildlife species or habitat that form our conservation targets to see whether it improves when our interventions are implemented successfully, and threats are reduced (e.g., Are ape populations doing better due to the reduction of hunting with firearms?).

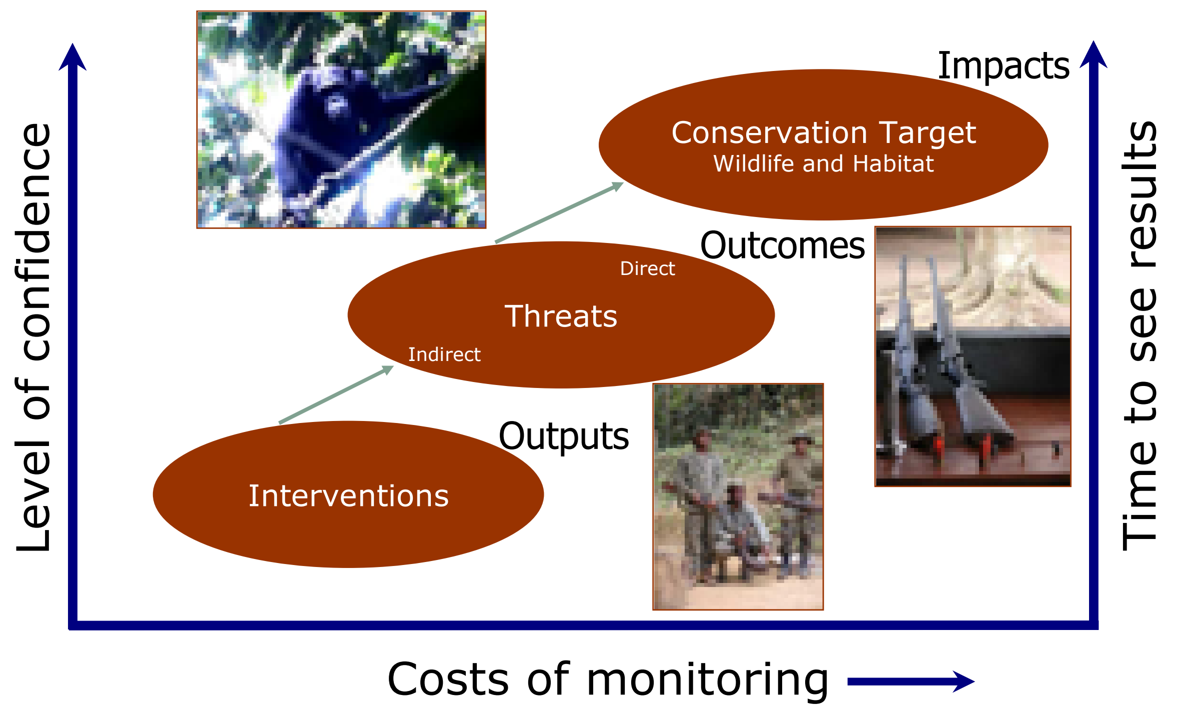

Figure 5: The relationship between confidence, cost and time to results for the different components that could be monitored over time. Monitoring interventions, threats or conservation targets is frequently referred to measuring our outputs, outcomes and impacts, respectively.

The improved state of our conservation targets is the ultimate indicator of success and knowing what that state is gives us the greatest level of confidence that we might be doing the right thing, yet it is often the most difficult to do, costs the most, and may have longer lag-times (see Figure 5). If we monitor the intervention results and threat reductions as proxies for our progress there are definite tradeoffs. The time frame to seeing results and the costs of monitoring decline as we move from directly monitoring changes in wildlife and their habitats, to monitoring reduction in threats, to monitoring whether or not our interventions were implemented as planned. However, using these proxies that change within a shorter time frame also lowers our level of confidence in whether the information informs us meaningfully about our actual conservation success (Wilkie *et al*., 2002b & 2006a).

As we will see in subsequent section, even if we decide to monitor the conservation target directly the type of indicator we choose for this can vary and give very different results. For the remainder of this document we will focus on monitoring our conservation targets for the Nam Kading Landscape, rather than monitoring the threats or interventions.

Monitoring tracks changes over time and this distinguishes it from a survey, which estimates conditions at a single point in time. Thus monitoring uses survey results at many instances in time. The next section considers a general survey framework upon which the monitoring results are built.

2.2 The General Sampling Framework

Usually our areas of interest for monitoring wildlife are large and difficult to access (the Nam Kading PA being a case in point; see Figure 2). Thus when designing a survey we will seldom be able to cover the entire area of interest, but instead select a manageable sub-region. Within that sub-region referred to as the survey area we usually select sampling units or cover the entire survey area. Distance sampling described in more detail below is an example of a survey method where the former is true and α the proportion of the survey area covered needs to be estimated in order to produce an estimate for the entire survey area and not just the sampling units. In contrast, with mark-recapture techniques one attempts to cover the entire survey area, as individual animals are the unit of interest.

No matter which technique is used, wildlife surveys depend on the detection of animals, either through direct or indirect (sign, vocalization) observations of animals. Data of raw counts or presence/absence of animals or their sign on a sampling unit are frequently the survey result used in monitoring to detect changes in populations over time. This is not recommended because it leads to biased survey results and unreliable interpretation of trends in the population under observation. Positive or negatively biased estimates consistently over- or under-estimate the quantity of interest and bias is defined as the difference between the true value of a parameter and the sample estimate of that parameter. In this case, the bias arises because the use of raw count statistics or presence/absence data assumes that animals are always detected when they occur in a sample, an assumption that is almost never true.

If E(C) is the expected value of the count statistic C (number of animals counted or number of presences observed) and p is the detection probability, then the relationship between the count statistic and the true population size or occupancy N is given by:

$$E(C) = pN \tag{1}$$

When detection is 100% ($p = 1$), the count statistic provides an accurate estimate of N . However, when $p < 1$, the count statistic provides a biased estimate of N . For example, if 10 animals were observed and in fact $p = 1/2$ then half of the 20 animals in the survey area were missed. Once the detection probability has been estimated, then the estimate of abundance or occupancy can be obtained from count statistics as follows:

$$\hat{N} = \frac{C}{\hat{p}} \tag{2}$$

The equation is generalized as follows to incorporate the proportion of the survey area covered α

$$\hat{N} = \frac{C}{\hat{p}\alpha} \tag{3}$$

Note that the hats indicate estimated parameters. See Williams *et al.*, 2002 for a more detailed description of this canonical estimator.

If detection probabilities remained constant across space and time then the use of a count statistic is justifiable as a proxy for changes in the parameter being monitored, because the count would be expected to track changes in that parameter. For example if abundance increases, then the count also increases and similarly a decline in abundance is reflected by a decline in the count. Detection probabilities are seldom constant in space and time and thus need to be estimated to enable reliable trend estimation from the raw counts. Without an estimate of the detection probability it is usually impossible to interpret results due to the unpredictable and unknown fluctuations in the relationship between C and N. All of the survey techniques we consider for monitoring wildlife in the Nam Kading PA permit the estimation of the detection probability p.

2.3 Accuracy

As mentioned previously, biased estimates are those that have a systematic error in the parameter estimate. These problems with accuracy can be caused either by the sampling method or the analysis technique. Heterogeneity in detectability on a survey can lead to biased population estimates if we do not take account of or control for the sources of variation. With distance sampling techniques heterogeneity in detectability will not necessarily bias the results as the analysis methods are robust to that type of heterogeneity and may only lead to an increase in variability. Mark-recapture techniques, however, tend to produce biased results if one does not appropriately deal with heterogeneity by collecting the covariate data and incorporating this information during analysis.

For example, a source of variation might be observer skill and we can either try to take account of this during analysis or control for it by training observers to the same level of ability as far as possible, by using multiple observers on a transect, and by rotating observers over different sampling units so that observers with different skills do not collect all the data on a single sampling unit (lock their bias into the data). Variation in detection probability due to environmental or human influence factors can be accounted for during analysis by collecting covariate data that reflect that variation and incorporating those into the analysis.

Biases can also creep in if there are problems in correctly identifying wildlife species or their sign and care must be taken to train observers so they can correctly identify species and sign. If sign cannot be correctly identified, then that sign should not be used in a monitoring program based on detection.

Not only human observers, but also camera traps might have different associated detection probabilities due to variations in camera reliability (problems include misfires, failure to fire and failure to operate). A misconception regarding the performance of camera traps is that they need to detect species perfectly when they pass in front of the camera. Just as humans do not need to perfectly detecting animals when they are present, neither do cameras need to photograph every animal that crosses its lens.

For paired cameras there are at least 6 reasons for detection failure: camera 1 and 2 fire but animal is too close to camera 1 and we get a blur; camera 1 fires and animal turns back never passing though camera 2; camera 1 fires but animal is too far from camera 2 and not detected; cameras 2 sensor is positioned incorrectly; there is systematic failure in camera 2; there is a random failure in camera 2. Some of the issues can be resolved by taking care in placement of cameras (training), some are random events attributed to the animal's behavior and movement.

Random camera failure is not controllable and reduces detection probability but does not lead to bias, unless we are attempting abundance estimation using mark-recapture techniques and this leaves a large enough "hole" in the grid that would mean individual animals have zero probability of capture. Systematic camera failure may also lead to bias. It should, however, be possible to deal with these problems by removing or repairing the offending camera or rotating the camera such that it is not paired in a systematic fashion with a particular camera. If the detection system performs poorly, low detection probabilities result, but not necessarily biased estimates. If the detection system performs in a systematically uneven fashion, then bias problems may result unless we understand the heterogeneity in performance and control for it either in the field or during analysis.

Biased estimates of abundance or occupancy are best avoided by careful assessment of the potential sources of variation due to environmental factors or in data collection and attempting to control or take account of this through training or collecting information on covariates. In addition when attempting to survey rare or heavily exploited species where detection probabilities are low, sufficient sampling effort must be applied to avoid introducing biases because of insufficient sample sizes.

2.4 Precision

Precision is the similarity between a series of individual measurements. When considering precision of an estimate, $\hat{N}$ say, it is convenient to use the coefficient of variation (CV) as a measure of precision, where $CV(\hat{N}) = \frac{\sqrt{\mathrm{var}(\hat{N})}}{\hat{N}}$. $CV(\hat{N})$ gives the size of the variance of the estimate $\mathrm{var}(\hat{N})$ relative to the size of the estimate $\hat{N}$ and as a unit-less quantity it can be used to compare different studies or estimators in terms of precision.

When conducting surveys over time for the purpose of monitoring, precise estimates are desirable as this makes it easier to detect a trend (see next section on Power Analysis for other factors that impact one's ability to detect a trend). An estimates precision is influenced by the natural variation inherent in the population of interest, but also by the variance introduced during sampling (see Figure 6). There are usually limited possibilities for reducing natural variation, so we need to focus on the sampling variation that we can influence to some extent.

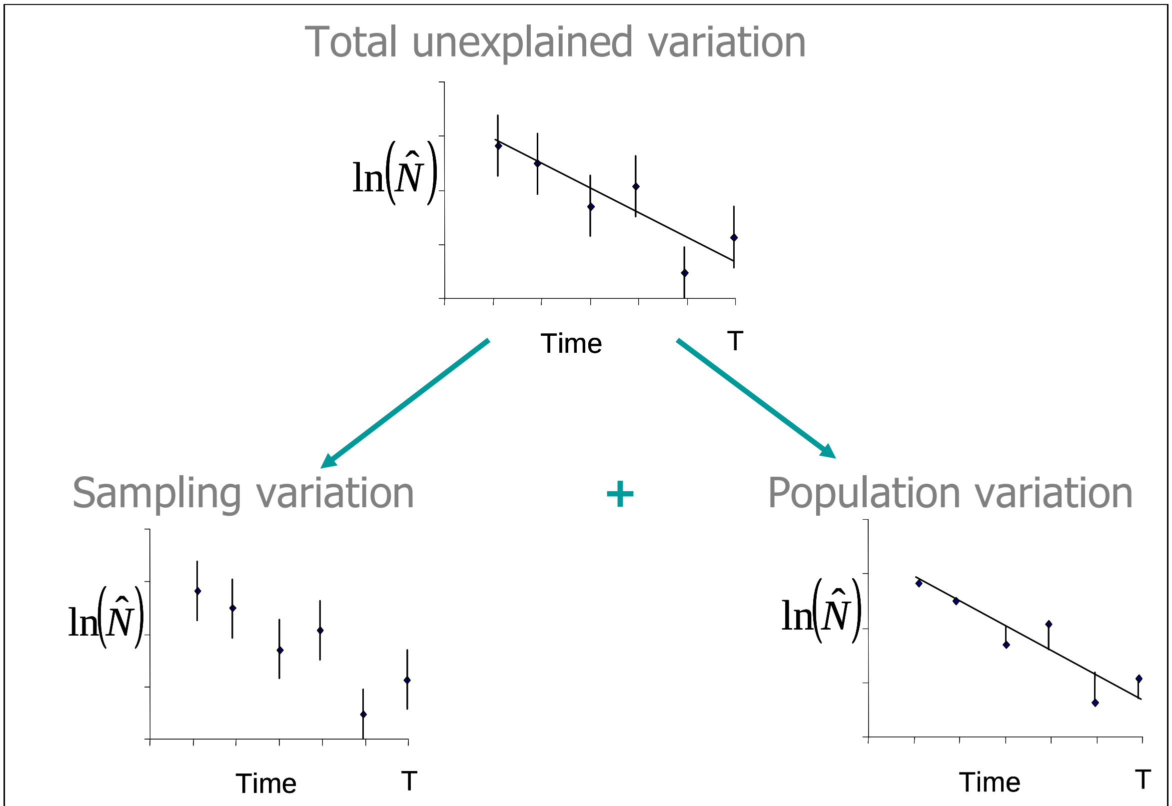

Figure 6: The variation associated with an abundance estimate for a wildlife population is due to both the natural fluctuations in the population size over time and the variation introduced by the sampling process.

The first thing to consider is whether certain sampling techniques are more appropriate given the population characteristics in terms of reducing variance. Thus, for example, line transect distance sampling may achieve better precision than mark-recapture techniques when estimating density for a fairly visible species that covers a large area and whose population is numerous, because to achieve good precision with the latter a large proportion of the population would need to be sampled, whereas the former can achieve good results with a set number of observation (regardless of population size). The options with regard to choosing a suitable survey technique is determined by the characteristics of the species (e.g. cryptic species are seldom surveyed using distance sampling methods as the effort required to obtain sufficient sample sizes to estimate detection would be astronomical) or by other constraints (such as the technical capacity available to implement a particular technique).

Whichever technique is selected, there are some simple guidelines that can be followed in an attempt to reduce variation:

Stratification: During stratification the population is divided into homogeneous subgroups or strata and sampling units are selected independently in each stratum. To improve overall precision, different stratifications may be selected for different components of an estimator. For example, in distance sampling the components that contribute to variance in the density estimate are encounter rate, detection probability (and mean group size for animals that aggregate). Geographic stratification by habitat is often sensible as one might expect both density or occupancy and the probability of detection to change by habitat type. This is only possible if the habitat types are not too fragmented and intertwined so as to make stratification by habitat type impossible. For distance sampling, the possibility for those areas would be to keep a record of when the habitat changes or to classify every x meters of line according to the predominant habitat. One would then have a total for the amount of effort spent in each habitat type, which would allow you to post-stratify by habitat during analysis, after the data have been collected. Similarly, for patch occupancy studies covariate data can be collected to permit stratified analyses. Variables such as season, time of day, weather might also affect encounter rate or detection probability and stratification by these variables should be considered.

Effort Allocation: If one is interested in estimating abundance and something is known about the relative number of animals within each stratum, then an approximate rule of thumb is to allocate effort proportional to abundance in each stratum (for distance sampling see Buckland *et al*., 2001). If the study area is stratified according to the value of some covariate and nothing is known about density in each of the strata then effort should be allocated in proportion to stratum size (Cochran, 1977). Increasing sampling effort decreases variance. However, sampling effort is usually not infinite, but limited by cost. Formulae exist to estimate potential precision for different amounts of effort. See Appendix 1 for a brief explanation of how to estimate precision for line transect distance sampling that includes a few scenarios in terms of effort allocation.

More effort is required for species with low detection probability in order to be able to obtain reliable estimates of detection probability. Given a finite amount of effort, we might spread our monitoring over a wide area and survey each unit relatively few times per monitoring interval (extensive sampling), or sample a smaller area with more visits to each unit within the monitoring interval (intensive sampling). In general, species that are rare require an extensive sampling approach, species that are hard to detect require an intensive sampling approach, and species that are rare and hard to detect require a combination of intensive and extensive sampling.

Orientation of the sampling units: For those survey techniques that have a spatially explicit sampling units, such as line transects in distance sampling, the variation in counts (equivalently encounter rate) is generally due to spatial variation in animal density between sampling units. This variance is often the largest component of variance of the estimate. For line transect surveys, ideally to achieve greater precision one should orientate transect lines parallel to any gradients of density, so that any variation in encounter rate is maximized within transects and minimized between them. So, for example if one suspects that density decreases with increasing distance from a habitat edge or a topographic feature such as a river, then transects would be placed approximately perpendicular to the habitat edge or river.

Note that for distance sampling, in order to get a reliable estimate of variance in observed sample size (or equivalently encounter rate) one needs at least 20-25 replicate lines per stratum. The larger the number of line transects the more reliable the estimate of variance.

In the next section we consider which other factors aside from precision might impact our ability to detect a trend with sufficient sensitivity.

2.5 Power Analysis

	No change	Real change
Monitoring detects change	False-change error (Type I) α	No error (Power) 1-β
Monitoring does not detect change	No error 1-α	Missed-change error (Type II) β

The ability of a sampling program to detect a real effect (or a response) when it exists is called the power of the sampling program and analysis. Power increases with increasing sample size, and increasing size of the effect or response. Power decreases as the variance and standard error increases. Power analysis is most useful when planning a study or monitoring program. Power analysis can be used to explore the relationship between the range of possible sample sizes, response sizes that are important, levels of variance that are expected to occur (usually from literature or pilot data), and the desired level of statistical power (see Appendix 2). The goal is to be able to design a monitoring program (the sampling) that will detect the effect or response with sufficient sensitivity to guide management decisions. Low power in a monitoring program means high uncertainty in interpreting the data.

False-Change (Type I) Vs Missed-Change (Type II) Error? The alpha level corresponds to the percentage of times one incorrectly concludes there is an effect or population has undergone significant change. As the alpha level decreases, there is a corresponding decrease in power. Monitoring populations is different to conducting experiments on populations or other subjects with a high degree of scientific rigor. When monitoring the consequences of sounding a false alarm are usually small compared to failing to detect a severe population decline. So it is preferable to not set standards too high, i.e., alpha level above or equal to 0.1, and to rather 'cry wolf' a couple of extra times.

Also, it's worth keeping in mind that, for example, the detection of at least a 50% decline over 20 years translates into a -3.4% trend *per year*. So, when conducting a power analysis, then all things being equal, one needs more samples to detect smaller trends over shorter time intervals. For comparative purposes trend are usually expressed on a per year basis rather than as total trend. The table helps in converting between long- and short-term trends.

Trend per year	**-5%**	**-3%**	**-2%**
Trend over 5 years	**-22.62%**	**-14.13%**	**-9.61%**
Trend over 10 years	**-40.13%**	**-26.26%**	**-18.29%**
Trend over 15 years	**-53.67%**	**-36.67%**	**-26.14%**
Trend over 20 years	**-64.15%**	**-45.62%**	**-33.24%**

There are freeware programs that are designed to calculate the power to detect trends in species abundance over time. Two of these that are fairly easy to use are MONITOR (Gibbs & Ramirez de Arellano, 2006) and TRENDS (Gerrodette,1996) - see Appendix 2. TRENDS takes an analytical approach, whereas MONITOR estimates power using Monte-Carlo simulations. TRENDS & MONITOR can handle equal and unequal sampling intervals, but the former is restricted to monitoring at a single site and the latter can be used for monitoring data from multiple sites. Some papers that will give you an insight into some of the debates regarding appropriate methods for power analysis of trends include Gerrodette (1987), Link and Hatfield (1990), and Gerrodette (1991), and for determining trends at multiple sites (Gibbs *et al*., 1998). Too seldom are power analyses conducted prior to setting up a monitoring or research design, however, some good examples include Taylor & Gerrodette (1993) and Hatch (2003). Some researchers believe that conservation management questions should not be posed in a hypothesis testing framework, which most power analyses assume. Instead they believe that decision making in the face of uncertainty should at least rely on multiple hypotheses and that associated models should be used to help make these decisions (Kendall, 2001; Williams *et al*., 2002; Nichols & Williams, 2006). These methods work well in data rich environments, but are difficult to implement in situations of data paucity and limited technical capacity. Although power analyses placed in a hypothesis testing framework are perhaps not ideal they do promote more careful thought about the data requirements for a monitoring program and are very informative in terms of illustrating how difficult it is to show that our conservation actions are effective.

2.6 Distance Sampling Along Line transects

Distance sampling is one of a number of survey methods that can be used to estimate animal density D or abundance N (Buckland *et al*., 2001). Both line and point transect sampling are forms of distance sampling. During the former type of sample survey, which we will focus on here, observers traverse a series of transect lines recording animals sighted, together with the perpendicular distances (or radial distances and angles from which perpendicular distance can be derived) of those observations from the survey line. There are some key assumptions underlying the sampling technique:

Assumption 1: Line transects are located randomly with respect to the distribution of the animals.

By locating the line transects according to a well-defined survey design there is no need to assume that animals in the population being sampled are randomly distributed in the study area (an assumption that is unlikely to be true). Random line placement by means of a survey design algorithm helps ensure valid statistical inference at two levels: (a) One can extrapolate from observations made during the survey in the sampled area to the entire study area. This relies on the assumption that the surveyed lines are representative of the study area as a whole, and (b) One can extrapolate from the observed distances to estimate the proportion of animals counted $\hat{p}$. This relies on the assumption that all animals in the study area are uniformly distributed in the interval [0, w], where w defines the distance from the line out to which observations are made.

Assumption 2: Animals on the line are detected with certainty.

If this assumption does not hold then estimates of density or abundance will be negatively biased as the proportion of animals counted $\hat{p}$ will be underestimated.

Assumption 3: Animals are detected at their initial location.

If animals systematically move towards or away from the observers, and such responsive movement takes place before the animals are detected, then estimates of density or abundance will be positively or negatively biased, respectively. In line transect surveys slow non-responsive movement of the animals relative to the speed of the observers (i.e. observers moving at least twice as fast as the animals) is generally not problematic.

Assumption 4: Measurements are exact.

Ideally, distances are recorded correctly and without measurement error. It is especially important that distances near the line transect are recorded both precisely and accurately.

Assumption 5: Detections are independent events.

When detections are dependent (e.g. animals fleeing and disturbing others that are subsequently detected) this has little effect on the point estimate of density or abundance. However, theoretical estimates of sampling variance will be negatively biased, but this problem can be alleviated by using empirical estimators or resampling methods for variance estimation (e.g. using bootstrapping that only assumes independence between transect lines). An obvious case where this assumption is violated is when animals tend to aggregate and occur in groups or clusters. In this case we treat the cluster as the object of interest and measure the distance to the center of the cluster, as well as the cluster size. If animals move in response to the observers and are thus detected several times on the same or adjacent transect line or point this is problematic as it can cause substantial positive bias (assuming repeat counting is common during the survey). If the same animal is detected more than once while sampling the same transect at different times this is not a problem. Distance sampling theory also allows for an animal to be detected from different transects due to random movement of the animal.

The key to distance sampling is that by fitting a detection function to the perpendicular distance to each observation, these data can be used to estimate both the proportion of animals detected and counted $\hat{p}$ and the proportion of the survey area covered α. Thus, the canonical estimator of equation (3) can be applied to the raw counts to obtain an unbiased estimate of abundance. Fortunately, the Distance software exists to help us with distance sampling design and analysis (Thomas *et al.,* 2001).

2.7 Patch Occupancy

The use of occupancy as a state variable is frequently of interest to wildlife managers assessing the impact of management actions, especially in long-term monitoring programs (Manley 2004). Typically, there is no guarantee that a species will be detected even when present at a site, so the naïve estimate of proportion of area occupied given by: (# sites where species detected) / (total # sites surveyed) will underestimate the true proportion of area occupied. MacKenzie *et al*. (2002) propose that by repeated surveying of the sites, the probability of detecting the species can be estimated which then enables unbiased estimation of the proportion of area occupied. The method is similar to the capture-recapture method of population estimation, but instead of collecting capture histories of individual animals during repeated capture attempts, the data collection focuses on collection of detection events at individual sample units, during repeated visits to the units. These capture histories allow for estimation of detection probability and hence also unbiased estimation of the probability of occupancy, which takes into account that detection probability.

The method assumes that the population is closed (no new additions or loss of individuals) during data collection and is able to handle spatial and temporal variation in detection probability, if the appropriate covariate data is collected. It is also robust to uneven sampling effort and missing data, and can be used to analyze data from point transect samples, line transect samples, camera trap samples, direct observation and sign. The model has been extended by MacKenzie *et al*. (2003) to also enable multi-season modeling and the estimation of colonization and local extinction probabilities. Finally, the method can be used with count data under certain assumptions, to generate abundance data (Royle & Nichols, 2003). The flexibility of the method makes it attractive for monitoring several species simultaneously, using a number of detection methods, and does not require identification of individual animals or measurements of distances to determine detectability (for more details see MacKenzie *et al*., 2005). Finally, free software called PRESENCE is available (at http://www.mbr-pwrc.usgs.gov/software/presence.html) to enable estimation of the proportion of area occupied, or similarly the probability a site is occupied, detection probability (and colonization and local extinction probabilities for multi-season data).

3. Design and Implementation of Wildlife Monitoring in the Nam Kading National Protected Area

After having put monitoring in the context of good practices for successful conservation management and the planning approach applied to the Nam Kading NPA (the Landscape Species Approach), and then detailed important sampling considerations and design options, this section describes the specific survey designs for long-term monitoring in the Nam Kading NPA.

3.1 Introduction

Creating a statistically rigorous, but feasible wildlife monitoring designing for the Nam Kading NPA is challenging. The majority of the Nam Kading NPA with an area of 1570 km^2 is incredibly rugged and difficult to access (Figure 2). The results from the baseline investigation into the status of wildlife in the Nam Kading NPA (Van Der Helm and Johnson, 2007), as well as qualitative reports from the area indicate that wildlife densities are extremely low adding further difficulty to the task of putting together a realistic and meaningful monitoring design.

Through the process of applying the Landscape Species Approach (LSA) our key species we aim to monitor over time are well defined and include Asian elephant (*Elephas maximus*), tiger (*Panthera tigris*), southern serow (*Naemorhedus sumatraensis*), Eurasian wild pig (*Sus scrofa*), white-cheeked crested gibbon (*Nomascus leucogenys*), and the great hornbill (*Buceros bicornis*). Similarly, as part of applying the LSA the desired increases in the population that we hope to achieve by the end of 2010 through our conservation work have been clearly articulated as follows (Johnson *et al.* 2006):

- A 10% increase in the white-cheeked crested gibbon population
- A 35% increase in the great hornbill population
- A 20% increase in the tiger population
- A 50% increase in the southern serow population
- A 100% increase in the Eurasian wild pig population
- No decline in the Asian elephant population

Limited resources and technical capacity dictate that the monitoring program should be kept fairly simple (e.g. Danielsen *et al*. 2000) to ensure that it can be correctly carried out and maintained by the Integrated Ecosystem and Wildlife Management Project (IEWMP)[2] in the long-term. However, it must also be able to collect sufficient and appropriate data to detect relevant changes in the Landscape Species.

3.2 Past experience

During the process of developing and implementing an extensive monitoring design for the Nakai-Nam Theun National Protected Area (O'Brien, 2006) many important lessons were learned. Experience here has shown that methods involving camera trapping and line transect surveys can be successfully implemented with local capacity (Johnson & Johnston, 2007). In the Nam Kading NPA context camera traps could be used to monitor tiger, serow and wild pig and other ground dwelling animals, while line transects could be used to collect information on gibbon and hornbill (the great hornbill and other hornbill species including wreathed, brown and oriental pied). A decision was made to deal with elephant separately in a future monitoring design process probably using fecal DNA mark-recapture methods due to the potential small size of the Nam Kading NPA elephant population based on experiences from the Nakai Plateau and surrounding areas (Hedges *et al*. 2007).

3.3 Absolute Density or Patch Occupancy?

Unbiased and precise abundance or density estimates are the most informative when it comes to monitoring the status of a wildlife population. Estimation techniques such as distance sampling or mark-recapture can very successfully be employed to obtain such estimates under the appropriate circumstances. An important consideration is that an additional level of technical skill is required both for data collection and analysis.

The data from Nakai-Nam Thuen that potentially has similar animal densities to the Nam Kading area, as well as the encounter rates obtained during the baseline studies in the Nam Kading NPA (that had a fairly limited extent) suggest that an inordinate amount of effort would be required to obtain reliable abundance estimates for tigers (or other wildlife that could be individually identified) using mark-recapture camera trapping techniques. With mark-recapture one aims to achieve a high capture (detection) probability and also to capture a large number of individual animals. When animals occur at very low densities this means that a survey that is both intensive and extensive is required, i.e., camera traps placed at a small spacing (to maximize detection probability) over a very large area. The combination becomes almost infeasible if one considers the logistics of camera placement with the available human and other resources in combination with the rugged terrain of Nam Kading, given that the survey would need to be completed in a reasonably short time frame to meet the population closure assumptions underlying the method.

Given these considerations we decided to employ camera traps in order to obtain data that could be analyzed using the patch occupancy technique. Results from Nakai-Nam Thuen indicated that for the species we would gather data on with the camera traps the precision of both the detection probability and the probability of occupancy would be low (Johnson and Johnston 2007). However, using camera traps has the ancillary benefit that we can for the first time obtain extensive and systematically collected information on wildlife in the area that might not be possible with any other survey technique.

Another consideration that is extremely important is to use the information gained (in particular the photographs of wildlife) to build a constituency for wildlife conservation in the Nam Kading NPA and surrounding area. The hope is that this will provide the impetus to motivate people with regard to rigorous law enforcement monitoring that to date has not existed (and is currently in it's initial setup phase). If things go to plan, then in a couple of years when tiger populations have again increased it should be possible to estimate densities. The patch occupancy camera trapping has been designed

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[2] IEWMP is a cooperative project between the Bolikhamxay Provincial Agriculture and Forestry Office, the Department of Forestry and the Wildlife Conservation Society.

with this scenario in mind (in terms of desirable sampling intensity and camera spacing that avoids any animals having a zero capture probability). The patch occupancy design would initially have a single camera to allow for more extensive coverage of the area with the fixed number of cameras (50) currently available for the survey, but eventually paired cameras would be put in place when obtaining accurate and precise tiger densities becomes a possibility.

Previously in the Nakai-Nam Theun monitoring design and implementation, line transects had been used to obtain occupancy data for arboreal mammals and birds (Johnson and Johnston 2007). Each transect was defined as a patch and revisited four times to collect data to permit estimation of detection probability. These methods will be replicated in the Nam Kading NPA monitoring design, however, distances to arboreal mammals and hornbills will also be measured to allow for density estimation, in particular of gibbons and great hornbills.

Encounter rate data from monitoring in Nakai-Nam Theun and from the initial investigations in Nam Kading indicate that the encounter rates (potentially in the region of 0.05/km for both species) would allow for sufficient data to eventually estimate density. Generally 60-80 observations are required to reliably fit a detection function in the distance sampling context. It seems logistically feasible to complete approximately 500 km of line transect effort during the field season that takes place during the dry season (again taking population closure assumptions into consideration). This may produce approximately 25 observations for great hornbill. If these were combined with the other large hornbill species (wreathed) that would quite feasibly have a similar detection process to estimate the detection function, then it may be possible to obtain a density estimate in the first year. Otherwise, the data could be combined for several years to fit the detection function while encounter rate would still be estimated by survey zone separately for each year.

Appendix 1 describes how precision can be calculated for a set amount of line transect effort for a given encounter rate (or vice versa how much effort would be required for a desired precision). The table in this appendix show that for a series of different potential encounter rates for the Nam Kading Landscape (including 0.05/km), and three different options for effort, namely 250, 500 and 750 km, estimated precision expressed as the coefficient of variation (CV) of the density estimate can vary dramatically. The first set of estimates does not include variation due to group size estimation, as we do not have accurate group size information for gibbons). For great hornbill group size data from Thailand was used. For both gibbons and hornbills the CV are very high for low encounter rates, but if we do manage to increase hornbills by 35% and gibbons by 10% by 2010, then these CV's would be dramatically reduced.

The table in Appendix 2 contains the results from a simple power analysis that considers how statistical power would be influenced by a 1-2% (gibbons) or 5% (hornbills) increase in population size. It is striking how dramatically low the power to detect a trend is with these relatively small rates of population increase and fairly large CVs. What is interesting to note is that power increases nicely if the sampling occasions are doubled. The initial surveys will be completed over two years, which will mean that it would take 10 years to obtain 5 sampling occasions. Initially, this option is preferable as so little is known about the Nam Kading NPA that 2 years are required to obtain moderate survey coverage across the NPA. Once the first two years of data collection have been completed the situation will be re-evaluated and there may be re-allocation of survey effort and an increase in survey frequency.

The patch occupancy results for Nakai-Nam Theun achieve good precision for the arboreal species (ranges between 6-11% for the different species) (Johnson and Johnston 2007), thus it should be easier to detect a trend with these methods. The drawback with patch occupancy is that it is harder to interpret a change in occupancy, especially for mobile species. For gibbons that are very territorial the results of patch occupancy methods are more meaningful with regard to trend estimation. For species like hornbill or wild pig, for example, that might move considerable distances from one year to the next or within a season to obtain food or water resources interpretation becomes more problematic. Hence it will be very important to triangulate the results obtained by applying the occupancy methods with density estimates obtained through distance sampling or other information obtained through law enforcement monitoring.

Generally it is easier to train field teams in the correct application of field protocols for patch occupancy methods compared to distance sampling. However, given that the teams are going to be covering transects to obtain occupancy data anyway, there will be little additional expense in terms of field time. Also, the risk of potentially obtaining bad distance data seems worthwhile given the small initial investment (training and purchase of range finders) and large potential long-term gains (density estimates and increased technical capacity).

3.4 Defining the Survey Zones and Frequency of Surveys

Given that the Nam Kading NPA is fairly large and very rugged it will only be possible to cover a portion of the target area in a single survey season (the dry season of approximately 6 months). Accessibility was the main consideration in defining the survey zones. We divided the Nam Kading NPA into areas we thought were accessible based on the baseline surveys. Villages that are found in the NPA or adjacent to its boundary are going through the process of defining their own management areas for subsistence hunting in proximity of each village. As these distinct management areas have not yet been finalized we considered a core area within the NPA that remained after we excluded buffer areas of 7.5 km around each of the villages in question. Eventually we decided not to exclude these buffered regions as government regulations for wildlife management (MAF 2003) indicate that villagers are not supposed to hunt any of the Landscape Species, except for wild pig. Hence, once law enforcement activities are properly underway we expect the densities to increase not only in the core zone, but also in these village management areas.

We did however buffer the road to Nam Tek village (within the NPA) by 1 km and the area around the village itself by 3km, as the disturbance these cause would hinder monitoring and we also excluded the area that will potentially be flooded by the Nam Theun 1 dam, as we do not want any of our monitoring sites to be underwater in the future! Once we had excluded these areas and very inaccessible areas in terms of rugged terrain the combined area that remained for the placement of survey blocks was approximately 607 km^2. This represented approximately 35.9% of the park. However, given the resources available for monitoring the amount of effort we could reasonably expend, and our desire to obtain a baseline within 2 years instead of 3, we decided to select the best 25% (in terms of access) of these areas to be used for monitoring purposes. This equates to approximately 400 km^2.

Our criteria for further refining the areas for monitoring also included finding large enough survey zones on reasonable slopes. Ideally we were hoping for zones of approximately 100 km^2 that could alternatively be used for the placement of camera traps and line transects. A zone of this size could be covered by the field teams available in the 6 month time period available, but still provide sufficient data for analysis.

For camera trapping surveys this would allow for the placement of 50 single cameras each in a grid cell of 2 km^2 (a size that had worked well in Naka-Nam Theun) in two different 100 km^2 survey zones during the field season (allowing for maximum coverage of the park in contrast to using paired cameras that would allow half the coverage – this seemed important given the limited information available for any area in the NPA and the added value of surveyor presence acting as a deterrent to poachers). For distance sampling along line transects this would allow for sufficient replication to estimate variance in encounter rate and for patch occupancy this would allow for sufficient resolution in the occupancy estimate. To find areas with more reasonable slopes we conducted a slope analysis with 7 classes (0-10, 11-20, 21-30, 31-45, 46-50, 51-55, 56+ degrees) and attempted to restrict the survey zones to slopes mainly in the first two classes.

The final survey zones are shown in Figure 7. So in a single survey year the Phou Ao and Nam An-Pa Paek zones would be covered by the camera trapping teams, while the remaining survey zones would be covered by the line transect teams and vice versa in the next survey year. This will give maximum coverage of the NPA and the extra presence in the field would act as a deterrent for poachers.

Survey Zone	Area (km^2)
Phou Ao	105.799
Phou Chomnyok	57.607
Nam Tek	42.732
Phou Talabat	99.448
Nam An-Pa Paek	85.277

3.5 Collecting Covariate Data to Improve Precision

In patch occupancy studies to avoid bias and improve the precision of the estimate we must consider which covariates might impact (a) occupancy of the patch by the animal (this would remain constant throughout the survey), or (b) the detection probability on a patch (this would usually change over the duration of the survey). Similarly, for distance sampling along line transects different covariates would influence detectability and encounter rate. The covariates likely to influence occupancy or encounter rate for a particular species were divided into environmental and human influence classes as follows. The covariates are detailed in Sections 2 and 3 and the data forms have been designed to allow for collection of these data (see Appendices 5-8). While some covariate data will be collected in the at the camera trap sites and along the line transects in the field (F), others will be determined using GIS analysis in the office (G).

Environmental Covariates

- Altitude: F; G (min/max/average for trap cell and for transect patch)
- Slope: G (min/max/average for trap cell and for transect patch)
- Aspect: G (average for trap cell and for transect patch)
- Permanent water: G (percent for trap cell and for transect patch)
- Forest/non-forest cover: G (percent for trap cell and for transect patch)
- Water body within 100m of trap site: F
- Grassland within 100m of trap site: F
- Mineral lick within 100m of trap site: F
- Swamp / grassland along transect: F
- Mineral lick along transect: F

Anthropogenic Covariates (Human Influence)

- Distance to road: G
- Distance to navigable river: G
- Distance to nearest village: G
- # of people living within 7.5 km: G
- Percent of trap cell or transect path in Core or Managed Zone: G
- Human sign per km walked by enforcement team: G (#/km for trap cell and transect patch)
- Level of enforcement: G (# of km of patrol effort for trap cell and transect patch)
- Human sign within 100 m of trap: F (livestock, snares, camps, humans, weapons, NTFP collection, fires, harvested carcasses)
- Human sign along transect: F (livestock, snares, camps, humans, weapons, NTFP collection, fires, harvested carcasses)

For camera traps, covariates that influence detection probability include the proportion of days the camera worked while in field. Temperature and humidity might influence both camera reliability and the availability of animals for detection, but obtaining this information would require weather loggers. Similar covariates could be used to improve precision for patch occupancy or distance sampling estimation from line transect data.

3.6 The Camera Trap Survey Design

The Distance software (Thomas *et al.*, 2006) was used to generate a random systematic design for the placement of camera traps using the systematic random point design option with a 1.4 km spacing between points so that each point corresponds to a 2km^2 grid cell. This resulted in the placement of 200 points. The design can be seen in Figure 8 and the coordinates for each point in Appendix 3.

Survey Zone	**Area (km^2)**	**# Points**
Phou Ao	105.799	55
Phou Chomnyok	57.607	27
Nam Tek	42.732	22
Phou Talabat	99.448	51
Nam An-Pa Paek	85.277	45

See Section 2 for a detailed description of the field protocol for camera trapping and Appendix 5 for the data sheet that will be used during the survey.

3.7 The Line Transect Survey Design

Name	Area (km^2)	# Lines	Effort (km)
Phou Ao	105.799	56	70.429
Phou Chomnyok	57.607	28	37.774
Nam Tek	42.732	23	29.154
Phou Talabat	99.448	54	66.973
Nam An-Pa Paek	85.277	43	56.488
Total	390.863	204	260.818

Using the Distance software 204 sampling units with a total length of just over 260 km were generated using the systematic segmented trackline design option (this was used instead of the segmented grid design, as it tended to place transects at different altitudinal gradients, which should lead to a more representative sample). The split segment option was chosen to avoid uneven coverage probabilities and transects were oriented at 45 degrees to approximately follow potential density gradients. Segment length was set at 2 km with a spacing of 1 km between them. Results of field surveys indicate that detections of gibbon vocalizations in mountaineous areas usually do not exceed 1 km (Brockelmand and Srikosamatara 1993). The implication for the occupancy studies is that the same individual should only be detected at a single patch surrounding a line transect. As each transect line is covered four times this equates to about 520 km of effort per year over a two year survey cycle. The results are shown in Figure 9 and the coordinates of the start and end points of each transect line in Appendix 4.

See Section 3 for a detailed description of the field protocol for line transect sampling for the collection of both patch occupancy and distance sampling data and Appendix 6 for the data sheets that will be used during the survey.

3.8 Monitoring Framework for the Nam Kading NPA

The monitoring framework for the conservation targets of the Nam Kading NPA is summarized in Table 1. The framework visually depicts the objective that we want to achieve in a given time frame for each landscape species. The method describes briefly how we will gather the monitoring information. The indicator describes what variable we plan to monitor for the species with more details added in the comments section of the table. The “Who” field identifies the individuals that will be responsible for gathering the information.

Component of Conceptual Model	Landscape Species	Objective	Method	Indicator	Who	Comments
Conservation Target	Tiger	To raise the population of Tiger by 20% over five years	Camera trapping	Patch occupancy - area used	2 Camera trap teams	Density; # of individuals/km2 ; in the future after populations increase
Conservation Target	Southern Serow	To raise the population of Southern Serow by 50% over five years	Camera trapping	Patch occupancy - area occupied	2 Camera trap teams	
Conservation Target	Eurasian Wild Pig	To raise the population of Eurasian Wild Pig by 100% over five years	Camera trapping	Patch occupancy - area used	2 Camera trap teams	
Conservation Target	White-cheeked Crested Gibbon	To raise the population of White-Cheeked Crested Gibbon by 10% over five years	Dry season forest transects	Patch occupancy - area occupied	4 Forest transect teams	Density; # of individuals/km2 ; in the future after populations increase
Conservation Target	Great Hornbill	To raise the population of Great Hornbill by 35% over five years	Dry season forest transects	Patch occupancy - area used	4 Forest transect teams	Density; # of individuals/km2 ; in the future after populations increase
Conservation Target	Asian Elephant	To have no decline in the population of Asian Elephant over five years	Fecal DNA capture-recapture	Density; # of individuals/km2	To be determined	To be initiated in 2009

Table 1. Monitoring Framework for the Nam Kading National Protected Area

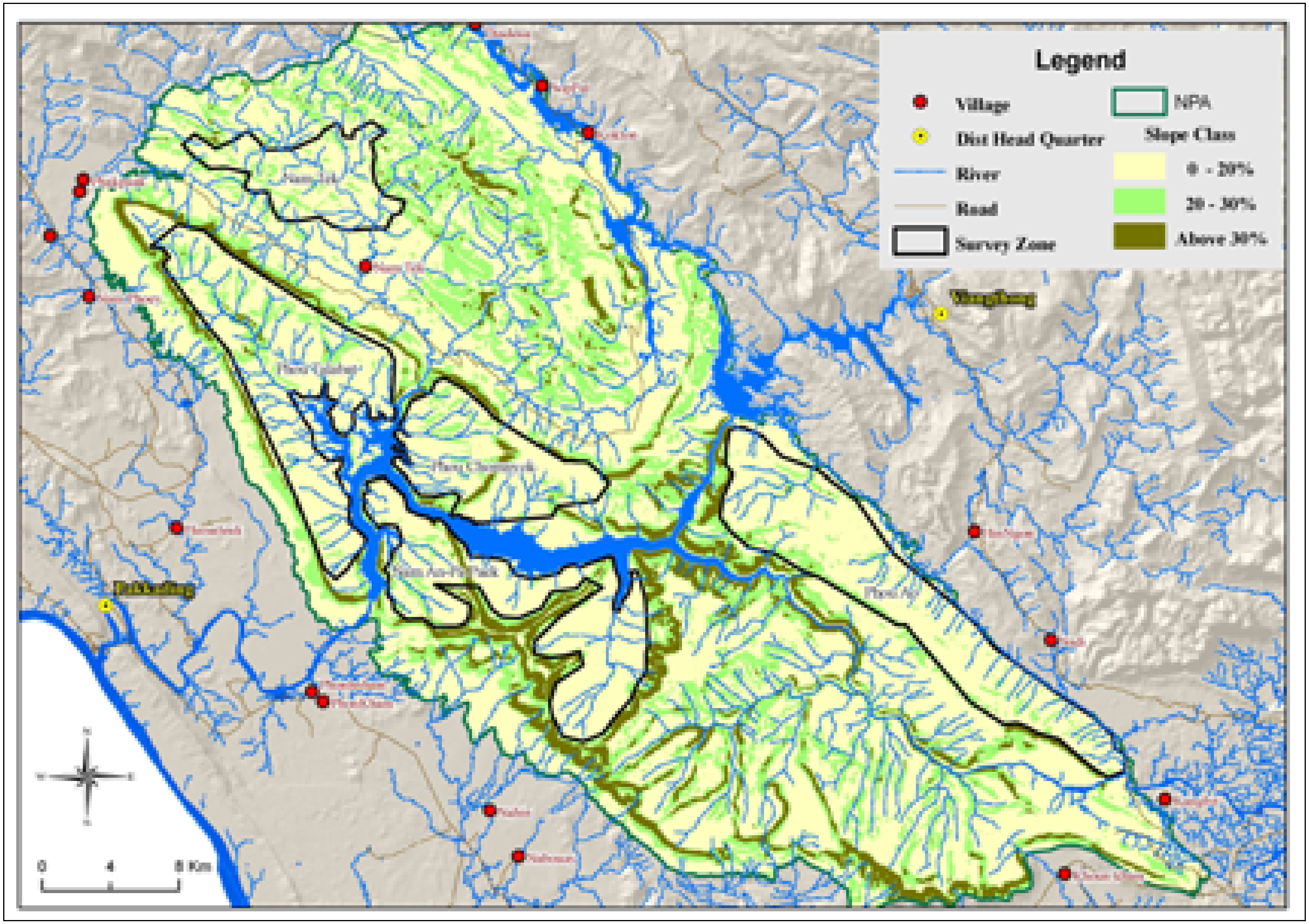


Figure 7: The survey zones within the Nam Kading NPA superimposed on different slope classes. The reservoir of the potential NT1 dam is also shown.

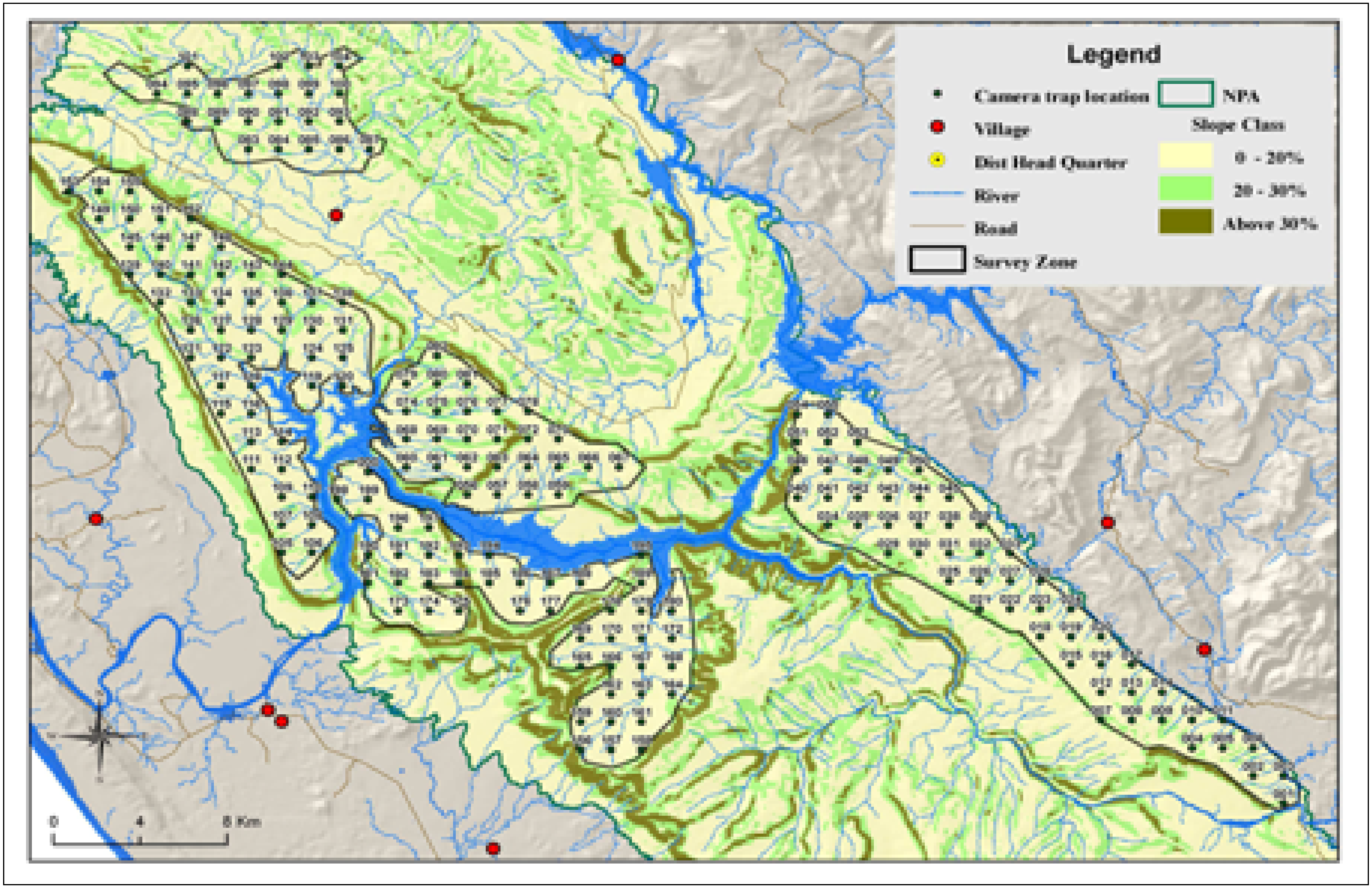


Figure 8: The survey design for the camera trap locations within the survey zones of the Nam Kading NPA.

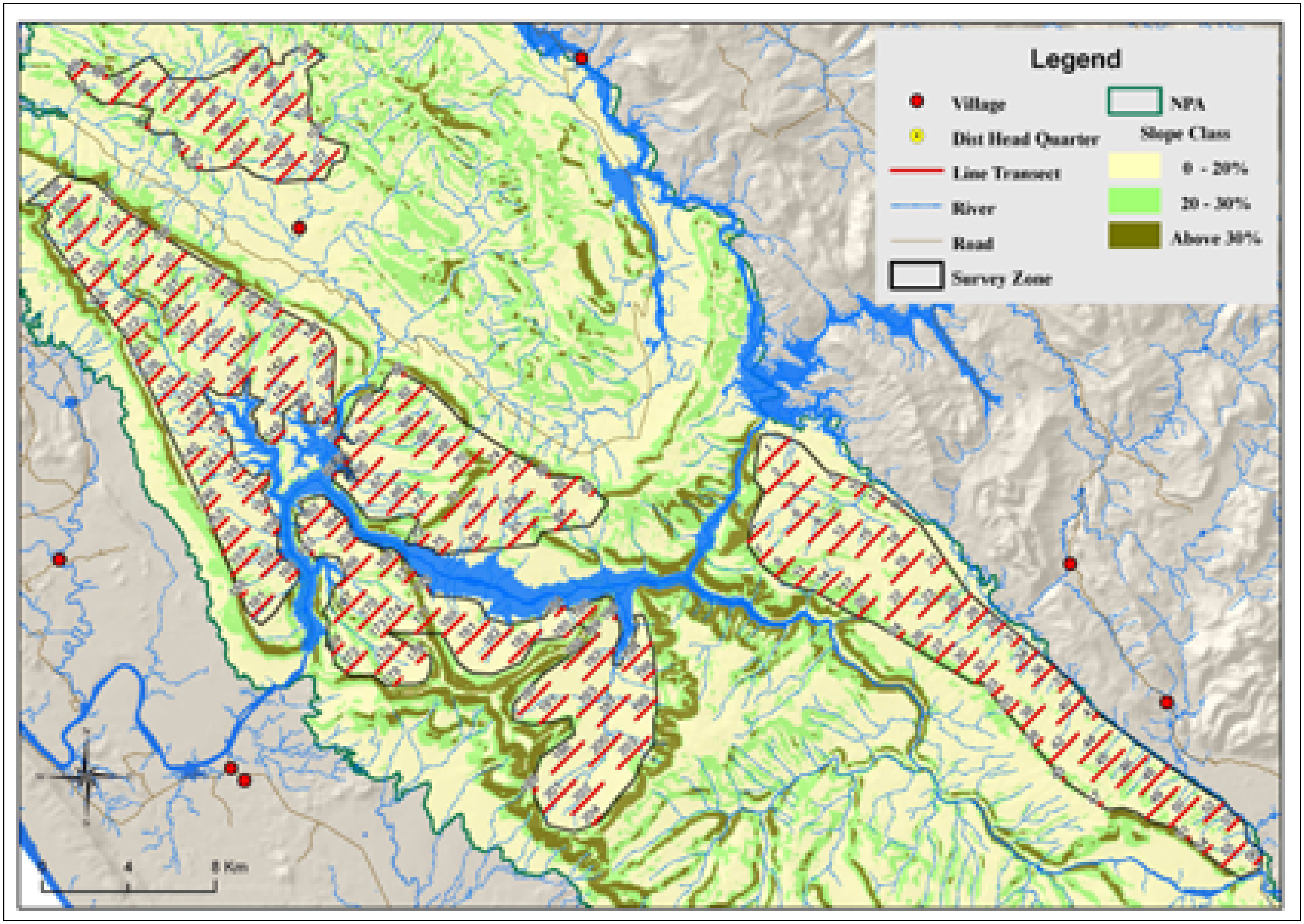


Figure 9: The survey design for the line transects within the survey zones of the Nam Kading NPA.

Section 2. Field Protocol for Camera Trapping of Ground Dwelling Mammals in the Nam Kading National Protected Area

1. Introduction

Following the monitoring framework and rational for sampling outlined in Section 1 of this report, this second section briefly summarizes the principle points of a sampling strategy for ground dwelling mammals using camera traps.

The landscape species to be monitored in the Nam Kading NPA using this protocol are tiger, southern serow, and Eurasian wild pig. Other forest ungulates that may be detected include gaur (*Bos gaurus*), sambar (*Cervus unicolor*), red muntjac (*Muntiacus muntjak*) and possibly other species of muntjac (*Muntiacus sp*.) or wild pig (*Sus bucculentus*). Other large to medium-sized forest cats that may be detected are leopard (*Panthera pardus)*, clouded leopard (*Pardofelis nebulosa*), golden cat (*Catopuma temminckii*) and marbled cat (*Pardofelis marmorata*).

The initial variable to be monitored is patch occupancy-based detection of “presence” or “absence” of the landscape species at a single camera point. A two-year sampling regime is proposed for camera trapping. Over the two-year period, ground dwelling mammals will be monitored at a total of 200 camera points across approximately 400 km^2 of the NPA.

Each dry season, 100 camera points will be set over 200 km^2 (Table 2), which will be divided into two sampling areas of ~100 km^2 each at a spacing of one camera point per 2 km^2 cell (Figure 8). The sampling of each 100 km^2 area will require two camera trap teams (of 3 people per team) over a 2-month period, for a total of approximately four months from November to March needed to complete the annual dry season sampling of 200 km^2 of the NPA.

Appendix 9 presents and indicative budget for camera trap monitoring over the two-year baseline period (2007-2009).

Table 2. Schedule for two-year rotation of camera trapping in monitoring zones in the Nam Kading NPA

Sampling Zones	**Year 1 (# Points)**	**Year 2 (# Points)**
Nam Tek	22	
Phou Talabat	51	
Phou Chomnyok	27	
Nam An – Pa Paek		45
Phou Ao		55

2. Training for camera trap monitoring.

Before beginning the field work, camera trap team members will undergo an initial two-week classroom and field training with WCS and the IEWMP that is specific to the methods for camera trap monitoring (see examples from Johnston and Johnson, 2007a). Each subsequent season, teams will undergo a one-week refresher training to review methods and improve procedures based on lessons learned from the previous season. Methods for camera trapping are straightforward but do require the deployment and care of specialized camera trap equipment as well as a topographic map, GPS, and compass. The training will include the following modules:

- Introduction to principles of wildlife management relative to managing the Nam Kading NPA
- Introduction to principles of wildlife monitoring to evaluate management interventions
- Indicator Species: natural history of forest ungulates and cats.

- Camera traps: how to set and pick up a camera trap, to test if the camera is working properly, and how to care for a camera trap
- Data forms: how to complete a data form when setting and picking up camera traps
- Navigation: using topographic maps, compass and GPS to locate camera traps in the sampling block
- Enforcement protocol: procedures for handling an enforcement event encountered during camera trap surveys
- Working as a team: identifying team member responsibilities and leaders
- Camping protocols to minimize environmental impact
- First aid and health care in the field
- Preliminary introduction to data storage, entry, analysis, and products. The purpose of this is for team members to understand why the data is important and how it will be processed and used by the IEWMP. This topic will be covered in much more detail in subsequent trainings for IEWMP team leaders and the IEWMP management staff including the monitoring specialist and supervisors.
- Practice and testing in all modules.

3. Protocol for camera trap monitoring

- *Camera trap placement*: Camera traps will be placed at a density of 1 trap per 2 km^2. A UTM coordinate marking the center of each 2 km^2 sampling cell has been identified (See Figure 8 and Appendix 3). Teams will deploy the camera trap in an optimal location within 500 meters of the cell center coordinate near an active animal trail to optimize the probability of detecting landscape species (tiger, serow and wild pig). In the event that a suitable location cannot be identified within 500 meters of the cell center, only then should teams search for a location that is within 700 meters of the cell center. Camera traps should not be deployed beyond 700 meters of the cell center.

- *Equipment and supplies needed:*

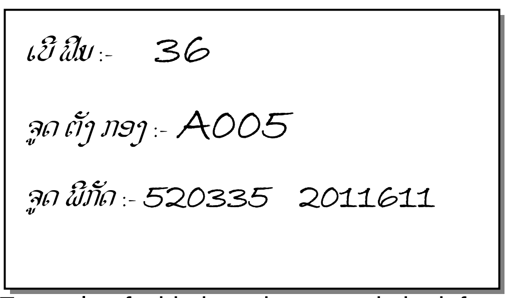
  + camera trap unit
  + field data sheet with waterproof plastic pouch and pencil
  + numbered film
  + AA (1 pair) & C (2 pairs) batteries
  + cable-lock and combination padlock
  + GPS and AA batteries
  + compass
  + stretchy strap and cable to secure the camera
  + whiteboard (40x 25cm) for displaying the film number, GPS point and datum

- *Setting camera traps*: Camera traps will be mounted on trees at a height of 45 cm at 3 meters from a game trail. A cable lock will be used to secure the trap to the tree to protect the trap from vandalism. In areas where elephants are present, steel cases may be needed to protect the traps from damage. Each camera trap will be programmed to operate 24 hours per day and to delay sequential photographs by 20 seconds. The flash on the camera will be set to "on" and the date on the camera will be set to show "day" and "24-hr time" (e.g., 26 15:10 representing the 26^{th} day of the month and 15:10 representing the time when the camera was set). The correct day and time for the camera will be recorded from the GPS.

- *Following the field data form to set up the camera:* At the camera trap point, team members will record details of camera trap setting on a standardized data form (see sample in Appendix 5). When setting the cameras, the team leader will instruct team members in the camera trap set up in the following order:

1. Record the datum from the GPS (Indian Thailand or other)
2. Record camera trap number (1 to 50)
3. Record the waypoint in the GPS and on the data form. A unique 4-digit ID number is used to identify the UTM coordinate at the center of each $2km^2$ cell. The ID numbers range from 001 to 200 with the letter "C" at the front (e.g. C001; see Appendix 3). The letter "C" indicates that this is the ID number for <u>center</u> of the cell. The waypoint is a unique 4-digit ID number that identifies the <u>actual</u> location where the camera trap is set within each $2km^2$ cell. The waypoint number is the same as the number at the center of the cell (001-200) except with the letter "A" at the front. The letter "A" distinguishes the actual camera trap point from the point at the center of the 2 km^2 cell. You will download this point from your GPS when you get back to office.

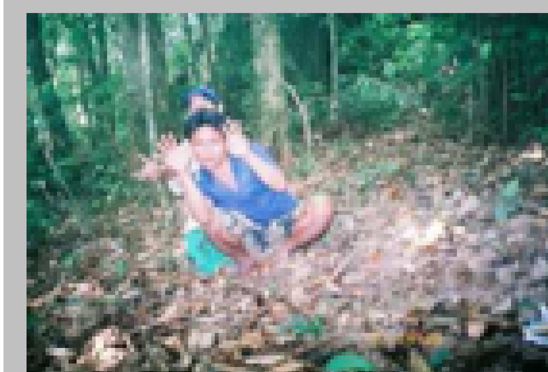
4. Record from GPS the easting, northing, elevation and date (day/month/year)
5. Put the camera trap on your lap to set up
6. Insert AA batteries. Push flat end of battery against spring. Turn ON.
7. Insert C batteries. Push flat end of battery against spring.
8. Check that IF sensor is off (Red light)
9. Turn all timer switches to “off”. Set timer to 1-6-8.
10. Set clock on camera: day/month/year and 24-hour.
11. Set clock to: “DAY , HOUR”
12. Record film number (1 to 55)
13. Turn on camera.
14. Set flash on.
15. Insert silica in camera box (perforate plastic first).
16. Be sure all cords are in before closing the camera trap lid.
17. Check that clock is set to “DAY, HOUR” and that flash is “ON” by looking through window in box.
18. Attach camera trap to tree that is 3 meters from animal trail.
19. Turn off IF sensor (show RED light) to aim the camera.
20. Aim camera to take photo on game trail at height of 45 cm at 3 m distance. Check distance and height.
21. Turn on IF sensor (GREEN) to take photos.
22. Write on the 40x25cm whiteboard; 1) Film number, 2) Waypoint (A001-A200), and 3) GPS coordinates. Take a test photo holding this board. Be sure that the whiteboard is not facing into the sun or the script will not be visible in the photo.



Example of whiteboard to record site information on test photograph (from Johnston and Johnson 2007a)

Alternative method of recording film number on a test photo if whiteboard is lost (from Johnston and Johnson 2007a).

Take test photo. Fingers show number of film. Left hand indicates first digit of film number (1-5). Right hand indicates second digit (0-5). Use second person when second digit ranges from 6-9.



Test photo at camera set-up indicating film 36

23. After taking the test photo, look through the window in box and record the film frame number.
24. Finally, record any wildlife signs seen on the trail in front of the camera trap in the “Remarks” column.

- *Covariate data collection at the camera trap point:* At the camera trap point, team members will also record information on landforms and human use within 100 meters of the point on a standardized data form (see Appendix 6). The purpose of collecting this data is to be able to test if any environmental or anthropogenic factors may be affecting the presence of landscape species at the camera trap point. Starting from the camera trap point, team members will walk 70 paces (~100m) along three different compass bearings (0^o, 120^o and 240^o) and record the number of swamps/grasslands and mineral licks of various size classes and evidence of human activity (hunting camps, snares, humans, animal carcasses, burned or cut areas of forest, domestic livestock or agricultural crops).

- *Transferring information from field data forms into the computer:* The raw field data forms should be photocopied and filed safely away as soon as they return to the office. The information on the form should be transferred to an Excel digital format that is more durable, easily filed away in the computer, and can be printed out for use when the teams return to the field.

- *Uploading and downloading waypoints from the GPS to Map Source.* See details on how to do this in relevant sections of a "Camera-Trapping Manual: A Handbook for Biodiversity Monitoring using Camera Traps in the Nakai-Nam Theun National Protected Area" (Johnston and Johnson 2007a).

- *Picking up the camera traps:* After 30 days, teams will retrieve the cameras from the field. To do this, the equipment and supplies needed are:

  + field data sheet (copy) from camera setting activity
  + GPS with actual waypoints loaded
  + large zip lock bag for film
  + zip lock bags for batteries
  + camera trap bag
  + whiteboard

1. Record the date (day/month/year) and 24-hr time on data form from the GPS before approaching the camera
2. Record the number of photos that the camera has taken.
3. Subtract the number of photos taken from the start frame number to estimate the number of photos taken over the the 30-day sampling period.
4. Take test photo holding whiteboard with, 1) film number, 2) waypoint, and 3) GPS coordinates
5. Record if flash worked when taking the test photo.
6. Record if film advanced when taking the test photo
7. Record the battery level (as % of battery remaining)
8. Turn off IF sensor - RED. Record if IF sensor is working; flashing red.
9. Record any wildlife signs seen on the trail in front of the camera trap in the "Remarks" column.
10. Untie the camera trap from the tree.
11. Put the camera trap on your lap and open.
12. Rewind film.
13. Take film out and put in plastic zip lock bag.
14. Turn off camera and put back in camera trap.
15. Turn off AA battery pack. Take out AA batteries. Put in zip lock bag.
16. Take out C batteries. Put in zip lock bag.
17. Close camera trap and pack in cloth bag for transport to avoid scratching sensors and lens window.

- *Data entry and storage:* After returning to the office, raw data forms should be photocopied, filed with information entered into Excel on the computer. The films should be developed at Konica 'Modern Color Lab" in Vientiane and camera trap photo results systematically recorded into an Access database. For each camera, film number, GPS location, date and time camera set, and date and time camera retrieved will be recorded. For each roll of film, frame number, frame date, frame time, and frame object/s will be recorded.

Original film negatives should be stored in an air-conditioned room at the WCS office in Vientiane in archival plastic sheets in separate binders for each camera setting. Hard copy contract prints should be stored in the IEWMP office in Pakxan. Copies of digital contact prints should be stored on back up drives and on CDs in Vientiane and in Pakxan.

4. General protocols

- *Recording and reporting evidence of threats to law enforcement personnel:* Monitoring teams represent important eyes and ears of the NPA in the field. It is essential that they diligently record and report evidence of threats to NPA law enforcement personnel. Each camera trap team will complete standardized threats forms (See Appendix 7) while they are working in the field and will file a report with the enforcement unit of the NPA when they return to the office.

- *Camping protocols*. The following procedures should be followed by all team members and may require clear and repeated training:
  - appropriate disposal of litter while in the field: paper and thin plastics (bags, noodle packets, sweet wrappers etc) should be burnt; tins and other large objects should be carried back to NPA headquarters and not left in the forest or in villages; sweet wrappers, cigarette butts and packets and other artificial materials should not be discarded in rivers, the forest or in villages. All used batteries of all sizes should be carried back to the NPA headquarters for disposal and not left in villages or buried;
  - all team members and porters involved in camera trap monitoring agree not to eat or trade in wildlife;

Section 3. Field Protocol for Monitoring Forest Hornbills and Arboreal Mammals along Line Transects in the Nam Kading National Protected Area

1. Introduction

Following the monitoring framework and rational for sampling outlined in Section 1 of this report, this third section briefly summarizes the principle points of a sampling strategy for forest hornbills and arboreal mammals using line transects.

The landscape species to be monitored in the Nam Kading NPA using this protocol are Great Hornbill and White-Cheeked Crested Gibbon. Other hornbills that will be monitored along transects are Wreathed Hornbill (*Rhyticeros undulatus*) as well as two species of small hornbills, Oriental Pied Hornbill (*Anthracoceros convexus)* and Brown Hornbill (*Anorrhinus austeni*). Other primates that may be recorded along transects are Francois's Langur (*Semnopithecus francoisi*), Phayre's Langur (*Semnopithecus phayrei*), Douc Langur (*Pygathrix nemaeus*), and four different species of macaques (*Macaca sp.)*. We will also monitor Black Giant Squirrel (*Ratufa bicolor*).

As described in Section 1 of this report, the monitoring method will utilize both patch occupancy-based detection of "presence" or "absence" and distance sampling of forest hornbills and arboreal mammals along forest transects of fixed length. In anticipation of potentially being able to determine density of these species in the future (See Table 1), we will also record distance, sighting angle and group size of any sightings of hornbills, gibbon, langurs, macaques and Black Giant Squirrel. A two-year sampling regime is proposed for the line transects. Over the two-year period, a total of 1,043 km of forest transects will be monitored in the Nam Kading NPA within five survey zones totally 391 km^2 in total size. Monitoring will be conducted along 204 transects, spaced at 1 km intervals and ranging from 200-2000m in length (see Figure 9 and Appendix 4), summing to a total of 261 km of transects across the five survey zones. Each transect will be visited four times summing to an estimated total of 1,043 km of transect sampled over a two-year period.

Each dry season, a total of approximately 510 km of transects will be sampled. This annual sampling effort will require four transect teams (of 3 people per team) over a five-month period (December-April) (see Table 3) when detection of forest hornbills and arboreal mammals is optimal.

Appendix 9 presents and indicative budget for line transect monitoring over the two-year baseline period (2007-2009).

Table 3. Schedule for two-year rotation of line transects monitoring in survey zones in the Nam Kading NPA

Survey Zones	Year 1 (Transect ID & Km)	Year 2 (Transect ID & Km)
Nam Tek		085-107 (29.2 Km)
Phou Talabat		108-161 (67.0 Km)
Phou Chomnyok		057-084 (37.8 Km)
Nam An – Pa Paek	162-204 (56.5 Km)	
Phou Ao	001-056 (70.4 Km)	

2. Training for dry season forest transect monitoring

Before beginning the field work, line transect team members will undergo a two-week classroom and field training with WCS and the IEWMP that is specific to the methods for line transect monitoring (see Johnston and Johnson, 2007b from the Nakai-Nam Theun NPA) and distance sampling. Each subsequent season, teams will undergo a one-week refresher training to review methods and improve procedures based on lessons learned from the previous season. The training will include the following modules:

- Introduction to principles of wildlife management relative to managing the Nam Kading NPA
- Introduction to principles of wildlife monitoring to evaluate management interventions
- Indicator Species: natural history and identification of hornbills, black giant squirrel, langurs, macaques and gibbon
- Protocol for monitoring indicator species along dry season forest transects: methods, use of equipment, completing data forms
- Distance sampling methods: use of a rangefinder to accurately estimate distance from the line to individuals and groups, use of a compass to estimate angle of observation; estimating and recording group size.
- Navigation: using topographic maps, compass and GPS to locate sampling blocks and transects. Using "Go To" function of GPS to determine transect bearing.
- Enforcement protocol: procedures for handling an enforcement event encountered during the transect
- Working as a team: identifying team member responsibilities and leaders
- Camping protocols to minimize environmental impact
- First aid and health care in the field
- Preliminary introduction to data storage, entry, analysis, and products. The purpose of this is for team members to understand why the data is important and how it will be processed and used by the IEWMP for the Nam Kading NPA. This topic will be covered in much more detail in subsequent trainings for Nam Kading management staff.
- Practice and testing in all modules.

3. Protocol for dry season forest transect monitoring

Each transect will be walked on four different, usually consecutive, days. The equipment and supplies needed are:

+ Hip chain (1 per team)
+ Cotton rolls (about 3km per transect)
+ field data sheet with waterproof plastic pouch and pencil (see data form in Appendix 8)
+ AA batteries (1 pair)
+ GPS (with tracking)
+ Compass
+ Rangefinder

***Day 1**:* Teams should begin walking the transect at 06:00 and finish collecting data at 12:00. Depending on the distance of the camp to the start point, the team will need to leave the camp in sufficient time to be able to arrive at the transect start point a few minutes before 06:00.

Before leaving the camp, the team leader should record the survey zone, transect number, visit number and date on the data form.

Use the "Go To" function of the GPS to locate the transect start point (see Appendix 4) from camp. Record the actual transect start point on the data form. Save this waypoint as a 4-digit number starting with the letter "B" and the three numerical digits that make up the unique ID number of the transect (see Appendix 4) (e.g., B124 indicates the actual starting point of transect #124).

At the start point of the transect, the team leader should also record the start time and altitude from the GPS.

Use the "Go To" function on the GPS to determine the bearing from the transect start point to the transect end point (see Appendix 4). Record the bearing on the data form.

The team leader will use the compass to follow the bearing to the end point of the transect. One team member will walk in front of the team leader and quietly clean the trail by making only small cuts to the vegetation. Using the compass, the team leader will instruct the team member to stay left, right or straight to maintain the bearing of the transect. The team should stop every 20-60m to listen for movement or calls of indicator species.

Another team member will follow the team leader with the hip chain and GPS to measure the trail distance. Turn the GPS "tracking function" "on" to record the trail location, which will be downloaded to the GIS when you return to the office.

The observers should move slowly and silently along the transect scanning the treetops and openings for signs and sounds of indicator species. Observers should not scan for footprints or sign of terrestrial wildlife during the survey.

If indicator species are seen, the team leader will use the rangefinder to estimate the distance from the line to the center of the animal group (or to the center tree that the animal group is located on or nearest to – especially if the group has moved) and will use the compass to record the angle at which the center of the group of animals was sighted from the line. This information and the coordinates and time from the GPS will be recorded on the data form. The group size will also be recorded on the data form.

If indicator species are heard but not seen, the team leader will record only the time and coordinates from the GPS on the data form. For gibbon only, the team leader will also record the bearing at which the vocalization was heard from the line.

<u>At the end of the transect or by 12:00, whichever comes first,</u> record the end time from the GPS and the distance walked from the hip chain on the data form.

At this time, also fill out the section of the data form that summarizes the weather conditions over the hours that the transect was walked:

- *Rain*: 1) no rain; 2) misty rain on canopy but not reach forest floor; 3) rain penetrates canopy and reaches the forest floor; 4) heavy rain impedes vision
- *Wind*: 1) No wind; 2) light breeze with leaf movement; 3), windy with large branches and stems swaying in most trees
- *Cloud Cover*: 1) No cloud; 2) 25% cloud cover; 3) 50% cloud cover; 4) 75% cloud cover; 5) 100% cloud cover.

<u>If this is the end of the transect</u> (see transect distance in Appendix 4), also note the coordinates of the final point and save in the GPS and record on the data form. Name the waypoint "F124" where "F" indicates the final point of transect #124. Then tick that the transect was "finished" on the data form. Record the altitude on the data form.

<u>If the team did not reach the end of the transect by 12:00</u>, they should tick that the transect was "not finished" and given an explanation of why it was not finished on the data form. The team should continue to clean and mark the remainder of the transect before they return to camp, if this has not been completed already. When they reach the end of the transect, they should note the hip chain distance on the data form and the coordinates of the final point and save in the GPS and record on the data form. Name the waypoint "F124" where "F" indicates the final point of transect #124. Record the altitude on the data form.

Days 2-4: Begin walking the transect again at 06:00 and pace yourselves to arrive at the end point of the transect by no later than 11:00. For shorter transects it may be possible to cover more than a single transect segment in a day.

There should be three people in each team per day; team members should never be out of visual contact with each other. One team member should be in front of the group looking and listening for target species only. This person needs to be skilled in detecting wildlife. The team leader should be in the middle, writing down the target species sightings, filling out data form, covariate and threat forms. As the team leader, this officer needs to maintain the survey protocol. The third team member should be at the back of the group looking for indicator species but also noting various human sign (livestock, snares, camps, humans, weapons, fires or carcasses) as well as landforms (mineral licks, grassland and permanent water) along transects.

4. General transect guidelines

- Transects should not be conducted during rain or high winds that would limit detection of indicator species.

- Don't smoke while on the transect.
- When two or more transect teams working in the same area of a survey zone, they should space start points and walking direction of transects to avoid counting the same animals.
- While moving along the transects, the team leader should record all observations on the standardized data form (see sample data form in Appendix 8).
- Hornbills should recorded as either Large Hornbill or Small Hornbill unless the observer is absolutely sure of the species identification. Large Hornbills include Great Hornbill and Wreathed Hornbill. Small Hornbills included Brown Hornbill and Oriental Pied-Hornbill (see sample data form in Appendix 8).
- An enlarged covariate data form may be developed and tested to collect additional data on habitat (canopy height, canopy cover, and habitat type) along each transect.
- After completing the transect and before returning to the camp, check the datasheet. Have all fields been filled in?
- Uploading and downloading waypoints between the GPS and Map Source***.*** See details in relevant sections of, a "Line Transect Manual: A Handbook for Biodiversity Monitoring using Line Transects in the Nakai-Nam Theun National Protected Area" (Johnston and Johnson 2007b).

5. General protocols

- *Recording and reporting evidence of threats to law enforcement personnel:* Monitoring teams represent important eyes and ears of the NPA in the field. It is essential that they diligently record and report evidence of threats to NPA law enforcement personnel. Each line team will complete standardized threats forms (See Appendix 7) while they are working in the field and will file a report with the enforcement unit of the NPA when they return to the office.
- *Camping protocols*. The following procedures should be followed by all team members and may require clear and repeated training:
    + appropriate disposal of litter while in the field: paper and thin plastics (bags, noodle packets, sweet wrappers etc) should be burnt; tins and other large objects should be carried back to NPA headquarters and not left in the forest or in villages; sweet wrappers, cigarette butts and packets and other artificial materials should not be discarded in rivers, the forest or in villages. All used batteries of all sizes should be carried back to the NPA headquarters for disposal and not left in villages or buried;
    + all team members and porters involved in camera trap monitoring agree not to eat or trade in wildlife.

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Appendix 1: Expected precision for distance sampling line transect surveys

Prepared by: Samantha Strindberg

When designing a distance sampling survey, as for any other survey design, a balance has to be reached between the precision of the density or abundance estimate and the resources available for the survey. The trade-off between desired precision and the cost of implementing the survey usually dictates the survey effort and design used in sampling a particular study area. A pilot survey is the best way to estimate the amount of survey effort required to achieve a desired precision. The time and cost constraints associated with a particular type of survey in a given study area will usually dictate whether the desired precision is feasible and which survey design is most suitable for the given circumstance.

When considering precision of a density estimate, it is useful to use the coefficient of variation (CV) as a measure of precision, where $CV(\hat{D}) = \frac{\sqrt{\mathrm{var}(\hat{D})}}{\hat{D}}$. $CV(\hat{D})$ gives the size of the variance of the density estimate $\mathrm{var}(\hat{D})$ relative to the size of the estimate $\hat{D}$ and as a unit-less quantity it can be used to compare different studies in terms of precision.

If animals groups of are the units of observation for the distance sampling survey, as they would most likely be in a hornbill survey, for example, then the distance to the center of the group rather than to the individual animal is measured. In addition, the group size for each observation is recorded.

By applying the formula $L = \frac{b + \left[s\hat{t}d(s)/\bar{s}\right]^2}{\left[CV_t(\hat{D})\right]^2} \frac{L_0}{n_0}$ (A1.1) one can estimate the total length of transect line required for a given encounter rate $\frac{n_0}{L_0}$ and a target CV for the density estimate $CV_t(\hat{D})$.

The standard deviation of group size is $s\hat{t}d(s) = \sqrt{\sum_{i=1}^{C'} (s_i - \bar{s})^2 \Big/ (n-1)}$, where $\bar{s}$ is the mean group size and s_i the size of the i^{th} group, which assumes group size is independent of detection distance. The parameter b is known as the dispersion parameter or variance inflation factor and generally takes a value in the range 1.5-3. If the spatial distribution of the animals were random then $b \cong 1$ as one would expect the count on each line to approximately follow a Poisson distribution. If the population is highly aggregated then b takes on larger values. To avoid underestimating L for planning purposes it is suggested that one use a value of 3 for b (assuming it is not possible to estimate b from a pilot study or use a value calculated previously from a similar study).

Similarly, by applying the formula $CV(\hat{D}) = \sqrt{\frac{(b + \left[s\hat{t}d(s)/\bar{s}\right]^2)L_0}{Ln_0}}$ (A1.2), one can estimate the precision for a set amount of effort. If the available resources determine the total effort in terms of line length L, then it is possible to estimate $CV(\hat{D})$ using equation A1.2. If $CV(\hat{D})$ is too large, then it may not be worthwhile conducting the survey. Similarly, we can calculate the amount of effort L required to achieve our desired precision $CV_t(\hat{D})$ and possibly conclude that we do not have the resources to achieve that precision and decide whether a reduction in precision is feasible given the goals of the survey. All of these equations assume that the lines are distributed randomly (or systematically with a random start) within the study area. Additionally, if detection on the line is not certain and needs to be estimated or other multipliers need to be estimated, then greater effort is required to achieve a target precision (equivalently the same amount of effort will give lower precision).

Ideally a pilot study would be carried out to estimate the encounter rates to be expected during the actual survey and the mean and standard deviation of group size. These values can then be plugged into the above equations to estimate the amount of effort required to achieve the desired precision or the estimated precision that can be obtained for a fixed amount of effort. A simple pilot study during which distances to the animals are not measured can be conducted to estimate these values. If the pilot study is more comprehensive, and also includes distances to detected animal then the dispersion parameter *b* can be estimated and its value can be plugged into the above equations.

For more detailed explanations and example calculations see Buckland *et al*. (2001: pp. 241-4)[3].

We can illustrate the above by examining the estimated precision for a potential distance sampling survey for gibbons and great hornbill in the table below.

Table A1.1: Estimated precision expressed as the coefficient of variation of the density estimate $CV(\hat{D})$, for a dispersion parameter value of 3, a series of different potential encounter rates $\frac{n_0}{L_0}$ for the Nam Kading Landscape, and three different options for effort, namely 250, 500 and 750 km. Estimates for $CV(\hat{D})$ that do not include variation due to group size estimation were calculated for gibbons, as we do not have group size information for this species (shown on the left). For great hornbill a value of 0.7132 for $s\hat{t}d(s)/\bar{s}$ was used based on group size data from Thailand and the results are shown on the right.

$\frac{n_0}{L_0}$	L (km)				L (km)		
	250	500	750		250	500	750
	$CV(\hat{D})$				$CV(\hat{D})$		
0.01	1.10	0.77	0.63		1.18	0.84	0.68
0.02	0.77	0.55	0.45		0.84	0.59	0.48
0.03	0.63	0.45	0.37		0.68	0.48	0.39
0.04	0.55	0.39	0.32		0.59	0.42	0.34
0.05	0.49	0.35	0.28		0.53	0.37	0.31
0.06	0.45	0.32	0.26		0.48	0.34	0.28
0.07	0.41	0.29	0.24		0.45	0.32	0.26
0.08	0.39	0.27	0.22		0.42	0.30	0.24
0.09	0.37	0.26	0.21		0.39	0.28	0.23
0.10	0.35	0.24	0.20		0.37	0.26	0.22
0.11	0.33	0.23	0.19		0.36	0.25	0.21
0.12	0.32	0.22	0.18		0.34	0.24	0.20
0.13	0.30	0.21	0.18		0.33	0.23	0.19
0.14	0.29	0.21	0.17		0.32	0.22	0.18
0.15	0.28	0.20	0.16		0.31	0.22	0.18
0.16	0.27	0.19	0.16		0.30	0.21	0.17

[3] Buckland, S.T., Anderson, D.R., Burnham, K.P., Laake, J.L., Borchers, D.L., and Thomas, L. (2001). Introduction to Distance Sampling. Oxford University Press, London.

0.17	0.27	0.19	0.15
0.18	0.26	0.18	0.15
0.19	0.25	0.18	0.15
0.20	0.24	0.17	0.14
0.21	0.24	0.17	0.14
0.22	0.23	0.17	0.13
0.23	0.23	0.16	0.13
0.24	0.22	0.16	0.13
0.25	0.22	0.15	0.13
0.26	0.21	0.15	0.12
0.27	0.21	0.15	0.12
0.28	0.21	0.15	0.12
0.29	0.20	0.14	0.12
0.30	0.20	0.14	0.12
0.31	0.20	0.14	0.11
0.32	0.19	0.14	0.11
0.33	0.19	0.13	0.11
0.34	0.19	0.13	0.11
0.35	0.19	0.13	0.11
0.36	0.18	0.13	0.11
0.37	0.18	0.13	0.10
0.38	0.18	0.13	0.10
0.39	0.18	0.12	0.10
0.40	0.17	0.12	0.10
0.41	0.17	0.12	0.10
0.42	0.17	0.12	0.10
0.43	0.17	0.12	0.10
0.44	0.17	0.12	0.10
0.45	0.16	0.12	0.09
0.46	0.16	0.11	0.09
0.47	0.16	0.11	0.09
0.48	0.16	0.11	0.09
0.49	0.16	0.11	0.09
0.50	0.15	0.11	0.09

0.29	0.20	0.17
0.28	0.20	0.16
0.27	0.19	0.16
0.26	0.19	0.15
0.26	0.18	0.15
0.25	0.18	0.15
0.25	0.17	0.14
0.24	0.17	0.14
0.24	0.17	0.14
0.23	0.16	0.13
0.23	0.16	0.13
0.22	0.16	0.13
0.22	0.16	0.13
0.22	0.15	0.12
0.21	0.15	0.12
0.21	0.15	0.12
0.21	0.15	0.12
0.20	0.14	0.12
0.20	0.14	0.12
0.20	0.14	0.11
0.19	0.14	0.11
0.19	0.14	0.11
0.19	0.13	0.11
0.19	0.13	0.11
0.19	0.13	0.11
0.18	0.13	0.11
0.18	0.13	0.10
0.18	0.13	0.10
0.18	0.12	0.10
0.17	0.12	0.10
0.17	0.12	0.10
0.17	0.12	0.10
0.17	0.12	0.10
0.17	0.12	0.10

Appendix 2: Power Analysis Example Using the Trends software

Prepared by: Samantha Strindberg

Trends Description: TRENDS implements the power analysis for detecting trends in abundance using linear regression as described in Gerrodette (1987) and Gerrodette (1991). TRENDS is limited to situations in which monitoring occurs at regular intervals at one site and does not allow for arbitrary patterns of variance, detection of nonlinear patterns, and correlation among estimates. Another freeware program for power analysis MONITOR (Gibbs & Ramirez de Arellano, 2006) estimates power using Monte-Carlo simulations and can handle unequal sampling intervals and multiple sites.

The approach implemented within TRENDS assumes that we plan to make a series of independent estimates of abundance of some quantity of interest, at equal intervals of an independent variable, such as time or distance, and to follow the same methods of estimation on each sampling occasion. A trend is evaluated by regressing the estimates of abundance against time or distance and testing the slope of the regression line against a null hypothesis of zero slope.

TRENDS (or a similar power analysis) can be used to:

1. Assessing whether a proposed design has even a reasonable chance of detecting a trend,
2. Estimate the number of sample occasions that will be required,
3. Provide an estimate of the rate of change that will be detectable, and
4. Compare the efficacy of different proposed survey designs.

It must be kept in mind, however, that the results produced by TRENDS are **approximations** for the following reasons:

(a) Calculations are dependent on choosing the right model. TRENDS assumes we have selected the linear regression model to represent our system, but we should never forget that any model is an approximation of biological reality. It is an oversimplification, for example, to assume that population size will change in an exactly regular manner over a period of time, but that is the fundamental assumption of a linear regression on a time series of population estimates.

(b) Calculations are conditional on values of parameters not known in advance. Estimating a coefficient of variation that reflects all sources of variation is particularly important because the power calculations are sensitive to this parameter.

(c) Calculations are based on the same assumptions as linear regression - normal error distributions, equal variances, and independence of estimates. Often we do not know if these assumptions are true. Violations of these assumptions make the results of TRENDS (and the linear regression itself) approximate.

(d) Calculations are based on some numerical approximations even if these assumptions are satisfied.

TRENDS summarizes the power analysis in 5 parameters:

- duration of study n,
- rate of change r (note that although TRENDS focuses on abundance this rate of change can be associated with any state variable, e.g. occupancy),
- precision of estimates expressed as a coefficient of variation (CV),
- significance level α (probability of Type I error), and
- statistical power (1 – β, where β is the probability of Type II error).

The value of any parameter can be estimated if the other 4 are specified. The parameter of interest depends on the situation. Depending on which of the parameters is estimated the result can be interpreted as follows:

Parameter	**Interpretation of the result**
n	n is the minimum number of sampling occasions that are needed at the given error rates; the number of sampling intervals is n-1.
r	r is the minimum rate of change (per sampling interval) that can be detected at the given error rates.
CV	CV is the maximum permitted CV (minimum required precision) for the initial sample at the given error rates.
α	α is the probability of obtaining a significant trend (slope 0) falsely
power	statistical power is the probability of obtaining a significant trend (slope 0) correctly.

The relations among these parameters are affected by a number of factors:

<u>1. Whether change is linear or exponential</u>: If the nature of the process of change is multiplicative rather than additive, points will not be linear but will lie along an exponentially increasing or decreasing curve. This is a common situation for many practical problems of interest. A logarithmic transformation of the estimates will make them linear, and such a transformation usually has the additional positive effect of making the variances more nearly equal. Once we have collected data we could assess whether a linear or exponential model is more appropriate. **For this power analysis we have assumed an exponential model, as we hope the populations will be recovering rapidly.**

<u>2. Whether change is positive or negative</u>: We are hoping to be able to pick up increases in the populations due to improved law enforcement. We consider 3 different levels of increase during this power analysis, namely **1%, 2% or 5% increase between sampling occasions.**

<u>3. Whether the statistical test is 1- or 2-sided</u>: **We use the one sided test.**

<u>4. How the precision of the estimates depends on abundance</u>: Even if equal effort and identical methods are used on each sampling occasion, the variances of the estimates will in general not be equal, as required by linear regression, but will be some function of abundance A. TRENDS allows on to choose among 3 patterns of change of coefficient of variation (CV=standard error/mean) with abundance A, namely CV inversely proportional to A2, CV constant with A, or CV proportional to A2. **In distance sampling the CV is frequently inversely proportional to abundance thus this option is selected for the power analysis.**

<u>5. Whether the standard normal (z) or Student's (t) distribution is used in the calculations</u>: TRENDS also asks the user to choose either the standard normal (z) or Student's (t) distribution as the basis of calculation. In general, the t distribution should be used. Consider whether, on each sampling occasion, the method of estimation or measurement produces a single estimate of A, or whether an estimate of var(A) is also produced. The rationale for using the z distribution is to take advantage of the extra information present when an estimate of var(A) is available. Calculations based on the z distribution, however, make stronger assumptions and give more optimistic answers. **For this power analysis we use the more conservative t distribution.**

Table A2.1: The statistical power calculated by the TRENDS software for various combinations of the input parameters r, CV, and n.

Rate of change in abundance r	**Initial CV**	**Number of sampling occasions n**	
		5	10
		Power 1 – β	
1%	10%	16%	34%
1%	20%	13%	20%
1%	30%	12%	16%
1%	40%	12%	15%
1%	50%	12%	14%
2%	10%	24%	69%
2%	20%	16%	35%
2%	30%	14%	25%
2%	40%	13%	21%
2%	50%	13%	18%
5%	10%	54%	100%
5%	20%	28%	85%
5%	30%	21%	62%
5%	40%	18%	47%
5%	50%	17%	38%

Appendix 3: Camera Trap ID Numbers and Coordinates

LINKID	X	Y
001	453514	2018881
002	452114	2020281
003	453514	2020281
004	449314	2021681
005	450714	2021681
006	452114	2021681
007	445114	2023081
008	446514	2023081
009	447914	2023081
010	449314	2023081
011	450714	2023081
012	445114	2024481
013	446514	2024481
014	447914	2024481
015	443714	2025881
016	445114	2025881
017	446514	2025881
018	442314	2027281
019	443714	2027281
020	445114	2027281
021	439514	2028681
022	440914	2028681
023	442314	2028681
024	443714	2028681
025	438114	2030081
026	439514	2030081
027	440914	2030081
028	442314	2030081
029	435314	2031481
030	436714	2031481
031	438114	2031481
032	439514	2031481
033	440914	2031481
034	432514	2032881
035	433914	2032881
036	435314	2032881
037	436714	2032881
038	438114	2032881
039	439514	2032881
040	431114	2034281
041	432514	2034281
042	433914	2034281
043	435314	2034281
044	436714	2034281
045	438114	2034281
046	431114	2035681
047	432514	2035681
048	433914	2035681
049	435314	2035681
050	436714	2035681
051	431114	2037081
052	432514	2037081
053	433914	2037081
054	431114	2038481
055	432514	2038481
056	415900	2034426
057	417300	2034426
058	418700	2034426
059	420100	2034426
060	413100	2035826
061	414500	2035826
062	415900	2035826
063	417300	2035826
064	418700	2035826
065	420100	2035826
066	421500	2035826
067	422900	2035826
068	413100	2037226
069	414500	2037226
070	415900	2037226
071	417300	2037226
072	418700	2037226
073	420100	2037226
074	413100	2038626
075	414500	2038626
076	415900	2038626
077	417300	2038626
078	418700	2038626
079	413100	2040026
080	414500	2040026
081	415900	2040026
082	414500	2041426
083	405810	2051815
084	407210	2051815
085	408610	2051815
086	410010	2051815
087	411410	2051815
088	403010	2053215
089	404410	2053215
090	405810	2053215
091	407210	2053215
092	408610	2053215
093	410010	2053215
094	401610	2054615
095	403010	2054615
096	404410	2054615
097	405810	2054615
098	407210	2054615
099	408610	2054615
100	410010	2054615
101	403010	2056015

102	407210	2056015
103	408610	2056015
104	410010	2056015
105	407357	2031514
106	408757	2031514
107	407357	2032914
108	408757	2032914
109	407357	2034314
110	408757	2034314
111	405957	2035714
112	407357	2035714
113	405957	2037114
114	407357	2037114
115	404557	2038514
116	405957	2038514
117	404557	2039914
118	405957	2039914
119	408757	2039914
120	410157	2039914
121	403157	2041314
122	404557	2041314
123	405957	2041314
124	408757	2041314
125	410157	2041314
126	403157	2042714
127	404557	2042714
128	405957	2042714
129	407357	2042714
130	408757	2042714
131	410157	2042714
132	401757	2044114
133	403157	2044114
134	404557	2044114
135	405957	2044114
136	407357	2044114
137	408757	2044114
138	410157	2044114
139	400357	2045514
140	401757	2045514
141	403157	2045514
142	404557	2045514
143	405957	2045514
144	407357	2045514
145	400357	2046914
146	401757	2046914
147	403157	2046914
148	404557	2046914
149	398957	2048314
150	400357	2048314
151	401757	2048314
152	403157	2048314
153	397557	2049714
154	398957	2049714
155	400357	2049714
156	421130	2021587
157	422530	2021587
158	423930	2021587
159	421130	2022987
160	422530	2022987
161	423930	2022987
162	422530	2024387
163	423930	2024387
164	425330	2024387
165	421130	2025787
166	422530	2025787
167	423930	2025787
168	425330	2025787
169	421130	2027187
170	422530	2027187
171	423930	2027187
172	425330	2027187
173	412730	2028587
174	414130	2028587
175	415530	2028587
176	418330	2028587
177	419730	2028587
178	422530	2028587
179	423930	2028587
180	425330	2028587
181	411330	2029987
182	412730	2029987
183	414130	2029987
184	415530	2029987
185	416930	2029987
186	418330	2029987
187	419730	2029987
188	421130	2029987
189	423930	2029987
190	411330	2031387
191	412730	2031387
192	414130	2031387
193	415530	2031387
194	416930	2031387
195	423930	2031387
196	412730	2032787
197	414130	2032787
198	409930	2034187
199	411330	2034187
200	411330	2035587

Appendix 4: Line Transect ID Numbers, Coordinates, and Line Lengths

LinkID	Start_X	Start_Y	End_X	End_Y	Length_m
001	432493	2038766	431078	2037352	1999.98
002	432851	2037710	431437	2036296	1999.98
003	433602	2037047	432188	2035633	1999.98
004	431480	2034925	430572	2034017	1284.40
005	434989	2037020	434483	2036514	715.58
006	433776	2035807	432362	2034392	1999.98
007	431654	2033685	431080	2033111	811.99
008	431824	2032440	432664	2033280	1187.99
009	433371	2033987	434785	2035402	1999.98
010	435492	2036109	436020	2036637	746.58
011	432749	2031951	433635	2032837	1253.40
012	434342	2033544	435756	2034959	1999.98
013	436463	2035666	436875	2036077	581.82
014	433843	2031631	434846	2032634	1418.16
015	435553	2033341	436967	2034755	1999.98
016	437674	2035462	437680	2035468	8.02
017	434715	2031089	436124	2032498	1991.97
018	436831	2033205	438245	2034619	1999.98
019	438596	2033556	437182	2032142	1999.98
020	436475	2031435	435639	2030599	1182.40
021	439643	2033188	439065	2032610	817.58
022	438357	2031903	436943	2030489	1999.98
023	439855	2031986	438440	2030572	1999.98
024	437733	2029865	437481	2029613	356.46
025	440848	2031565	439686	2030403	1643.52
026	438979	2029696	438360	2029077	875.46
027	439238	2028541	440033	2029336	1124.53
028	440740	2030043	441614	2030917	1236.04
029	442380	2030269	441840	2029729	763.94
030	441133	2029022	440116	2028005	1438.21
031	443147	2029621	442749	2029224	561.77
032	442042	2028517	441055	2027530	1396.09
033	441865	2026925	442292	2027352	603.89
034	442999	2028059	443913	2028973	1292.64
035	442507	2026153	443007	2026654	707.34

036	443714	2027361	444662	2028308	1340.21
037	445400	2027632	444933	2027165	659.78
038	444226	2026458	443150	2025382	1522.77
039	443792	2024610	444129	2024947	477.21
040	444836	2025654	446037	2026855	1697.92
041	446697	2026101	446483	2025887	302.06
042	445776	2025180	444434	2023838	1897.86
043	445077	2023066	445149	2023138	102.12
044	445856	2023845	447270	2025260	1999.98
045	447868	2024443	446454	2023029	1999.98
046	448985	2024146	447570	2022731	1999.98
047	446863	2022024	446763	2021924	142.02
048	449965	2023712	448651	2022398	1857.97
049	448967	2021300	450382	2022714	1999.98
050	451341	2022259	449998	2020917	1898.90
051	450850	2020354	450922	2020426	101.08
052	451629	2021133	452482	2021987	1207.40
053	453206	2021296	452645	2020735	792.58
054	451938	2020028	451601	2019691	476.13
055	452388	2019064	453465	2020141	1523.86
056	453917	2019179	454221	2019482	429.25
057	411839	2038859	411535	2038555	429.13
058	414739	2041759	414673	2041693	92.54
059	413966	2040986	412552	2039572	1999.98
060	411579	2037185	411465	2037070	161.83
061	412115	2037721	412014	2037619	143.85
062	415622	2041227	414424	2040029	1694.31
063	413717	2039322	412302	2037908	1999.98
064	415803	2039995	414389	2038580	1999.98
065	413682	2037873	412268	2036459	1999.98
066	416569	2039346	415155	2037932	1999.98
067	414448	2037225	413033	2035811	1999.98
068	417509	2038872	416095	2037458	1999.98
069	415388	2036751	413974	2035337	1999.98
070	418301	2038250	416887	2036836	1999.98
071	416180	2036129	415198	2035147	1388.54
072	415398	2033932	415830	2034364	611.44
073	416537	2035072	417951	2036486	1999.98
074	418658	2037193	419631	2038165	1375.12

075	416403	2033523	416845	2033965	624.87
076	417552	2034672	418966	2036086	1999.98
077	419673	2036793	420513	2037633	1187.51
078	417927	2033633	418501	2034207	812.47
079	419208	2034914	420622	2036328	1999.98
080	421329	2037036	421395	2037101	92.23
081	419481	2033773	420830	2035122	1907.75
082	421537	2035829	422733	2037025	1692.25
083	423503	2036381	423285	2036163	307.74
084	422578	2035456	421693	2034571	1252.19
085	400120	2056044	399403	2055327	1014.12
086	400976	2055485	400877	2055387	139.89
087	400170	2054679	400160	2054670	13.95
088	401148	2054244	402552	2055648	1986.03
089	403708	2055390	402418	2054099	1825.19
090	402799	2053067	402923	2053190	174.80
091	403630	2053897	405044	2055311	1999.98
092	404683	2053536	406098	2054951	1999.98
093	406805	2055658	407869	2056722	1504.96
094	404417	2051855	404767	2052206	495.02
095	405474	2052913	406888	2054327	1999.98
096	407595	2055034	408649	2056088	1490.43
097	410634	2056658	410273	2056298	509.56
098	409566	2055591	408152	2054177	1999.98
099	407445	2053470	406031	2052055	1999.98
100	405324	2051348	405171	2051195	216.43
101	406677	2051287	407938	2052548	1783.56
102	408645	2053255	410059	2054670	1999.98
103	408146	2051343	409560	2052757	1999.98
104	410268	2053464	410361	2053558	132.62
105	408820	2050602	410140	2051922	1867.37
106	410847	2052630	410891	2052673	61.09
107	410327	2050695	411698	2052066	1938.90
108	398156	2049331	399313	2050488	1636.01
109	400211	2049972	398797	2048558	1999.98
110	399146	2047493	400560	2048907	1999.98
111	401267	2049614	401355	2049702	124.33
112	402147	2049080	400821	2047753	1875.65
113	400114	2047046	399512	2046444	851.22

114	402999	2048517	402187	2047705	1148.77
115	401480	2046998	400116	2045635	1927.96
116	403851	2047955	403800	2047904	72.02
117	403093	2047197	401679	2045783	1999.98
118	400972	2045076	400730	2044834	341.69
119	401369	2044058	402541	2045231	1658.29
120	403248	2045938	404662	2047352	1999.98
121	404903	2046179	403489	2044765	1999.98
122	402782	2044057	401964	2043240	1155.83
123	402408	2042270	403005	2042867	844.15
124	403712	2043574	405126	2044988	1999.98
125	405834	2045695	406429	2046290	841.50
126	402852	2041299	403671	2042119	1158.48
127	404378	2042826	405793	2044240	1999.98
128	406500	2044947	407290	2045737	1117.90
129	408171	2045204	407548	2044581	882.09
130	406841	2043874	405426	2042459	1999.98
131	404719	2041752	403305	2040338	1999.98
132	404438	2040057	405370	2040989	1317.20
133	405415	2041034	405898	2041517	682.78
134	406605	2042224	408019	2043638	1999.98
135	408727	2044345	409074	2044693	491.89
136	405883	2040088	404817	2039022	1508.09
137	409938	2044142	408523	2042728	1999.98
138	407816	2042021	406585	2040790	1741.31
139	406430	2039220	406247	2039038	258.67
140	405540	2038330	404641	2037432	1270.62
141	410963	2043754	410447	2043238	729.36
142	409740	2042531	408326	2041117	1999.98
143	405355	2036731	406769	2038146	1999.98
144	408608	2039984	410022	2041398	1999.98
145	410729	2042105	411498	2042874	1087.81
146	405543	2035505	406188	2036150	912.18
147	406895	2036857	407376	2037338	680.50
148	408638	2038600	409182	2039144	769.48
149	410070	2040032	410459	2040421	550.00
150	411166	2041128	411430	2041392	374.04
151	408447	2036994	407297	2035845	1625.94
152	406590	2035138	405966	2034514	881.44

153	411538	2040085	410990	2039538	774.06
154	408493	2035627	408249	2035383	344.48
155	407542	2034676	406372	2033505	1655.70
156	408918	2034638	408675	2034394	344.28
157	407968	2033687	406777	2032496	1684.47
158	407182	2031487	407405	2031710	315.51
159	408112	2032417	409075	2033380	1361.98
160	409802	2032693	409351	2032242	638.00
161	408644	2031535	407698	2030589	1337.21
162	409978	2034463	411324	2035809	1903.43
163	410405	2033476	410474	2033544	96.55
164	411181	2034251	412061	2035131	1244.76
165	412521	2034177	411987	2033643	755.22
166	413164	2033406	411750	2031992	1999.98
167	411489	2030317	412903	2031731	1999.98
168	413610	2032438	414552	2033380	1332.20
169	411429	2028842	411901	2029314	667.78
170	412608	2030022	414022	2031436	1999.98
171	414729	2032143	415197	2032610	661.38
172	412012	2028011	412958	2028958	1338.61
173	413666	2029665	413876	2029876	297.95
174	413881	2029880	415084	2031083	1702.04
175	415791	2031790	415820	2031820	41.31
176	414782	2029367	413397	2027982	1958.67
177	416322	2030907	415241	2029826	1528.58
178	414255	2027426	414589	2027760	471.41
179	415296	2028467	415688	2028859	555.02
180	416507	2029678	417529	2030700	1444.96
181	417172	2028929	418587	2030343	1999.98
182	418301	2028643	419715	2030057	1999.98
183	419588	2028517	421003	2029931	1999.98
184	421710	2030638	422093	2031021	542.15
185	422131	2029645	422348	2029862	307.02
186	422726	2030240	423540	2031054	1150.81
187	419998	2026098	421413	2027513	1999.98
188	422120	2028220	423508	2029608	1963.08
189	423645	2029745	423671	2029771	36.91
190	424379	2030478	424494	2030594	163.83
191	420957	2025642	422255	2026941	1836.15

192	422962	2027648	424376	2029062	1999.98
193	422703	2025975	424118	2027389	1999.98
194	424825	2028096	426088	2029360	1786.65
195	420674	2022531	420825	2022682	213.33
196	421532	2023389	422946	2024803	1999.98
197	423653	2025510	425067	2026924	1999.98
198	425774	2027632	426247	2028104	668.42
199	426339	2026782	425397	2025840	1331.56
200	424690	2025133	423276	2023719	1999.98
201	422569	2023012	421155	2021598	1999.98
202	422457	2021486	423871	2022900	1999.98
203	424578	2023607	425993	2025022	1999.98
204	423754	2021369	423409	2021024	487.56

Appendix 5: Camera Trap Data Form

Nam Kading NPA Camera Trap Form (Version: 05 November 2007)

Datum: IndianThailand ☐ Other ☐

Survey Zone:	List people setting cameras:	List people picking up cameras:

Camera Number	Way Point	X coordinate (East)	Y coordinate (North)	Elevation (m)	Date set (d/m/y)	Put in C and AA batteries	Turn battery switches on	Turn timer switches off	Timer setting 1-6-8	Clock set at (d/m/y, 24 hr)	Flim roll number	Turn on camera	Set flash	Insert silica	All cords in	Set and aim	Signal green	Test Photo (film number)	Start frame number	Remark (wildlife)	Date retrieved (d/m/y)	Time retrieved (24 hr)	Last frame number	Number of photos taken	Test photo (film number)	Film advance?	Flash working?	Batteries level (%)	Rewind film	Remove batteries	Remarks (wildlife)

Appendix 6: Landform and Human Use Data Form

CAMERA TRAP LANDFORM AND HUMAN USE DATA FORM

Nam Kading NPA Version: 05 November 2007

Recorder Name:		**Date (dd/mm/yy):**
Survey Zone:	**Camera no:**	**Time (00:00):**
X Coordinate:		**Waypoint no:**
Y Coordinate:		**Elevation (m):**

Habitat and Threat Survey

Walk 70 paces on a compass bearing of 0^o, 120^o and 240^o from camera position. Fill out tables below recording the total number of swamp/grasslands, mineral licks and threats encountered.

Swamp/Grassland Size	**Number**
0 - 2 ha	
2 - 5 ha	
> 5 ha	

Mineral Lick Size	**Number**
0 - 2 m^2	
2 - 5 m^2	
> 5 m^2	

Threats	**Number**		
Active hunting camp			
Non-active hunting camp			
Snare			
Human			
Animal carcass		Type	
Livestock		Type	
Burned area (ha)			
Agricultural Crop (ha)		Type	
Tick (X) if present			
Timber harvesting			
NTFP collection			
Other?			

Appendix 7: Form for recording evidence of threats to report to law enforcement

Sheet: _____of ____

Evidence of human/threats to report to law enforcement

Version: 5 November, 2007

Name of observer: | **GPS No:**

If more than one threat is encountered at the same location you can record on the same line

***** Record "unusual" ecounters in the comments***

Tick (√) each new threat as it is encountered and make comments describing each threat.

PERSON = record the number (#) of people seen

WEAPON = **G** (gun), **GS** (gun shot), **CB** (cross bow)

TRAP = **S** (snare), **F** (fishing)

CAMP = **AC** (active camp), **NA** (not-active)

DOMESTIC ANIMAL = **LS** (livestock), **D** (dog)

HABITAT LOSS = **L** (logging), **CR** (crop), **B** (burnt area)

MINERAL LICK = **SML** (0 - 2 m^2), **MED** (2 - 5 m^2), **LGE** (>5 m^2)

HORNBILL = record **NH** (nest height) (m) and GPS location of active nests only. Record tree species in comments if known.

PERMANENT WATER = (permanent water) record GPS location of permanent water if suitable for camp site

Date (dd/mm/yy)	Time (00:00)	Waypoint no.	GPS Coordinate		PERSON	WEAPON			TRAP		CAMP		DOMESTIC ANIMAL		HABITAT LOSS			MINERAL LICK			HORNBILL	PERMANENT WATER	Comments
			X (East)	Y (North)	#	G	GS	CB	S	F	AC	NA	LS	D	L	CR	B	SML	MED	LGE	NH (m)		

Appendix 8: Line Transect Data Form

Nam Kading NPA Line Transect Form (05 November 2007)		**Form _____of ______**
Team Names:	**Survey Zone:**	
Transect #:	**Start Coordinates** **X**	**Y**
Visit No: 1 2 3 4 *(circle)*	**Bearing to go to:**	
Date (dd/mm/yy):		
Start GPS: X Y	**Start Altitude (m):**	
End GPS: X Y	**End Altitude (m):**	
GPS Datum: IndianThailand ☐ Other:______	**Transect finished?** Yes ☐, No ☐,	
Start Time (00:00):	**If transect line not finished, why? Explain**	
End Time (00:00):		
Length of transect (hip chain):		

Rain During Survey: (√)	No Rain ☐	Mist rain; not through canopy ☐	Rain on canopy & forest floor ☐	Heavy rain (impairs vision) ☐

Wind: (√) No wind ☐ Light wind (leaves move) ☐ Strong wind (branches move) ☐

Cloud Cover: (√) No Cloud ☐ 25% Cloud ☐ 50% Cloud ☐ 75% Cloud ☐ 100% Cloud ☐

Target species: Large Hornbill (Great or Wreathed), Small Hornbill (Brown or Oriental Pied), Gibbon, Langur (Douc, Francois's, Phayre's), Macaque, Black Giant Squirrel.

Seen (S) or Heard (H)

Target Species	**Time (00:00)**	**S/H**	**GPS Coordinates**		**Distance (m)**	**Angle**	**Group size**	**# of infants**	**# of black gibbon**	**Remarks**
			X	**Y**						

Appendix 9: Indicative monitoring budget for Year 1 (equipment costs for Year 2 will differ)

Budget for baseline over 2 years		**US$**	
Description	**Unit /Amount**	**Unit Cost**	**Total**
A. Monitoring Personnel			
WCS Monitoring Team Data coordinator	12	70	840
WCS Camera trapping team leader	12	70	840
WCS Transect Line team Leader	12	70	840
IEMWP Camera Trapping Team Leader	12	25	300
2X IEWMP Camera Trapping Deputy Team Leader	12	70	840
WCS GIS Officer	4 months	525	525
Monitoring Personnel - Subtotal			*4,185*
B. Food and Transport			
B1. Camera trapping			
Per-diems for 6 camera trapping staff (2 teams x 3 people+4 Gards)	10px15dx2bx2trips	3	1,800
Porters (8 villagers to carry cameras, food, equipment)	8px8dx2bx2trips	5	1,280
Transportation to field (12 truck drop & pick up); use 4x4 Ford Ranger (12 trips)	4	60	240
Training for Camera Trap team (10 Days)	Lumpsum	1	1,300
B2. Line Transect Monitoring			
Per-diems for field staff (4 team of 2 people+4 guards)	12px40dx2bx2trips	3	5,760
Porters (5)	5px8dx2bx2trips	3	480
Fuel to the field (8 truck drop & pick up=8 trips); Use 4x4 Ford Ranger	4	70	280
Training for Transect Line Teams (7 days)	Lumpsum	600	600
B4. Monitoring Coordination / Implementation (12 months)			
Field per-diem for WCS Field Research Supervisor	36 days	3	108
Per-diems for driver to drop off and pick up monitoring teams at field sites	12 days	6	264
Fuel for 4x4 Ford Ranger for monitoring coordination	Lumpsum		250
Food & Transporation - Subtotal			*12,362*
C. Field equipment and supplies for monitoring			
Backpacks for monitoring personnel (12) (Have 7)	5	35	175
Field Hammocks for monitoring personnel;(Have 3)	9	25	100
Flash lights;	12	5	55
Sleeping bag; have already	0	0	0
GPS (4XTransect teams 2XCamera Trap Team)	6	210	1,260
Compasses (6)	6	25	150
Cameras trap film, batteries and developing			
4 C-batteries * 50*2 cameras	400	1.25	500
110 films	110	3	330
Develop 110 films	110	1.25	138
110 contact prints	110	1.75	193
Print 110 films	110	0.85	94
Dry boxes and archival negative and contact print storage for 110 films	Lumpsum	170	170
GPS batteries for all monitoring teams (165 pairs of AA batteries)	165	1.5	248
Silica for camera traps; field notebooks; cook kits for field teams	Lumpsum	245	245
~~Laser Range Finders~~	4	~~150~~	~~600~~
Jazz digital cameras (1 each Team= 6)	6 units	50	300
Field Equipment & Supplies - Subtotal			*4,556*
D. Purchased Services			
Printing reports, photo reprints and photocopy data forms	Lump sum	440	1,760
Commmunication satellite and land phones - NKNPA	Lump sum	400	400
Purchased Services - Subtotal			*2,160*
IEWMP Monitoring Total			**23,263**