

TIGER AND PREY BASE MONITORING PROTOCOL 2017 (NEPAL)



Government of Nepal Ministry of Forests and Soil Conservation Department of National Parks and Wildlife Conservation

Tiger and Prey Base Monitoring Protocol 2017 Nepal



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The goal of managing wildlife population is frequently expressed in terms of population size. When dealing with endangered species like tigers, we are trying to increase population size. The St. Petersburg Declaration on Tiger Conservation (2010) by the head of states of 13 tiger range countries has committed to strive to double the number of wild tigers across the range by 2022. Tigers are distributed along Nepal's southern frontiers, in Terai Arc Landscape (TAL), which extends from Bagmati River in the east to Mahakali River in the west. As a part of this, Nepal has also committed to attain a demographically stable meta-population of at least 250 adult tigers in the Nepal TAL by 2022. Population size is thus the currency by which the success of species management ultimately is judged.

Population size has the central role in wildlife management. Conservation and management of such important species like tigers require basic information on population dynamics and distribution at different time scale. Policy makers, planners, wildlife managers and conservation organizations need clear and reliable information on tiger population. However, a single estimate of population size at one point in time and space is usually of limited value. Instead, regular estimates of population size would help place a particular estimate in proper perspective for the species long term survival. Such regular estimates allow inferences about population status relative to previous years, gives trend which reflects direction and magnitude of change over a period of time.

Monitoring of tigers and their prey bases is an exercise in which a set of quantitative and qualitative observations are made, usually by means of a standardized procedure and within a restricted period of time. This protocol has been prepared by incorporating the past experiences and recent scientific findings in tiger monitoring and aims at providing a standardized method which is scientifically robust yet practically implementable at the field level.

On behalf of the Government of Nepal, I would like to acknowledge the contribution of Department of Forests, NTNC, WWF Nepal and ZSL Nepal for providing necessary support in preparing this protocol. Many scientists and professionals have contributed to the development of this protocol. I appreciate the inputs, expertise and experiences of all of them. Special thanks go to Dr Maheshwar Dhakal, other technical team members and reviewers for improving this revised protocol.

Finally, I would like to assure that the Department of National Parks and Wildlife Conservation is committed to implement and institutionalize periodic tiger and prey base monitoring in Nepal.

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Glossary

Abundance:

Total number of individuals or items of interest in some defined area and time period; also known as absolute abundance.

Census:

A complete count of individuals, objects, or items within a specified area and time period.

Covariate:

A variable that may relate to a parameter of interest.

Density:

Total number of individuals or objects of interest per unit area (also known as absolute density). Sometimes, the concept is broadened to mean number of animals per unit resource, where resource could be suitable habitat, food abundance, etc.

Estimate:

A numerical value calculated from sample data collected from a sampled population and used to represent the parameter of interest.

Lowland Protected Areas:

The protected areas geographically situated in the low-land areas of Terai and Churia Bhabhar tract. These include Koshi Tappu Wildlife Reserve, Parsa Wildlife Reserve, Chitwan National Park, Banke National Park, Krishnasar Conservation Area, Bardia National Park and Shuklaphanta National Park.

Lowland Outside Protected Areas:

Forested areas outside protected areas system including corridors and connectivity of lowland Nepal.

Population Closure:

The duration of survey in which it is assumed that there has been no birth, death, immigration and emigration in the population being surveyed.

Sample:

A group of sampling units selected during a survey.

Abbreviations and Acronyms

AIC	Akaike Information Criterion
BCC	Biodiversity Conservation Center
BNP	Bardia National park
BaNP	Banke National Park
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CNP	Chitwan National Park
CHAL	Chitwan-Annapurna Landscape
DNA	Deoxyribonucleic Acid
DNPWC	Department of National Parks and Wildlife Conservation
DoF	Department of Forests
GoN	Government of Nepal
GTF	Global Tiger Forum
GPS	Global Positioning System
GTRP	Global Tiger Recovery Program
ID	Identification
INGO	International Non-Governmental Organisation
IUCN	International Union for Conservation of Nature
Km	Kilometer
Km ²	Square Kilometer
М	Meter
МСР	Minimum Convex Polygon
MMDM	Mean Maximum Distance Moved
NAST	National Academy of Science and Technology
NGO	Non-Governmental Organization
NTNC	National Trust for Nature Conservation
PAs	Protected Areas
PWR	Parsa Wildlife Reserve
SECR	Spatially Explicit Capture Recapture
ShNP	Shuklaphanta National Park
TAL	Terai Arc Landscape
WWF	World Wide Fund for Nature
ZSL	Zoological Society of London

Royal Bengal Tiger by DNPWC/NTNC/Panthera/ZSL

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1 Introduction

Tiger (Panthera tigris) is an apex species in terrestrial ecosystems. As a top predator, they also serve as umbrella species and also popularly known as charismatic species. Tigers are globally endangered in IUCN redlist (Goodrich et al. 2016), listed in Appendix-I of CITES and listed as protected species in the National Parks and Wildlife Conservation Act 2029 (1973), Nepal. Tigers are found in wide range of habitats from tropical rain forests of Sumatra, mangrove forests of Bangladesh, alluvial grasslands of Terai, deserts of Rajasthan, forests of Bhutan to temperate regions of Russian far east. Tropical humid forests are the main tiger habitat across all tiger range countries. Habitat loss and degradation, poaching and illegal trade and conflicts with local communities are major threats to tiger conservation. In addition, effects of climate change and diseases epidemics are other prominent threats.

The Government of Nepal, particularly the Department of National Parks and Wildlife Conservation (DNPWC) and the Department of Forests (DoF) are putting special efforts to save the tiger and its habitat from extinction. The contribution of conservation partners including the National Trust of Nature Conservation (NTNC), WWF Nepal and Zoological Society of London (ZSL) is imperative in this regard. The role of Nepal Army under National Parks and Wildlife Reserve Directorate to control poaching in and around the protected areas; and the role of the Nepal Police to control the illegal trade of wildlife and wildlife parts across the country is equally praiseworthy. Similarly, community based anti-poaching units (CBAPU) are also actively engaged in curbing illegal wildlife activities outside the procted areas.

The "St. Petersburg Declaration on Tiger Conservation - 2010" by the head of states of

13 tiger range countries has committed to "strive to double the number of wild tigers across the range by 2022" by formulating the Global Tiger Recovery Program (GTRP). GTRP has identified seven major areas of interventions to double the tiger numbers by 2022. These interventions are habitat management, institutional and policy reform, control of poaching of prey base and tiger, control of illegal trade of tiger, engagement of local communities and reduction in human tiger conflicts, research and monitoring, and transboundary cooperation. As a part of this, Nepal has also committed to attain a demographically stable meta-population of at least 250 adult tigers in the Terai Arc Landscape (TAL) in Nepal by 2022, with transboundary ecological links. Since then, tiger conservation has received additional attention worldwide and Nepal is working together with other tiger range countries to achieve the goal. Many international donor agencies including I/NGOs are also working in the line of doubling the world tiger numbers by 2022.

Periodic monitoring of tigers is necessary to generate information on the status and distribution of tiger which helps to develop focused conservation strategies and initiate programs to safeguard tiger populations. Such information is also important to see whether certain conservation measures have worked or not. Thus, the Government of Nepal has been focusing on regular annual or biannual monitoring in the low tiger density protected areas and periodic monitoring in high tiger density protected areas.

In the past (before 2008), the methods adopted for surveying and monitoring of tigers in Nepal were inconsistent. First attempt to standardize the tiger and prey base survey was initiated in 2009 and a monitoring protocol for tigers and their prey base in



Nepal was published in 2009 by the Department of National Parks and Wildlife Conservation (DNPWC). Following the protocol, first national tiger and prey survey was done in winter of 2008 and early 2009 covering most of the tiger habitats in Nepal excluding Siwalik Hills (Karki et al. 2009). Similar effort of nationwide survey was replicated in 2013 with some improvements. The survey of 2013 can be considered a milestone as it was conducted in the single season covering the entire areas which are known to have breeding tiger populations in Nepal (Dhakal et al. 2013). Moreover, similar survey was conducted in Indian part of TAL which made it possible to a transboundary joint analysis. As a result, a joint report with India on "Tigers of The Transboundary Terai Arc Landscape: Status, distribution and movement in the Terai of India and Nepal" was published in 2014.

In an attempt to further improve the protocol by incorporating the past experiences and recent

scientific findings, this updated version of the protocol has been prepared. This protocol aims at providing a standardized method which is scientifically robust yet practically implementable at the field level. As some tigers share habitat both in Nepal and India, it is important to identify those tigers to avoid double counting in the two countries. Hence, the protocol also aims to make the tiger survey methods compatible and comparable with India so that it will help to minimize the risk of population overestimation.

Many scientists and professionals have contributed to the development of this protocol. Please refer to page II for the list of technical experts, reviewers and contributors to the development of this protocol.

2 Objective

The objective of this protocol is to standardize the tiger and prey base survey methodology so as to ensure scientifically robust results by maintaining consistency, accuracy and comparative data. Specifically, it provides detailed framework for:

- a. Estimating tiger populations
 - Abundance and density in/adjacent PAs
- b. Estimating tiger prey-base
 - Prey-base density in/adjacent PAs
- c. Estimating habitat occupancy by tiger and prey base across TAL
- d. Assessing human impact on tiger habitat





3 Protocol

The next sub-sections present in detail the protocols for tiger, prey base and human impact monitoring. The table below summarizes the general methodology:

Objectives	Scope	Methods	Analysis	Fieldwork time	Frequency
Estimate tiger abundance (density based)	Inside PAs high density areas	Camera trapping Genetic	Capture and recapture Molecular	November to February	2-4 years
Estimate tiger abundance (density based)	Inside PAs - in low density areas and high poaching prone areas	Camera trapping Genetic	Capture and recapture Molecular	November to February	Every year
Estimate prey base abundance (density based)	Inside PAs	Line transects	Distance sampling	March to April	2-4 years
Estimate prey base abundance (density based)	Inside PAs - in low density areas and high poaching prone areas	Line transects	Distance sampling	March to April	Every year
Estimate tiger abundance (density based)	Corridors and Protected Forests	Camera trapping Genetic	Capture and recapture Molecular	November to February	Every year
Estimate prey base abundance (density based)	Corridors and Protected Forests	Line transects	Distance sampling	March to April	Every year
Estimate distribution of tigers and prey base (in tiger habitat)	Entire Nepal	Patch occupancy	Occupancy	November to February	2-4 years
Estimate minimum tiger population (occupancy)	Outside PAs	Patch occupancy	Occupancy	November to February	2-4 years
Assess human disturbance on tiger habitat	Entire Nepal	Patch occupancy	Occupancy	November to February	2-4 years

Table 1. General Methodology for monitoring Tiger and Prey Base

3.1 Estimating tiger population

Nepal has 45 years of history (since 1970s) and experiences in research, monitoring and estimating the tiger population. Initially, the population census was based on pugmark methods for identification of individual tigers. Later camera trapping was introduced as an unbiased and practical method for identification and monitoring of tiger abundance. This methodology involves setting out camera traps within the area of interest to photographically 'capture' and 'recapture' tigers. Through the camera trapped photographs, individual tigers can be unambiguously identified based on their unique body stripe patterns. In addition, it is useful because of the elusive nature of the tiger. Further, the capture-recapture models provide a statistically robust framework for estimating species abundance and density, particularly when a population is said to be closed to births, deaths, immigration or emigration during the survey period (Karanth, 1995). Karanth (1995), Karanth and Nichols (1998, 2002) and Wegge et al. (2004, 2009) have described in detail about the camera trapping of tigers for estimating abundance. Spatially Explicit Capture Recapture (SECR) models are developed to address the limitations of conventional approaches (Efford et al. 2004, Efford et al. 2009, Royle et al. 2009). There are two types of SECR models developed, based on multinomial likelihood and Bayesian hierarchy. Multinomial based models ('secr' package in R, Efford et al. 2016) and Bayesian hierarchial models ('SPACECAP' package in R, Gopalswamy et al. 2012) are latest advancement in estimating population abundance



Figure 1: Terai Arc Landscape

and density. These models are based on the fact that capture probability of animals are dependent on the distance of camera traps from the activity center of animals. Based on information of capture and recapture of animals, SECR models estimates number of activity centers within the sampled area which is ultimately used for population size estimation.

3.1.1 Survey design

In the past, tiger monitoring was confined to the core areas of the PAs (Figure 1). These areas have networks of fire lines (forest roads) that provide easy accessibility. In addition to ecological characteristics of the tiger, availability of cameras and technical personnel are key factors to be considered for covering the area of interest. The situation would have been very ideal if all areas could be surveyed at the same time, however it is not always possible. In such case, the area can be divided into blocks with shifting camera traps successively to cover the entire area of interest.

The size of the monitoring blocks is constrained

by available logistics, human resources and the number of camera traps. Furthermore, the use of capture and recapture model demands the survey to be completed within a short period of time (if the analysis is done under the assumption of a closed population model). Based on past experiences, each PA can be divided into required number of blocks, in which the sampling can be completed within an acceptable time period. The size of required blocks occupied by the number of trapping stations along with the length of the trapping period is crucial in a model-based tiger estimation process.

A trapping duration at each set of camera traps (i.e sampling occasion) should be at least 15 days (nights), with distance between neighboring traps not exceeding 2 km (Wegge *et al.* 2004), while maintaining the trap distance, care should be taken not to leave any potential holes and thus sampling area of interest to minimize the error. "Population closure" is another important factor that should be taken into consideration. According to Karanth *et al.* (2011), assuming a closure period of 30-60 days may be justifiable whereas preference should be given to even shorter duration. An area of interest

Camera Trap Parameters	Parsa Wildlife Reserve*	Chitwan National Park	Banke National Park	Bardia National Park	Shuklaphanta National Park
Trap distance (km)	2	2	2	2	2
Sampling occasions per block	Minimum 15 days	Minimum 15 days	Minimum 15 days	Minimum 15 days	Minimum 15 days
Camera stations (Grid Cells)	177	362	118	238	88
Number of sample blocks	3	3	2	3	2
Number of camera pair required	74 (59+15 additional)	136 (121+15 additional)	69 (59+10 additional)	95 (80+15 additional)	54 (44+10 additional)
Area sampled (km²)	1,043.51	3,110.35	1,485.54	2,367.91	485.76

Table 2. Recommended Camera Trap Configuration for Individual Protected Areas

with 150 camera stations and 15 days sampling occasions can be surveyed in 3 blocks with 50 camera pairs in 45 days. Recommended camera trap configuration for protected areas is given in Table 2. Camera trap configuration for corridors and protected forests should be designed in a similar way. Care should be taken to retain additional five pairs of camera per block as replacement in case of theft or damage.

In low-density areas, trap distance (grid size) may be reduced and/or the number of sampling occasions be increased, if the availability of resources permits.

Based upon logistics, man power and camera constraints, number of sample blocks may be increased further than recommended in Table 2 (especially in case of Chitwan National Park and Bardia National Park), but care should be taken not to exceed the closure period of maximum of 60 days.

3.1.2 Field methods

The manual by Karanth and Nichols (2002) gives a detailed description of camera trap design for estimating tiger abundance. As explained in Royle *et al.* (2009), camera trapping can be done in shifting blocks.

Systematic grids of 2x2km should be overlaid across the survey area and a pair of camera traps to be placed in each grid. It is advisable to replicate the surveys in the grids used in 2013 for a better comparison purpose. Camera trap stations should be selected in areas with high frequency tiger movement, which can be identified, based on the signs such as pugmarks, scrapes, scat or urine smell during field surveys prior to the placement of cameras. Generally, such signs are found along forest roads, river and stream beds, ridge lines and trails that are frequently used by tigers. New travel routes may be constructed, at strategic points, in areas without forest roads, fire lines or other natural travel routes by clearing vegetation to ease



Figure 2: Protected areas in Terai Arc Landscape

placement of cameras. Camera pairs should be set 6 - 10 m apart, 45 - 60 cm above ground, focusing on the animal trail in between the cameras. In case of white flash cameras, camera pairs should not face each-other straight to avoid the blank shots due to flash of opposite camera.

Owing to their comparative advantage over analog cameras, digital cameras should be used. But, as the technical capability of different digital cameras varies greatly care should be taken regarding their performance and associate risk of losing data. Hushson *et al.* (2010) found that photographic rates and number of species detected by motiontriggered cameras can vary significantly even among identical models, which have important implications regarding data interpretation. So, camera devices of similar models should be deployed as far as possible.

To make cameras invisible from animals, camera traps should be camouflaged with natural vegetation and impression pads should not be made close to the camera stations (Wegge *et al*, 2004). If trap shyness is detected (tiger pugmarks showing avoidance of cameras), the camera device should be laid to and fro at 50 - 100 m distance at each trapping station. Likewise, the cameras can be set shortly before dark and removed in the early morning to avoid the problem of theft.

The basic procedure for setting up the camera trap follows the manual by Karanth and Nichols (2002). However, basic adjustment should be done by considering the field conditions. Based on previous survey experience, the following action points should be considered while carrying out camera trap surveys (adapted from WCS and modified for digital camera traps):

- Give distinct numbers to all the equipment (cameras) to help track its performance and to troubleshoot.
- Each trap station should have a unique location ID and be GPS-referenced.

- Field notes should be maintained and should contain detailed information on troubleshooting, battery change details, location change, trap shyness, exposures per day, etc.
- In case of fixed camera stations (fixed for continuous 15 days), camera traps have to be checked every second day to ensure their effective functioning.
- In case of daily set camera traps (to avoid theft), should have a clap shot each day during set-up, with date, exact time and location on slate. This also serves as a test shot to ensure equipment is working (check if both cameras fire), and to correct recorded time in case the camera trap's clock loses time (i.e. falls behind) during operations.
- Record the number of events, date and time of all events in the time zone.
- Ensure that camera date imprint mode is set to date and time in 24-hour mode (e.g. 24; 19:26).
- Every day check to ensure that time on camera is correct, and reset if necessary.
- Do not change camera/equipment number when shifting from one location to another; and
- The time zone, if available, may be set to start at dusk and end at dawn, particularly in areas with substantial movement of humans, cattle or non-target wildlife.

Even minute actions that have been implemented in the field should be recorded in detail in field logbooks. Any misinterpretation or confusion can seriously violate population estimate in the analysis phase. Hence, care should be taken to record details of camera performance in the field. Data sheet for camera trap location details is given in Annex I and for camera trap details is given in Annex II.

3.1.3 Frequency of monitoring

The source populations of tigers (tigers in PAs) should be intensively monitored.

Population density of tigers: Inside the PAs, tiger abundance and density should be monitored every two to four years. But in the following cases, tiger abundance and density should be monitored annually:

 In case of low density areas and high poaching prone areas; and

In case of corridors and protected forests.

- Occupancy of tigers in lowlands areas (PAs) should be carried out every two to four years.
- Photo registration of tigers: Pictures of individual tigers obtained by camera traps or by regular cameras should be maintained in the form of a photo identity album. Records should be kept of the location, condition (breeding status, injury, etc.) and associated tigers whenever a tiger is sighted/photo trapped. This will provide crude data on ranging patterns, demography and mortality. This information should be shared with anti-poaching and authorities working to halt wildlife trade so that the origin of poached tigers can be traced.
- Tiger pugmark and other signs: Regular monitoring of tiger signs (pugmark tracings, plaster casts, etc., Figure 3) should be carried out at every guard post at weekly interval with monthly compilation of data. Sign surveys and individual tiger monitoring should become a regular task of every guard post. The monthly data should be mapped and maintained to analyze trends.



Figure 3: A typical tiger pugmark

3.1.4 Data analysis

Tigers should be identified at individual level after rigorous examination of the unique stripe patterns on the flanks, limbs and forequarters in each tiger photograph (McDougal 1977; Karanth 1995; Jhala *et al.* 2008). Individual tigers can be unambiguously identified with their distinct different stripes patterns obtained in the photographs (example is illustrated in Figure 4).

Tigers should be identified by three observers independently. For large dataset (especially Chitwan and Bardia) Extract Compare or other pattern recognition software should be used to cross check the accuracy of the manual tiger identification. Capture histories of individual tigers should be generated as required for different software packages. Only animals that are classified as adults (>2 years old that had dispersed from natal territories) should be included in the capturerecapture analysis. No formal test for population closure need to be carried out because our

Individual identification





Legs stripes pattern to identify same animal

Figure 4: Individual tiger identification with different strips patterns

sampling period is less than or equal to 60 days for each site, which is small relative to the life span of a tiger. Hence we assume that the sampled population is demographically and geographically closed over the sampling period.

The following software programs can be used to analyze the data for better comparison of output:

- CAPTURE (Otis *et al.* 1978; White *et al.* 1982; Rexstad and Burnham 1991);
- SPACE CAP package Version 1 (Gopalaswamy *et al.* 2012), and
- Program DENSITY (Efford 2009).
- 'secr' package (Efford et al. 2016)

For analysis using the CAPTURE program, a capture history for each individual tiger should be developed in an X-matrix. Given the relatively high mortality and dispersal rates of wild tiger populations (Sunquist 1981, Smith 1993, Kenny et al. 1995, Kerley et al. 2003), closure test should be implemented in the CAPTURE program (Rexstad and Burnham 1991). Program CAPTURE 2 also provides a statistical test for the assumption of population closure. With the CAPTURE program, all possible models allowing for the major sources of variation should be evaluated: Models Mt, Mb, Mh and their combinations. Model selection should be guided by the discriminant function test that scores all plausible models between 0.0 and 1.0, with a higher score indicating a relatively better fit of the model to the set of observed capture histories.

SPACECAP program version 1.0 (Gopalaswamy *et al.* 2012) is a user-friendly software package that implements a Bayesian spatially explicit capture recapture (SECR) analysis (Royle *et al.* 2009). The advantage of SECR models in SPACECAP, unlike the conventional approach in CAPTURE, is that indirectly estimates animal density by explicitly using information on capture histories in combination with spatial locations of captures under a Bayesian modeling framework. This makes it possible to substantially deal with problems posed by individual heterogeneity in capture

probabilities in conventional capture-recapture analyses. It also offers non-asymptotic inferences, which are more appropriate for small samples of capture data typical of individual-capture studies, which is highly suitable for some of our study sites. The SECR models also have capability to address the issue of geographic closure (Royle *et al.* 2009).

With SPACECAP, three different types of input files (Animal Capture Detail file, Trap Deployment Details file and Potential Home Range Center file) are generated (Gopalaswamy et al. 2012). To create a potential home range center (activity center) file for each of the protected areas, mean maximum distance moved (MMDM) by tigers should be calculated by creating a minimum convex polygon (MCP) for each tiger. To define the state space S with in which activity centers for animals exposed to camera traps are likely to be located, twice MMDM should be used to create a buffer surrounding the camera trap polygon. Potential tiger activity centers should be represented by regularly spaced points at 580 m intervals representing an area of 0.3364 km² (Gopalaswamy et al. 2012).

Given that a number of these points could be located in non-tiger habitat areas (e.g. settlements or agriculture), the land use map should be overlaid to delineate habitat assigning the value (1) for tiger habitats and value (0) for non-tiger habitats. Files with this information should be used in SPACECAP version 1.0 under program R environment for analysis of the tiger population and density estimation.

Similarly, the DENSITY program (Efford *et al.* 2004; Efford 2009) or package 'secr' in R can be used to analyze the maximum likelihood-based SECR estimates (Brochers and Efford 2008; Efford 2016). Unlike the conventional CAPTURE method, DENSITY estimates both the population abundance and density. Three files (Animal Capture Details, Habitat Mask and Camera Trap Details) need to be created and analyzed to estimate population and density.

3.2 Estimating tiger prey-base

3.2.1 Survey design

Distance sampling based line transect survey has been widely used to estimate density of dispersed wildlife populations like deer and other prev species of tigers. Line transect survey is preferred for population abundance estimation through visual detection of animals (Anderson et al. 1979; Burnham et al. 1980; Buckland et al. 1993: Lancia et al. 1994: Buckland et al. 2005). Major drawback of this method is that it is useful only in the flat and open areas but violates many assumptions in undulating terrain. The method involves observers moving along straight trails called 'transects', counting animals seen on either side. When conducting transects for analyzing the data in the framework of Distance sampling, observers use range finders and compasses and measure the distance and angle from transect to the animals that are seen. During analysis, these

counts and associated distance data are used to generate detection probabilities and derive density estimates. Although the mathematical complexity underlying distance sampling models may appear formidable, essentially these models also compute sighting probabilities to estimate the animal abundance (N) in the sampled area from the counts (C) obtained in the survey. Because size of area sampled is incorporated into the estimation process, density can then be estimated directly, as opposed to the separate estimation of abundance and area sampled in capture-recapture sampling designs.

The strata for each PA include Parsa Wildlife Reserve (two strata: Churia and the lowlands), Chitwan National Park (two strata: Churia and the lowlands), Banke National Park (two strata: Churia and the lowlands), Bardia National Park (two strata: Karnali flood plains and the Babai Valley), and Shuklaphanta National Park (two strata: the core area and the extension area) (Table 3).

Transect Parameters	Parsa Wildlife Reserve	Chitwan National Park	Banke National Park	Bardia National Park*	Shuklaphanta National Park
Transect distance (km)	1-2	1-2	1-2	1-2	1-2
Spatial replicates	147	261	75	219	82
Temporal replicates of each transect	Temporal 2 replicates of each transect		2	2 (in case of 2 km long transect), 4 (in case of 1 km long transect)	2
Total km	286.5	497.7	333.7	397.7	154

Table 3. Prey Line Transect Surveys for Individual Protected Areas (based on Tiger Survey, 2013)

*The very steep terrain in Churia Strata requires the transect length to be no more than 1 km to maintain a straight line. In this case, because the transect length needs to be shortened relative to the others (2 km) and because of an expected lower prey encounter rate, the temporal replicates should be increased.

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3.2.2 Field methods

Each study site to be surveyed should be thoroughly explored to get a preliminary idea of the topography and relative animal densities in different parts of the study site (Karanth and Sunguist 1992; Kumar 2000). The transect alignments should be chosen to representatively sample the area using systematic placement of transect lines (Burnham et al. 1980). Line transects should be systematically placed in all 2 km x 2 km grid cells except in grid cells with undulating and hilly terrain so as to adhere to the straight line assumption of distance sampling. Length of transects could vary from 1.5 to 2.0 km. GPS locations of the start and end points of each line transect could be uploaded into a GPS prior to survey and the straight line navigation could be done following the actual bearing using a liquid filled compass and GPS. These straight transect lines should be cleared and, if necessary, cut and marked clearly, using painted tags or enamel paint or both, on tree or stone. Based on field conditions, the survey should be planned for after the winter season (normally after late burning). Care should be taken that a line transect is not located near a busy road; neither should it run parallel to a river or other features of the landscape, which may bias sightings of ungulates.

Two trained observers should traverse the transect line on foot or on elephant back (Wegge and Storaas 2009) counting prey animals observed on either side of the line. The sample counts should be done in early morning (06:00 - 10:00 based on season) or in late afternoon (15:00 - 18:00) when prey animal species are most active.



Figure 5: Data to be recorded while walking in the transect during prey survey

For each observation, the species, number of animals, the radial sighting distance to the animal and the sighting angle between the transect line and the centre of the animal cluster and animal behaviour upon and after the detection (to assess flight response bias in calculating the effective strip width) should be recorded (Figure 4). The sighting distance should be measured with optical or laser range finders (15 m - 400 m range), or both, and the angles should be calculated from the azimuths (bearings), recorded using a liquidfilled compass as detailed elsewhere (Karanth and Sunguist 1992; Kumar, 2000). To achieve adequate level of sampling effort, trained volunteers or wildlife technician or researchers, or a combination of them, should collect the field data from line transect survey. At each site, two field assistants should carry out the field survey. It is necessary to mark the straight transect lines beforehand in areas with dense vegetation for sampling on foot, but care should be taken to avoid excessive clearing of vegetation, which can influence animal distribution and artificially inflate visibility along the transect line.

The following information should be recorded on a standard datasheet (Annex III):

- GPS location of the start point of each transect
- Bearing of the transect
- Species identified from direct observation: chital, sambar, wild boar, barking deer, hog deer, swamp deer and nilgai.
- Group size (cluster size of each detection)
- Age and sex composition (age: adult, subadult, yearling, young; and sex: male or female) was recorded when observations are adequate
- GPS location of individual (or group) sightings
- Bearing of the animal clusters or individuals using a liquid filled compass
- Sighting distance from the observer to the animal cluster or individual using a laser range finder.

3.2.3 Frequency of monitoring

Prey species inside PAs should be monitored every two to four years. But in case of low density areas, high poaching prone areas, corridors and protected forests, prey species should be monitored annually. The survey should be completed within two months to maintain similar detection conditions at the various sites.

3.2.4 Data analysis

The line transect data should be analyzed under the distance sampling framework using the DISTANCE program (Burnham *et al.* 1980; Buckland *et al.* 1993; Buckland 2001; Thomas *et al.* 2010). The following two approaches should be used:

- pooling data for all species for fitting an overall global detection function for all species in the sampling area and
- b. fitting detection functions at species level for individual species with sufficient numbers of detections.

In order to model detection functions, appropriate modifications should be made so as to ensure liable fit of key functions and adjustment terms to the data in Akaike Information Criterion (AIC) and Goodness of Fit (p) tests should be used to judge the fit of the model. Using the selected model, estimates of group density (Dg), group size (Gs) and individual density (D) should be derived.

3.3 Estimating habitat occupancy by tiger and preybase across Nepal

3.3.1 Survey design

The basic conceptual framework for this survey design is provided by Williams *et al.* (2002) and Mackenzie *et al.* (2006). The goal of these surveys is to measure the 'true habitat occupancy' in order to be able to monitor relative abundance and distribution changes in multiple years. The basic sampling design can be described as follows:

- Given the size of the study area to be sampled (human resources, logistics, etc), sign-based surveys should be conducted for determining the occupancy patterns of tiger occupancy and relative prey abundance throughout Nepal (Fig. 6).
- There should be 100 per cent coverage of entire areas with suitable tiger habitat

for mapping actual tiger occupancy and relative prey abundance on the ground. It is uncertain whether suitable covariates extrapolating of tiger presence data can be extrapolated from surveyed cells to unsurveyed ones. Therefore, all grid cells with potential tiger habitat should be surveyed.

Occupancy surveys that aim to estimate the true habitat occupancy of tigers should be derived from the sampling units (e.g. grid cells) that reflect the home range size of a male tiger (approximately 150-200 km² in South Asia). A grid size of 225 km² (15 km x 15 km; Fig. 7) should be used as the sampling unit because this area will be sufficiently large to capture an average male tiger's home range and allow occupancy to be estimated within the PAs. In order to keep the grid standardized across the landscape, this grid cell size should also be used outside the PAs. An important reason for maintaining a standard grid cell size is to allow for the potential extrapolation of



Figure 6: Major and sub-grids for Tiger and prey base monitoring in lowland Nepal

tiger densities from inside PAs to outside PAs in areas of similar substrate or habitat type and tiger sign encounter rate.

- Given the size of the study sites, there will be a total of 96 grids (based on 2013 tiger survey experience) in the potential tiger habitat of Nepal to be surveyed, consisting of at least 10% of habitat coverage (Figure 6). The logic is that tigers cannot "live' in patches smaller than 20-30 km², although they may occasionally pass through them.
- Each grid should be labeled with a unique identity (Grid ID) for data management. A grid system covering the entire potential tiger habitat of Nepal (inside and outside the PAs) has already been developed and being used for large-scale tiger and prey monitoring survey.
- The survey should record signs of tigers (and tiger breeding) and principal ungulate prey species simultaneously to increase efficiency and reduce costs. Evidence of human presence (and associated impact such as cattle, grass cutting, wood lifting, etc.) should also be recorded along the ground survey to serve as covariates. Geographical covariates should be generated from both ground survey and remote sensing maps.
- Part of the tiger scats should be collected and geo-referenced. Half of the scat should be retained for diet analyses and the other half should be retained in case DNA analyses are later desired and permitted.
- To include an element of randomness in the spatial distribution of survey routes, each grid cell should be divided into 16 sub-cells of equal size (3.75 km x 3.75 km) (Figure 7), and one sub-cell per grid cell coded as tiger habitat should be randomly selected prior to the survey (Karanth et

al. 2008). This sub-cell should at some point during the occupancy survey of the grid cell be traversed by the team. The number of spatial replicates per grid cell (i.e. km walked) should be proportional to the percentage of tiger habitat (Karanth *et al.* 2008). For grid cells with 100% tiger habitat, 40 km should be sampled in the cell touching a random grid in every sampling route. Each contiguous 1 km segment should be considered a 'spatial replicate' (Barber-Meyer *et al.* 2013; Hines *et al.* 2010).

- The survey should be repeated once every two to four years to obtain multiple season data to be used in estimating population dynamics of tigers and prey using multiseason models. Such models allow us to estimate the rate of local extinction and colonization between sampling periods, in addition to probability of occupancy and detection parameters.
- Minimum tiger abundance outside the PAs should be assessed by evidence of the presence of a tiger in a grid cell equaling minimum of one tiger.



Figure 7: Dimensions of one grid cell with 16 sub-cells

3.3.2 Field methods

- The field team should move along trails, roads, ridge lines and river and stream beds in selected sub-cells, searching for tiger signs (scats, scrapes, pugmarks, kills and urination sites), prey signs (dung, footprints, calls and sightings), and human disturbance (wood cutting, lopping, grazing, poaching etc.) following high probability tiger sign areas (Barber-Meyer et al. 2013). To provide an element of randomness to the grid the team should traverse through the random cell that has been designated for them before the survey. The searching effort should be equal among teams. For grid cells with 100 per cent of tiger habitat 40 km should be traversed; for a cell with an estimated 50 per cent of tiger habitat 20 km should be traversed, etc.
- Each team should record each direct sighting of all study species. For tigers, each instance of new sign (e.g. not each pug mark in a long continuous trail) should be recorded (including scratch marks, tracks, scat, spraying and sightings) as well as a 'yes/no' for tiger signs every 100 m of each 1 km replicate should be recorded. For prey in case of calls heard, tracks, pellet or dung piles, only the first encounter of each such evidence within each 100 m of each 1 km replicate should be recorded. Each team should also record any signs of human presence. Records of human presence will serve as covariates.
- In order to estimate tiger and prey detection probabilities and then to incorporate these probabilities into tiger and prey occupancy estimates, each grid needs to be surveyed for tiger and prey signs (e.g. pugmarks and scats) more than once. As an alternative to temporal replicates, each 1 km segment along the sampled areas could be treated as a 'spatial replicate'.

- To reduce heterogeneity of detection probability for tiger and prey signs among grid cells, the number of replicates per grid cell should be proportionate to the extent of tiger habitat in each grid. However, each grid cell should have at least four replicates of 1 km walks each.
- As circumstances dictate, the measurement of 1-km walks should be based on a combination of GPS odometer and hipchains.
- To maintain consistency in data collection, each team should be supplied with standardized datasheets (as given in Annex IV), a manual, a label card and a card for animal sign identification.

3.3.3 Frequency of monitoring

The survey should be completed within six months (preferably within three months) to maintain similar detection conditions at various sites across potential tiger habitat in Nepal. Survey in entire landscape should be repeated once every two to four years to obtain multiple season data to be used for estimating population dynamics of tigers and prey using multi-season models. Such models allow us to estimate the rate of local extinction and colonization between sampling periods in addition to probability of occupancy and detection parameters. Repeated surveys in different seasons of the same year can be used to detect the areas where breeding tigers exist in the landscape. If tigers occupy the area throughout the year, it can be considered as residential or breeding tiger (Barlow et al. 2009).

3.3.4 Data analysis

Using the PRESENCE program (Hines 2013), a logistic regression analysis (incorporating detection probability) should be performed to obtain unbiased estimates of the factors that influence tiger and also tiger prey occupancy. This program implements the maximum likelihood approach of site occupancy models (MacKenzie *et al.* 2002; MacKenzie and Kendall 2002) and also permits the inclusion of the influence of site and sampling co-variates. In addition to providing estimates of site occupancy (proportion of sampled area in which tigers occur) and detection probability, these models also allow occupancy to be modeled as a function of environmental and anthropogenic covariates that were sampled along trails or derived from remotely sensed data. This helps to ascribe underlying causes for observed heterogeneity in site occupancy and detection between sampled cells.

Single season model should be run to estimate the parameters: proportion of area occupied (ψ) and detection probability (p). A number of models fitted to the observed data with the covariates: human disturbances (H), prey (P) and observer experience (O), and ranked by their AIC values to determine the most parsimonious model (Hines *et al.* 2010; Hines 2013; Barber-Meyer *et al.* 2013).

Covariates should be divided into: l) human activities to evaluate the influence of human activity on the probability of occurrence of tigers and prey, 2) geographic factors to evaluate the influence of environmental characteristics on the probability of occurrence of tigers and prey, and 3) a further group of covariates should be developed based on prey status and distribution as they relate to tiger occurrence.

A number of models can be fitted to the observed data and ranked by their AIC values to determine the most parsimonious ('best') model (Burnham and Anderson 1998), the model with the lowest AIC value and with the fewest number of parameters

is usually considered to be the most parsimonious model that best describes the data.

If there are a large number of potential models with similar AIC values, then multi-model inference techniques can be used to investigate the influence of covariates and determine parameter estimates (Burnham and Anderson 1998). Such analyses can be used to draw: l) the distribution of tiger and prey; 2) the influence of covariates on tiger occupancy and prey relative abundance (including the influence of prey relative abundance on tiger occupancy); 3) temporal changes in tiger occupancy and prey relative abundance; and 4) distribution and changes in tiger reproduction (assessed by tiger cub pugmarks).

Additionally, if areas of high tiger sign encounter rates outside of PAs are recorded during this survey, camera trapping should be considered in those areas.

3.4 Assessing human impact on tiger habitat

To quantify the anthropogenic impact on the tiger and its habitat, including prey, disturbance factors should be assessed in the same grid on which habitat occupancy surveys are conducted. Disturbance factors should include grazing pressure, encroachment, forest fire occurrence and intensity, illegal felling or lopping of trees, or both, counting of cattle dung piles and any other human disturbances, including evidence of poaching. Datasheets should record number of sign of lopping, wood cutting, presence of human or livestock foot trails, and number of snares. Standard datasheet is given in Annex V.

4 Data Sharing

The data should be maintained at three tiers: field, intermediate and central level. At field level, raw data should be maintained at parks and district forest offices. At intermediate level, both raw and compiled data should be maintained at regional forest directorates, project offices, universities, consultancies and NGOs. Compiled data should be maintained at central level (i.e. DNPWC). Mechanisms will be in place for sharing data maintained at the DNPWC with the DOF and vice versa. Individual researchers or consultants and NGOs must maintain and/or share data at individual park level or central level, or both.

In addition, a tiger photo identification database should be made available to facilitate transmittance of information as well as tracking the origins of poached tigers.



5 Future Direction

Molecular genetics has developed methods of DNA analysis of both invasive and non-invasive samples that allow the identification of each individual in a population. The genotypic identification of individual tigers is usually achieved by using polymorphic microsatellite loci to increase the amount of variation between individuals (Linkie *et al.* 2010).

Considering the recent developments in noninvasive molecular method of genotypic identification of individual tigers, genetic surveys could be an alternative/supplementary method in the future to monitor the tiger.

As tigers mostly use roads and trails and regularly mark their territories by depositing feces/scats and spray urine, fresh tiger scats can be searched along the roads and trails. The following methodology can be followed:

- Each road or trail should be sampled only once to avoid recaptures and maximize the number of different individuals in any of the area covered.
- Scat samples should be stored in silica gel or in absolute ethanol.
- DNA should be extracted from the scat samples using commercially available QIAamp DNA Stool mini kit (QIAGEN Inc.) following the manufacturer's instructions with slight modifications.
- Around 180-200 mg of sample from the outer parts of the scats should be used for each extraction. Ensure to leave at least half the mass of scats at its original place.
- The first overnight incubation should be conducted at room temperature with 1 ml ASL buffer, followed by a second incubation at 65°C for 60 min.

- DNA Elution should be done with 120 ul of TE buffer (pH 7.8). Species identification should be done by tiger specific target amplification on Cytochrome b gene in mitochondrial DNA.
- 10 microsatellite loci should be used for genotyping tiger samples and individual tiger identification (Mondol *et al.* 2009).

All the genetic analysis of the tiger samples should be done in Laboratory of NTNC-BCC, Agriculture and Forestry University, Rampur and National Academy of Science and Technology (NAST), Kathmandu.



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Annex I: Datasheet: Camera Trap Location Details

Block Id:	Group No:	GPS No:	Team Leader:
Group Members:			

Date Deployed: Date Ended:

S.N.	Camera ID	GPS Location		Site name	Habitat Type	Elevation	Terrain≠	
		Northing	Easting		*(Major five species ranking or scoring from 1 to 5)**			

***Habitat Type:** SF - Sal Forest, MF - Mixed Forest, RF - Riverine Forest, TG - Tall Grassland, SG - Short Grassland, W - Wetland, S - Streamed

**Species Ranking on the basis of dominance: 1-Highly dominant, 2-moderate, 3-dominant, 4- less dominant, 5-very poor dominance

≠Terrain: Hilly, Flat, Undulating

Annex II: Datasheet: Camera Trap Details

Block Id:	Group No:	GPS No:	Team Leader:
Group Members:			GRID ID.

Trap Day	Date	Camera ID	SD Card ID	Time	Exposure Details		etails	Remarks (Trap Response)
	<u> </u>	<u> </u>	<u> </u>		SE	EE	TOTAL	
1		А	А					
		В	В					
2								
3								
4								
5								
6								
/								
8								
9								
10								
10								
11								
10								
17								
15								
1/								
14								
15								
CT								

Annex III: Datasheet: Line Transect Survey

Observer:	Block No:	Grid No:	Transect No:
Transect Bearing:	Location Name:	Weather:	Habitat Type
Start GPS: E	Ν	End GPS: E	Ν
Date:	Start time:	End Time:	

SN	Time	Species	м	F	Y	Unld	Total No	Animal bearing	Angular sighting Distance	Habitat Type (two major species)	GPS
											N: E:
											N: E:
											N: E:
											N: E:
											N: E:
											N: E:
											N: E:
											N: E:
											N: E:
											N: E:
											N: E:
											N: E:
											N: E:

Habitat type: SF - Sal forest, MF - Mixed Forest, RF - Riverine Forest, TG - Tall Grassland, SG - Short Grassland, W-Wetland, S - Streamed

Annex IV: Datasheet: Species Occupancy Survey

Name of the observers:			Location name:	Date:			
Start Time:		Grid ID:	Start GPS lo Easting: Northing:	cation		End GPS loca Easting: Northing:	tion
End Time:							1
Segment	Stream courses/ Nala/Forest trails	GPS location	Species	Sign Type/ Direct Sighting (No)	Forest Type	Terrain Type	Remarks
		E:					
		N:					
		E:					
		N:					
		E:					
		N:					
		E:					
		N:					
		E:					
		N:					
		E:					
		N:					
		E:					
		N:					
		E:					
		N:					
		E:					
		N:					

Note:Carnivore species:Tiger, Leopard, Sloth bear, Hyena, Wild dog, Jungle cat, Jackals, Civets, Mongoose, other cat
speciesUngulate Species:Chital, Hog deer, Swamp deer, Gaur, Sambar, Wild pig, Barking deer, Hare, Four horned
antelope, Rhesus macaque, Langur, Porcupine, Elephant, Cattle, Goat, UnidSign types:Scats/Faecal matter, Dung, Pellet, Pugmark/Footprint, Scrape marks, Kills, Body partsForest types:Sal Forest/Riverine Forest/Grassland (short/tall)Terrain types:Flat terrain/Foot hills/Churias/River bed/

Annex V: Datasheet: Human Disturbance Survey

Nam	Name of the observers:		Location name:		Date:					
Start Time: Grid ID		Grid ID:	Start GPS location Easting:		End GPS location Easting:					
End	Time:		Northin	g:		Northing:				
Segment	Wood cutting (No of trees cut)	Lopping (No of trees lopped)	Tree felling (Stump count)	Presence of temp construction (Y/N) Number	Presence of human/livestock/ tractor trails (Y/N)	People seen	Livestock seen/ grazing (Number)	Presence of permanent construction (Y/N) Number	Others	Remarks

Note:

Temporary construction (huts, poacher's camp, hunting machan, illegal settlers, logging camps, picnic camps)

Others: Gun shot heard, snares found, fishing, poisoning

Annex VI: Pictures of frequently camera trapped animals



Camera trapped prey species from top left: Barking Deer, Gaur Bison, Nilgai, Sambar Deer, Spotted Deer and Wold Boar

Annex VII: Equipment List

Came	era Trap Surveys
1	Digital camera traps
2	GPS
3	Memory cards
4	Cat lure
5	Batteries
6	Maps
7	Tents
8	Sleeping bags
9	Mattress
10	Utensils
11	Bicycles
12	Personal field gear (Jackets and Shoes)
Dicto	nce Samplings
Dista	ice Samptings
1	GPS
1 2	GPS Range finders (optical/laser)
1 2 3	GPS Range finders (optical/laser) Compass
1 2 3 4	GPS Range finders (optical/laser) Compass Hip chains
1 2 3 4 5	GPS Range finders (optical/laser) Compass Hip chains Maps
1 2 3 4 5	GPS Range finders (optical/laser) Compass Hip chains Maps
1 2 3 4 5 Occup	GPS Range finders (optical/laser) Compass Hip chains Maps pancy Surveys
1 2 3 4 5 Occup 1	GPS Compass Hip chains Maps GPS GPS GPS
1 2 3 4 5 Occup 1 2	GPS Compass Maps GPS GPS GPS GPS GPS Compass
1 2 3 4 5 Occup 1 2 3	GPS Range finders (optical/laser) Compass Hip chains Maps pancy Surveys GPS Compass Hip chains
1 2 3 4 5 Occup 1 2 3 4	GPS Range finders (optical/laser) Compass Hip chains Maps pancy Surveys GPS Compass Hip chains Maps
1 2 3 4 5 Occup 1 2 3 4 5	GPS Range finders (optical/laser) Compass Hip chains Maps pancy Surveys GPS Compass Hip chains Maps Still digital cameras
Dista 1 2 3 4 5 Occul 1 2 3 4 5 4 5	GPS Range finders (optical/laser) Compass Hip chains Maps pancy Surveys GPS Compass Hip chains Maps Still digital cameras Tape measurer

Annex VIII: Camera trapping grids map



a. Parsa Wildlife Reserve

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c. Banke National Park



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