Assessment of a Framework for Monitoring Tiger Population Trends in India

A Report to the IUCN: World Conservation Union and India's Project Tiger

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Executive Summary

There are few examples of projects of this magnitude -- not just geographically, but in terms of labor and scope of data collection -- to estimate trends in populations of a rare and elusive species like tigers (*Panthera tigris*). Implementation of projects of this scale is bound to be fraught with issues of consistency. Given that this a first attempt at implementing this methodology across the entire country, the issues are surprisingly few. Substantial effort has gone into preparing data collectors to anticipate and implement a change in methodologies, and to help them develop ownership of this new methodology.

Our observations are meant to assist WII and Project Tiger in bettering the **Framework for Monitoring Tiger Population Trends in India**. Though we present suggestions for improving data collection and analysis, are intent is not to be critical. WII and Project Tiger have made significant steps toward improving tiger population monitoring in India.

Summary of key points

1) The implementation of the **Framework for Monitoring Tiger Population Trends in India** is immense in scope. Transparency and efficiency in implementation would have been facilitated significantly by preparing a *detailed* plan of activities, explaining the logic of the approach, listing the questions the data would be used to answer, and explicitly outlining the timeframes for completion of activities. There is also no detailed write-up of the technical analysis, *explicitly* identifying the analytical techniques to be used each phase of the Framework. These documents are essential for tiger monitoring in India to transform from the local, expert-based monitoring system used previously to a national science-based **Framework for Monitoring Tiger Population Trends in India** for the future.

2) Project Tiger took valuable steps to include national and international observers in the process for the developing the **Framework for Monitoring Tiger Population Trends in India**. Observers will bring insight into how the on-the ground and the other aspects of the Framework could be designed and implemented. The fundamental success of the Framework lies with the integrity of the primary data collectors, data compilers, and their supervisors. Phase I results will be cross-checked by WII/Project Tiger teams in Phase III. Discrepancies in the data obtained in Phase I and through the cross-checking exercise in Phase III can be used to estimate the error in the all Phase I data. However, methodology to consider the implications of error was not described in any documentation we received on the Framework. Explicit consideration of error (e.g., such as through sensitivity analyses), at all phases of data collection, would strengthen the efficacy of the results. Similar analyses could be conducted to explore the implications of using different probability cut-off values for high, medium and low habitat-use classes.

3) Issues that arose with data collection were related to clarity and completeness of instructions and manifested as issues related to consistency of data collection across jurisdictions and across individuals collecting data. The issues that we noted are described below.

4) We assume that the discrepancies in collecting tiger track data and how series of tracks are recorded as different individuals are dealt with by converting the beat sampling-level data to presence/absence data. If there are further applications for the data, this discrepancy will be a **significant source of error** in estimating tiger abundance.

5) We do not think the present methodology is adequate to estimate population levels or trends for dholes (*Cuon alpinus*), nor for distinguishing between bear species where Asian black bears (*Ursus thibetanus*) and sloth bears (*Melursus ursinus*) overlap in their distribution.

6) There was individual variation among data collection teams in applying the methodology (7) for ungulate pellet counts. This variation may be difficult to account for if using this data for density calculations.

7) There was substantial individual variation among data collections in applying the methodology (7) for vegetation sampling. Sources of variation were related to vagaries in how to record canopy cover, dead trees, stumps, and weeds. Clarification on these aspects of data collection could be provided in the manual. Primary data collectors may also benefit from more focused training on vegetation sampling.

8) There was individual variation among data collectors in applying the methodology (7) for transect location and use. We noted several substantive issues with variation in data collection detailed below. While errors are to be expected in a project of this size, it may be possible to help reduce the number of errors by providing supervisors with a checklist for double-checking transects. We noted that all transects were double-checked by supervisors. This provides an excellent opportunity for quality control of data. Uttaranchal has already developed a checklist system that might serve as an example. Their system could be modified further to consider the most commonly committed errors in setting up a transect line.

9) We were concerned about the variation in the number of people who comprise teams of data collectors. One of the major assumptions of all tests that will be performed on these data is that the probability of finding a track, pellet or animal, is related to the habitat type, and to not the search effort. The number of primary data collectors should be considered in any explanatory variable in model for animal density.

10) We reviewed some of the data that had been sent to WII and noted that there were some areas that were surveyed and that did not have forests, but had tigers recorded as present. We were unable to validate these sites and flag them as suspicious. We are unable to make further comment on the authenticity of the data.

11) We did not see a specification of statistical power to detect trends, or projected confidence intervals on tiger population estimates.

12) We observed that data collectors did not record tracks if the species was not clearly identifiable. This situation might arise where there were only partial tracks. This raises the issue of having false negatives, or beats recorded as "zeros", where no tiger was

found but may still be presents. The approach described for the Framework, and outlined below, does not deal with false negatives.

13) We recommend that WII scientists consider a use/availability design such as described in (14), rather than a presence/absence design. In this approach, tiger presence is coded as a one. The 'ones' are then considered against a random sample of all the sample units (or all sample units), or against a set of points representing 'availability' of resources. The available points, regardless of tiger presence, are then coded as 'zeros' and used in a logistic regression with the 'ones'. The intercept is dropped from the resulting algorithm because the sampling fraction cannot be estimated. This produces a relative probability, rather than an exact probability (or a resource selection function instead of a resource selection probability function). However, the relative probabilities can still be binned into high, medium, and low classes (most often through a quantile function). K-fold cross validation is used for model validation in this approach. Once densities have been determined using a mark-recapture framework in selected areas as per Phase III, reference (15) describes an approach that can be used to extrapolate densities to the entire country from the resource selection functions.

14) An assumption of the proposed explanatory models is that, apart from issues related to density, the probability of finding tiger sign must be the same from sampling unit to sampling unit. That is, the probability of tiger sign occurrence should not be reflected in the search effort for tracks or other signs. There is flexibility in the study design for data collectors to search between 9 and 15 km of linear distance to detect tiger sign. This means that, all else being equal, there will be a higher probability of a tiger sign being found in sample units where more distance per area is searched.

15) We recommend using an area-corrected method of specifying transect line length for each sampling unit. In the 2006 modeling exercise, it may be valuable to consider using a ratio of the length of transects sampled to the area in the sampling unit as a covariate in the modeling process. This will help assess bias created by having variable search effort in sampling units.

16) A substantive deficiency we noted in the **Framework for Monitoring Tiger Population Trends in India** is the absence of tiger mortality monitoring. While data appears to be available in forest guard records and records at higher administrative levels, we did not see evidence of an explicit methodology for analysis of this data or for incorporation of mortality data into the monitoring protocol. If habitat quality and prey densities are being monitored as a means to understand fluctuations in predator abundance, human-caused mortality probably plays a substantive role in tiger population dynamics. Populations of large carnivore can go and have gone extinct in habitats that have abundant food resources. Human-caused mortality should be monitored by tracking number of poaching incidents and number of human carnivore-human conflicts. Data should be spatially-explicit. These incident reports can become invaluable in the Framework. This information is critical for understanding the tiger population trajectory in the different landscapes and for providing targeted management recommendation to mitigate underlying problems with tiger population decline.

17) Without incorporation of group size into calculations of effective strip width for the distance sampling exercise, ungulate density estimates may be bias low.

18) During training, data collectors asked how to establish permanent transects in plantation forest, but did not receive a response from WII staff.

19) Vegetation data will be used to track the status of habitat and to map vegetation associations. Human disturbance data may be treated only as an explanatory variable for modeling animal densities, and as a variable used to monitor changes in human disturbance trends. While we are aware of what data will be used for, we have not seen explicit information on how vegetation or human disturbance data will be analyzed.

20) Recognizing that few researchers consider the implication of boundary selection on the inference that can be drawn, we emphasize, particularly given arbitrary selection of the grain of the attribute data (i.e., because of convenience as opposed to ecological phenomenon), that meta-population dynamics of the species should be a key consideration in analysis and reporting of population status.

21) Habitat connectivity and movement among populations are necessary for reducing the chance of species extinction. While acquiring better information on tiger densities, and modeling possible cause for fluctuations in tiger densities should be a primary activity for managing this species, understanding the meta-population dynamics and ecology of dispersal should be equally important.

22) There are several approaches for estimating connectivity probabilities for tiger populations. An explanatory model framework can be used to incorporate factors that influence tiger dispersal, including differential dispersal rates for tigers of various ages confounded by differential response to landscape attributes, tiger densities as it relates to land-cover types, reproductive and mortality rates, and human population densities or land-use patterns. We recommend the study of dispersal characteristics for tigers crossing various human-dominated landscape mosaics with their own characteristic tiger dispersal filter attributes be included as part of Phase IV. This is the least known component of tiger population dynamics. Formal studies have only been conducted in the Nepal Terai and in the Russian Far East but there are only a handful of antidotal observations from India to rely on. The technical details on how to estimate the probability of the connectivity between tiger populations should be made explicit, transparent, and peer reviewed.

23) The pugmark mark-recapture approach be treated as experimental and work continue during Phase IV to see if the method can be validated for low to medium tiger density areas. In the interim camera trapping has been shown to be an effective methodology to establish density estimates even for tigers living at very low densities (24, 25).

24) There are limitations to using the pugmark and genetic methods proposed in *Phase III* to augment the on-the-ground efforts in *Phase I*. The pugmark method was not meant to be used in low tiger density habitat. Genetic methods have not been fully developed for this application.

25) Most data collectors indicated that the Field Guide was very useful. Diagrams were helpful for interpreting the instructions for conducting transects and other measurement. Some data collectors felt that the Field Guide should have illustrations to help with identification and differentiation of ungulate pellets, specifically something to help scale the size of pellets.

26) Areas that have few resources for conducting the exercise should receive a disproportionate amount of training and attention from WII and Project Tiger Directorate. Despite limited resources, these areas were taking the exercise very seriously and working hard to make the exercise happen anyway.

27) While there were differences in the availability of resources (equipment, labor, and training) among jurisdictions, we could not determine how this would affect the data quality.

28) Data collectors reported that this method is easier than the previous method. Data collectors reported there is less pressure to find a pug mark, and they did not have to worry about identifying the gender or identity of the individual making the pug mark.

The Context for Monitoring Tiger Population Trends in India: Why this Assessment?

Despite the tiger's (*Panthera tigris*) ecological and social importance, there is a tension between tigers and people. As a consequence of this tension, wild tigers are endangered - *most tiger populations are critically endangered*. The vulnerability of tigers to extinction was first formally recognized in 1969 at the IUCN: World Conservation Union meetings in New Delhi. Demand for resources by expanding economies and populations are shrinking and fragmenting tiger habitat (19). Wild tigers are disappearing because of illegal hunting for their skins and bones to make clothing, home décor, and medicine (19). The tiger's prey base is also dwindling, largely due to illegal harvest, with cascading density-dependent effects on tigers (19). If present trends continue, tigers may disappear from the wild within decades or less.

India was among the first countries to act to change the downward trajectory that tiger populations faced. As first steps, India listed tigers on Schedule I as a fully protected species in the Wildlife Protection Act (1972), joined the International Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES), and launched Protect Tiger in 1973. The primary goal of Project Tiger (1) is: "To ensure the maintenance of a viable population of the tiger in India and to preserve, for all times, such areas as part of our natural heritage for the benefit, education and enjoyment of future generations." Project Tiger was a reflection of India's commitment to the future of the country and the species. In magnitude, Project Tiger was unlike previous conservation programs for the conservation of wildlife in Asia.

Since the inception of Project Tiger, the social and environmental context in which tiger conservation management occurs has changed. The historical methods used for censuring tigers have been demonstrated to be archaic and unreliable. Tools have improved for preparing and adjusting management systems to embrace emerging risks to tiger populations. Technologies and methodologies to monitor wildlife populations and land-cover with increasing statistical power, accuracy, and integration have vastly improved since the first scientific tigers studies. Further, our understanding of the ecological and life-history traits that make species, such as tigers, sensitive to human impacts has advanced substantially.

Tigers are considered a conservation-reliant species (2). Conservation-reliant species can maintain self-sustaining wild populations; however, they will require ongoing management actions because threats are pervasive, recurrent and put them at risk of extinction (2). The origins of these threats are rooted in the changing socio-economic, political and spatial organization of society in India. The societal forces coalesce to produce a landscape where tiger habitat and populations have been fragmented. Tigers become extinct in small fragments because of extrinsic factors such as pathogens, poachers, and catastrophic floods, fires, and droughts (10, 19). Tigers are at further risk because of intrinsic factors such a demographic stochasticity and genetic deterioration (10, 19).

Recognizing the conservation-reliance of the species, and keeping with the momentum for change in managing tiger populations, Project Tiger is transitioning to a national, science-based **Framework for Monitoring Tiger Population Trends in India.** The principal objective of the **Framework for Monitoring Tiger Population Trends in India** is to improve knowledge about the population status of tigers so that the species can be managed more effectively. Indeed, probability of success in reducing the risk of extinction can be improved by empowering conservation managers in three important ways:

1) By increasing the accuracy of the knowledge of the distribution and abundance of tigers and their prey so that conservation managers can precisely target and counter threats;
2) By increasing the understanding of the extent and character of the threats that create extinction risks for tigers so that conservation managers can precisely target and counter threats;
3) By diffusing this improved knowledge so conservation managers and conservationists can educate and engage key audiences and more effectively mobilize multi-sector support in efforts to secure a future for wild tigers.

As an example of how information from the Framework might be used,, management responsibility for tiger reserves currently lies primarily at the state level with co-funding and directions from the central government, Ministry of Forests and Environment (MoFE). A new governance structure for tiger reserve management is under review. Reliable information, on population status and threats to each population, obtained by implementation of the Framework, will aid the governance structure in seeing where funds and other resources are most needed.

The inclusion of national and international observers is an essential component in the design and implementation of the **Framework for Monitoring Tiger Population Trends in India.** Project Tiger asked IUCN: The World Conservation Union to recommend the international observers to participate in this assessment of the Framework. We were seconded by IUCN to meet this request. We were in India, engaged in these observations, between January 23 and February 6, 2006, and were occupied in writing this report over the ensuing 8 weeks.

Terms of Reference

In partnership with the Government of India, the IUCN: World Conservation Union requested that external observers/peers assess the emerging **Framework for Monitoring Tiger Population Trends in India.** The terms of reference were:

- "To observe the field procedure of primary data collection in selected areas of their choice;
- Overseeing and observing compliance of prescribed procedures for data collection;
- Overseeing and observing data compilation at field unit/district/conservancy/state levels;
- Oversee/observe the inference at the national level;
- Authenticate datasheets, apart from making observations, if any"

This was to be done in conjunctions with the all India Estimation of Tigers, Co-predators, and Prey Animals (3). For this report, we organized our observations and comments under the terms of reference. Sections explicitly pertaining to the terms of reference are preceded by "TOR". Our observations are meant to assist WII and Project Tiger in bettering the Framework. Though we present suggestions for improving data collection and data analysis, are intent is not to be critical. WII and Project Tiger have made significant steps toward improving tiger population monitoring in India.

Project Tiger and Land Potentially Available for Wild Tigers

Initially, nine tiger reserves were established as part of the Project Tiger mandate, covering 16 339 km^2. The number of reserves has subsequently increased to 28, distributed in 17 states in India, encompassing 37 761 km^2 of land. The total area of the tiger reserves is 1.14% of the total geographical area of India.

A 'core-buffer' design was used for most tiger reserves. The core area is theoretically kept free of biotic disturbances and forestry operations, where collection of minor forest produces, grazing, human disturbances. The buffer zone is managed as a 'multiple-use zone' with twin objectives of providing habitat supplement to the "spill-over" population of wild animals from the core conservation unit and to provide site specific eco-developmental inputs to surrounding villages for relieving their impact on the core. There are many villages in the "multiple-use-zones" and some even in the cores of most tiger reserves (5). The populations of tigers held in these reserves constitute some of the most important tiger source populations in the country, together with biodiversity-rich ecosystems and habitats for wildlife. With remarkable vision, the original Project Tiger Task Force recognized the concept of "viable populations" and realize that this could best be achieved by establishing large areas of >2000 km^2 as tiger reserves. In practice however reserves of this size were not obtainable in most areas (1).

It is commonly thought that more tigers live outside tiger reserves than live inside (19), though this assumption has not been confirmed. An assessment conducted by non-governmental organizations in 2005 found that of the total area for the Indian subcontinent bioregion - 2 969 805 km^2 - the potential land-cover in the Indian subcontinent where tigers may or could live is estimated to be 327 061 km^2, with the majority in India and outside of tiger reserves (11). In addition to tiger reserves, there are tiger populations, some of which are source populations, in other important protected areas, in many forest divisions, as well as lands in other ownership categories. These tigers are protected under the provisions of the Wildlife Protection Act.

The tiger has suffered a "range collapse" through its range in Asia that has accelerated in the last decade (11). It is estimated that tigers now occupy only 7% of its historic range. The distribution of tigers in these "other lands" outside of tiger reserves in India is not known with the enough accuracy to effectively manage these areas in way that include the tiger's survival needs, especially as India considers the future of these lands in relation to other societal demands (5). The **Framework for Monitoring Tiger Population Trends in India** will provide this critical detail for the first time.

Framework for Monitoring Tiger Population Trends in India

The ***Framework for Monitoring Tiger Population Trends in India*** replaces the previous Indian tiger census methodology based on counting individual tiger pugmarks (5). The Framework has four phases.

Phase I of the Framework uses broad scale sampling for five types of data:

- tiger and other carnivore sign,
- ungulate encounter rates,
- ungulate pellets
- vegetation structure,
- and human disturbance.

The forest department lands in ~80% of India have been demarcated into administrative units, called beats (or sub-beats in Bihar), ranging in size from approximately 7 to 50 km², and averaging 20 km². In Northeast India, where the beat system has not been in place historically, natural divisions (e.g., watershed boundaries) will be used to establish sampling units of about the same size. **Each beat is treated as a sampling unit**[1] and is surveyed for each of the five data types. Protocols for surveying the data types are outlined in (7), a manual meant for on-the-ground use by beat officers or guards with the assistance of a local hired assistant who, working together, serve as **the primary data collectors**.

The methodology in Phase I has been adapted for the Sundarbans (9) to be applied by boat. Further methodology changes have been made for the roadless forests in the Northeast but we have not seen those modifications.

Data collection will only be as accurate and precise as the data collectors, data compliers, and their supervisors make it. For the purposes of the Phase I sampling, we recorded that approximately 40,000 beats would be sampled, plus about 20% of the area is in the Northeast. Implementation of Phase I is an enormous undertaking.

In *Phase II* of the protocol, the data from Phase I one will be plotted in geographical information system (GIS) to develop a presence/absence map for tigers, at the beat level of sampling, across India. The presence/absence map is then to be used to develop a resource selection probability function (14) using attribute data on transportation network (i.e., linear features such as roads and train tracks), forest cover, normalized difference vegetation index (NDVI), vegetation cover, terrain model, hydrology, and night light satellite data (to represent human disturbance). The output of this phase will be a map with relative rankings of high, medium, and low probability of tiger occurrence throughout the country.

In *Phase III* of the protocol, scientists will estimate tiger and ungulate abundance using intensive sampling. The habitat rank map for tigers developed in Phase II will be used to draw a sample of locations for intensive density estimation of tiger and ungulate density.

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[1] For the purposes of this report we use the term beat is synonymously with the term ‘sub-beat’, used in Bihar and other references for the ‘sampling unit’.

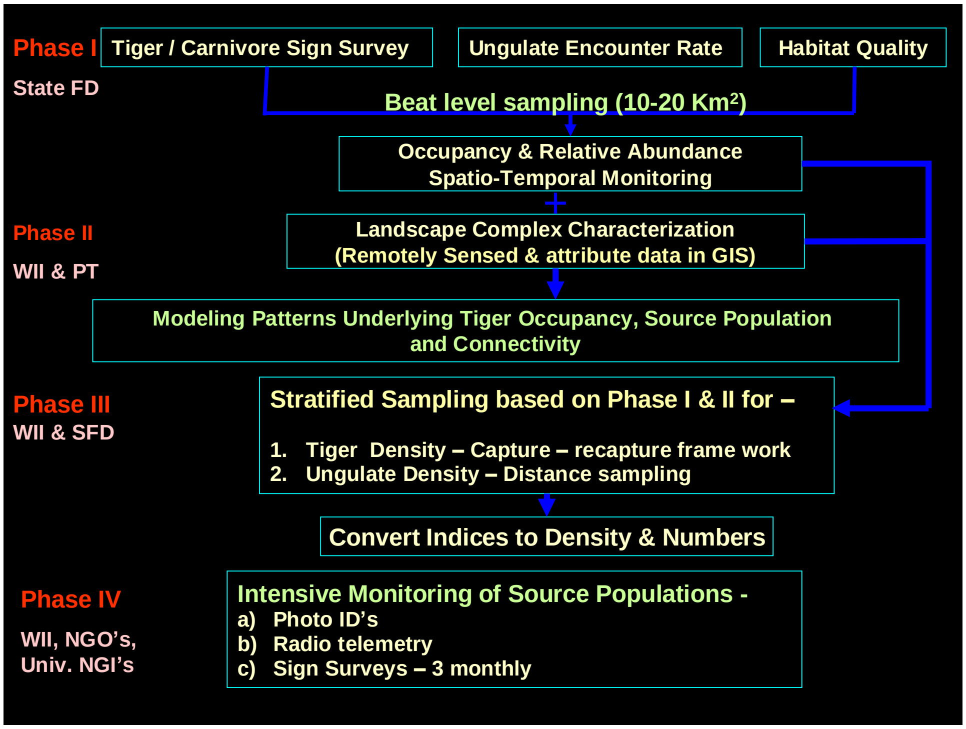
Tiger populations will be estimated using photographic mark-recapture sampling techniques in medium and high density (probability) areas and photographic and pug mark mark-recapture techniques in low density (probability) tiger areas.

Phase IV of the Framework involves intensive monitoring of tigers in areas that are considered key tiger source population areas using radio-collaring, weekly pug mark monitoring, and intensive photographic mark-recapture ("camera trapping").

Key Point: The implementation of the ***Framework for Monitoring Tiger Population Trends in India*** *is immense in scope. Transparency and efficiency in implementation would have been facilitated significantly by preparing a detailed plan of activities, explaining the logic of the approach, listing the questions the data would be used to answer, and explicitly outlining the timeframes for completion of activities. There is also no detailed write-up of the technical analysis, explicitly identifying the analytical techniques to be used each phase of the Framework. These documents are essential for tiger monitoring in India to transform from the local, expert-based monitoring system used previously to a national science-based* ***Framework for Monitoring Tiger Population Trends in India*** *for the future.*

The Framework was recommended to commence in 2005 by the *Tiger Task Force* (5) in its report to Prime Minister Singh, recognizing that many details had yet to be defined (5: p 75). Training of the data collectors was initiated in late 2005. Trainers, trained to teach the collection the prescribed data (7), were taught at the Wildlife Institute of India (WII) and sent to the 17 states with tiger reserves to facilitate Phase I data gathering. On-the-ground data collection was the responsibility of state forest department personnel. In January and February 2006, Phase I was implemented across the country. The remaining phases of the methodology will be implemented throughout the first half of 2006, leading up to a final population estimation of tigers in July (pers. comm. R. Gopal). The data collection for computing tiger densities (through camera traps and digitized pugmarks impressions using a mark-recapture framework) will be done by teams from WII at selected locations, in Phase III. Phase III has been initiated in some states.

The conceptual layout of the Framework (see below) was presented to us in a PowerPoint presentation and, subsequently provided to us in a handout (8) at WII on January 24.



The objective of the monitoring program for 2006 is to estimate the number of tiger populations and evaluate the status of tiger habitats throughout India. This information will act as a benchmark for future estimations. Future Indian tiger estimation exercises are planned at regular intervals with a view to establishing statistically reliable trends in India's wild tiger populations and their habitats (including status of prey populations and human created pressures on tiger habitats).

This first year of the Framework must be considered a learning year of a work in process. Honest mistakes will be made. In the Technical Note (8) on the methodology it is asserted that researchers have "… an audit mechanism in place to scrutinize the data collection, completion and analysis. National and international experts would act as observers while officers-in-charge will ensure adherence to prescribed protocol and transparences of protocol implementation." In science, the peer review process does not usually review the actual collection of data, unless irregularities have been detected up the chain. The integrity of the science enterprise depends on the integrity of the primary data collectors. Peer review usually is considered the process of reviewing the procedures used by investigators leading to the conclusions that scientists are seeking to publish. Papers and reports are sent before publication to peers and final decisions on publication are made by a journal's editors. In science findings are then checked by further observation and experiment made by other independent investigators testing the same or similar hypotheses with the same or similar methods to ascertain if the original findings are correct.

Key point: Project Tiger took valuable steps to include national and international observers in the process for the developing the ***Framework for Monitoring Tiger Population Trends in India****. Observers will bring insight into how the on-the ground and* *the other aspects of the Framework could be designed and implemented. The fundamental success of the Framework lies with the integrity of the primary data collectors, data compilers, and their supervisors. Phase I results will be cross-checked by WII/Project Tiger teams in Phase III. Discrepancies in the data obtained in Phase I and through the cross-checking exercise in Phase III can be used to estimate the error in the all Phase I data. However, methodology to consider the implications of error was not described in any documentation we received on the Framework. Explicit consideration of error (e.g., such as through sensitivity analyses), at all phases of data collection, would strengthen the efficacy of the results. Similar analyses could be conducted to explore the implications of using different probability cut-off values for high, medium and low habitat-use classes.*

It is reported that (8): "the spatial and aspatial data that are likely to influence tiger occupancy of a landscape will be used for modeling in a GIS domain." ***Most*** **details of how this is to be done are yet to be made explicit, transparent, and peer reviewed**. A "tiger atlas" will be generated to show presence/absence, and absolute abundance estimates of tigers throughout India. Results are to be disseminated to politicians, administrators, and field managers and used in conducting regional workshops and training to apprise the field staff in tiger number estimation, habitat monitoring, evaluation, and field-monitoring techniques. We are unclear to us how this information will be made available to the public.

Pilot Study for Estimation and Monitoring Tiger, Prey, and Habitat

In 2004, scientist from the Wildlife Institute of India and the Project Tiger Director conducted a pilot study (4). The pilot study was used to improve the methodology for spatial mapping and monitoring of tigers, prey, and habitat prior to "going to scale". The scientists conducted this pilot within 48 000 km² in the Satpura-Maikal landscape in Madhya Pradesh. This landscape included three prime tiger reserves (Kanha, Pench, Satpurt) set in a large, mosaic of forests and human-use areas landscape with 3150 forest beats in 178 forest ranges (4).

The methodology was designed and applied to all 3150 beats for data collection. After the pilot was completed, no further modifications were made to the overall monitoring framework before it was applied at a national scale in 2005-06 (12). However, a consultation process with field staff was used to develop a more field friendly manual to assist in collecting data. Modifications were made to the data sheets to make these more understandable before these were used in the 2005-06 estimation. Certain beats were re-evaluated and data collection was repeated (12).

Structure of Our Assessment

***TOR**: 1. Observe the field procedure of primary data collection in selected areas of their choice*

We were asked to provide approximately 10 days of observation in India including briefings at WII and the Project Tiger Directorate and travel. Areas to visit were our choice.

We chose to maximize our field time by visiting protected areas and forest divisions closest to Dehra Dun (home of WII) in the Northern Indian Tiger Landscape, as referenced in the ***Framework for Monitoring Tiger Population Trends in India.*** This landscape is also known as the Terai Arc Landscape or TAL by many conservation NGOs and by the Government of Nepal for the Nepal portion of this landscape. It is also has been recently surveyed by WII faculty (13) using a methodology that can be viewed as a stepping stone in the transitioning between the local, expert-based methodology of the past and the national, science-based landscape based methodology that is the ultimate goal of the emerging ***Framework for Monitoring Tiger Population Trends in India.*** We planed our travel to visit beats in protected areas and in adjacent and connecting forest divisions once we were provided with the work schedule. These included:

Uttaranchal

- Rajaji National Park
- Haridwar Forest Division
- Landsdowne Forest Division
- Corbett Tiger Reserve
- Ramanagar Forest Division
- Terai Central Forest Division

Bihar

- Valmicki Tiger Reserve

We designed our itinerary to minimize travel time and maximize the distribution of our visitations to reasonably accessible forest divisions and protected areas. We also wanted to view activities in at least two states.

We were able to observe and draw observations from the following:

- Half-day briefing with WII staff on methodology
- Observing activities and practices for data collection in and outside of tiger reserves in forest reserves in Uttaranchal ***in preparation*** for actual data collection including extensive interviews with primary data collectors and their supervisors.
- Viewing actual data collection operations ***in progress*** in Valmicki including extensive interviews with primary data collectors and their supervisors
- Discussions on methods and other aspects of the exercise with Dr. Rajesh Gopal.
- Reviewing references: 4, 5, 7, 8, 9
- A list of questions pertaining to survey methodology posed to Dr. Rajesh Gopal and Dr. Y. Jhala (12).

Observations and Assessment

***TOR**: 2. Oversee and observe compliance of prescribed procedures for data collection*

The Forest Department staff members (who we refer to as the primary data collectors) that we met with were extremely diligent in trying to apply the methods they have been given (7). They often followed the most rigorous standards optionally provided in the manual. For instance, all data collectors that we observed had developed their own style and method for demarcating the 15-m radius and the 1-m radius for vegetation plot sampling. Our discussions with the staff from the WII indicated that Forest Department staff was expected only to visually estimate the boundary of the vegetation plots, not exactly measure the distance. As another example, the District Forest Officer (DFO) in Bihar prepared a herbarium for staff to use in learning plants. Data collectors in both states seemed committed to following data collection instructions as closely as possible. All the Conservators showed an interest in taking the data collection further in the future, extending monitoring to other species, and doing some trend analyses in-house, but this did not interfere with the on-going program. We did not see any issues relating to non-compliance with data collection instructions from Project Tiger or WII (7).

Key Point: Issues that arose with data collection were related to clarity and completeness of instructions and manifested as issues related to consistency of data collection across jurisdictions and across individuals collecting data. The issues that we noted are these are described below.

A. Recording tiger sign

The Phase I tiger survey methodology was the best applied portion of the protocol. Data collectors were adept at finding tiger pug marks. The data collectors, for the most part, were experienced with the methodology and unlike with the old methodology, they felt no pressure to report pugmarks where they could not find them.

Importantly, we did note differences in whether pug marks were recorded as one individual or multiple individuals. In some beats, the slightest discontinuity in a set of tracks was treated as reason to suspect a different individual tiger, whereas in other beats primary data collectors use a minimum distance rule, or more subjectivity to record tracks that looked plausibly like the same individual.

*Key Point: We assume that the discrepancies in collecting tiger track data and how series of tracks are recorded as different individuals are dealt with by converting the beat sampling-level data to presence/absence data. If there are further applications for the data, this discrepancy will be a **significant source of error** in estimating tiger abundance.*

B. Recording other large carnivore sign

We noted that it was difficult to distinguish between dhole (*Cuon alpinus*) and domestic dog tracks and data collectors were often unsure which they were recording. We observed few leopard (*Panthera pardus*) tracks, and those we did observe were clearly differentiated from tiger tracks by the data collectors. We found surprisingly few bear tracks and think it unwise to try and distinguish Asian black bear (*Ursus thibetanus*) and sloth bear (*Melursus ursinus*) tracks although both occur in the Terai and probably in the Northeast.

Key Point: We do not think the present methodology is adequate to estimate population levels or trends for dholes, nor for distinguishing between bear species where Asiatic black bears and sloth bears overlap in their distribution.

C. Recording ungulates and ungulate sign

Distance-sampling transects: We did not walk the transect lines with the data collectors while they were recording data because we did not want to affect data collection by having many extra bodies present during the ungulate transect counts. However, we asked for demonstrations and from our discussions on how data collectors planned to conduct the survey, the application of the methodology appeared consistent across beats and states. All primary data collectors walked the transect line in the morning and prior to other activities, recording the ungulates that they saw. However, in Valmicki, data recorders insisted they were recording wild water buffalo (*Bubalus bubalis*), but we determined they were referring to gaur (*Bos frontalis*).

Pellet counts: There was individual variation in applying the methodology (7) for ungulate pellet counts. We noted several substantive issues with variation in data collection:

- The method of searching for pellets varied among data collectors. Some data collectors performed active searches, turning over leaf litter and sifting through the soil. Other data collectors recorded only at what was visible without turning over litter.
- Some data collectors delineated the 2-m x 20-m plot area before surveying it and then focused on searching for pellets, while some delineated the area as they surveyed.
- Some data recorders surveyed the area in one direction while others surveyed the area in both directions (i.e., there and back).
- Some data collectors recorded the total number of pellets for each species within the 20-m x 2-m plot, while others recorded the number of piles of a certain size. One of the data collectors was putting A in the column for pellet numbers if the count was anything less than 50.
- Finally, there were confounding problems with goat pellets and other ungulates and abilities to discern some wild ungulate species pellets. We note that WII staff had tried to account for this by asking data collectors to record the presence of livestock in the survey area or in the beat; however, we are uncertain how this information might be used to correct for misidentification of species.

Key Point: There was individual variation among data collection teams in applying the methodology (7) for ungulate pellet counts. This variation may be difficult to account for if using this data for density calculations.

D. Vegetation sampling

Vegetation sampling on transects appeared to be the most weakly applied part of the protocol (7). Data collectors were comfortable with the basic guidelines for collecting the data but in some cases, the vegetation data was collected incorrectly. All data collectors were aware of the size of plots required for data collection, the height structure for separating vegetation into, and all data collectors appeared adept at identifying species of trees. However, there were numerous discrepancies in how data were collected. The issues that we encountered included:

- There were simple discrepancies in selection of the side of the transect to survey. Uttaranchal data collectors always started on the right side and then alternated sides down the length of the transect. Data collectors in Bihar arbitrarily selected a side and then alternated. Uttaranchal plans to start on right side for sampling in perpetuity, while Bihar will arbitrarily select a side each year. The result will be more intra-year variation in Bihar's data than in Uttaranchal's.
- The placement of the 2-m plot varied from area to area. The data collectors in Uttaranchal were placing the plot 5-m from the centre, while the guards in Bihar were arbitrarily placing the plot away from the centre of the larger vegetation plot. The larger vegetation plot was sometimes also placed arbitrarily away from the transect line in Bihar.
- There were inconsistencies in how to deal with roads when doing vegetation plots. Where a transect crossed a road and the centre of the plot lay on the road, some data collectors would record the vegetation data noting the portion of the plot that was road. Others would move the plot away from the road and into a fully vegetated area. In some training sessions data collectors were told to make note of the road and not to move the plot. We are not sure how ubiquitously this instruction was disseminated.
- In some beats the canopy cover was estimated by some as the amount of visible leaf above 6 feet, whereas other data collectors projected the amount of canopy cover if the leaves were not shedding. We check to see how closely primary data collectors matched our estimates of canopy cover. Notably there was only one instance where the actual canopy cover estimate was grossly off our estimates.
- Data collectors were unsure whether to count dead tree species in assessing the five most dominant species, and were also unsure if they were to include dead trees as part of the canopy cover. No information was available in the manual on this topic.
- There was a problem with how the ground cover was recorded because the amount of exposed substrate (e.g., soil) was excluded from the 100% section on the data sheet, but should not have been mutually exclusive from the amount of litter or from the other vegetation types. In one region, the data collectors were including the amount of soil as part of the 100%; in other regions they were excluding it.
- Some areas recorded grass as "grass" and some areas identified the grass species.
- Data collectors in Bihar were uncertain how to deal with bamboo clumps and how to record these in the vegetation data.

- There were differences between data recorders in how the litter was recorded. Some recorded include litter that was advanced in decay; others only included large and very visible litter.
- The concept of 'weed' was confusing to data collectors. They indicated that it would be useful to have a definition of the term. Some data recorders used the working definition of 'anything not useful for wildlife.'
- There ambiguity with how to deal with tree stumps. The question for some data collectors was: Are the stumps to be treated as trees? Some data collectors use the stumps to project what the forest would look like if the stumps were full-grown trees, and subsequently recorded data using this projected scenario. Similarly, if stumps allowed another species to become dominant, the composition of the forest was back projected.

Key Point: There was substantial individual variation among data collections in applying the methodology (7) for vegetation sampling. Sources of variation were related to vagaries in how to record canopy cover, dead trees, stumps, and weeds. Clarification on these aspects of data collection could be provided in the manual. Primary data collectors may also benefit from more focused training on vegetation sampling.

E. Transect lines

- Line transects sometimes started on a road and could have been placed away a few hundred meters.
- We checked the datum of all GPS units; all were correctly set to WGS 84.
- We found that latitudes and longitudes were wrongly recorded for one of the four transects starts that we checked. The error in distance represented an error of 0.9623 km, which represents an analysis distance of approximately 1 pixel in the GIS.
- There was variation in selection of transects locations. Most were placed somewhere flat. All were placed in areas that were accessible. Some were placed arbitrarily, while some were placed in areas where the data collectors thought there may be good ungulate densities, or in places where they thought the vegetation was representative of the beat. Further, in some areas the transect lines were continuous through different habitat types, whereas in other areas the lines were broken among habitat types. In one instance, the survey line was not long enough.
- Though most transect lines that we saw were largely on flat ground, there was no correction for slope on transect lines that were on sloping terrain.
- Transect lines were cleared prior to surveying them. Where transect lines were cleared, the areas become travel routes for animals because the trails, most often lead to nullahs. Consequently, there may be an artificial increase in the number of prey species in future distance sampling surveys. For example, elephants began using one of the cleared transect lines, where there was no use before. Similarly the cleared transects were being used as travel paths for locals, and consequently have more human disturbance on them than prior to clearing; we observed bicycle tracks on one transect.

- There was variation in the number of people that do the surveys. Sometime there were two people doing the survey and sometimes there were three. This affects the probability of encountering a tiger track in a nullah, or seeing pellets and animals along distance sampling transect. *One of the major assumptions of all tests that will be performed on these data is that the probability of finding a track, pellet or animal, is related to the habitat type, and to not the search effort.*
- Some data collectors were recording other species as well, such as monkeys. We assume that this is not an issue as the database for entering the information did not appear to have columns for extraneous findings. It does signify the variation in data recording in each area and the desire for each area to record information on other species.
- The subjectivity in recording the human disturbance information creates some discrepancy in how the information is recorded. Bihar created its own way of quantifying the information. They used a non-linear scale of impact, relating the percent of trees cut to an ordinal rank (e.g., if there are 80% or more trees cut, then they register the human disturbance rank as a "4").
- In some areas, data collectors had practiced walking the transect lines and data collection protocols three to four times. In other areas, data collectors had not practiced. As might be expected, in the areas where they had not practiced, there was more confusion as to how to collect the data than in the areas where data collectors had practiced. Practicing the data collection routine before hand seems to improve data collection quality and should be promoted. We recognize, however, that some regions of the country have few resources to enable staff to practice data collection.
- We felt that there was an excellent system in each jurisdiction to help primary data collectors with plant identification. If data collectors were unsure of identification, each data collector was equipped to be able to take specimens of each plant and fecal samples back to someone that could offer identification.
- Human activities were halted in Corbett to reduce the potential for disturbing data collection. This was not noted in other regions, though there is considerably variation in the levels of human activities through the areas being sampled.

Key Point: There was individual variation among data collectors in applying the methodology (7) for transect location and use. We noted several substantive issues with variation in data collection in the report. While errors are to be expected in a project of this size, it may be possible to help reduce the number of errors by providing supervisors with a checklist for double-checking transects. We noted that all transects were double-checked by supervisors. This provides an excellent opportunity for quality control of data. Uttaranchal has already developed a checklist system that might serve as an example. Their system could be modified further to consider the most commonly committed errors in setting up a transect line.

Key point: We were concerned about the variation in the number of people who comprise teams of data collectors. One of the major assumptions of all tests that will be performed on these data is that the probability of finding a track, pellet or animal, is related to the habitat type, and to not the search effort. The number of primary data collectors should be considered in any explanatory variable in model for animal density.

***TOR**: 3. Oversee and observe data compilation at field unit/district/conservancy/state levels*

Our observations related to data compilation were restricted to examining the Access database into which data will be entered, and discussions with Forest Department staff around the timeframe for data entry, and standards for quality control. The Access database was developed for ease of data entry. There were pull-down menus where possible. This will reduce the number of data entry related errors. All states have staff available to facilitate data entry. These individuals were reported to be ‘data entry specialists’. We did not meet any of the data entry technicians and therefore are not able to comment on their competencies or on issues the technicians may have had with the database. While in Bihar, we inquired as to how data would be double-checked once entered. The Conservator of Forests and the Deputy Director for Valmiki indicated that the Assistant Conservator of Forests would do random quality control checks (actually spot checks) on the data.

Key Point: We reviewed some of the data that had been sent to WII and noted that there were some areas that were surveyed and that did not have forests, but had tigers recorded as present. We were unable to validate these sites and flag them as suspicious. We are unable to make further comment on the authenticity of the data.

***TOR**: 4. Oversee/observe the inference at the national level*

Our observations on the inference drawn at the national level are restricted to the information obtained from our discussions with WII staff and Project Tiger staff. Here we comment on technical issues relate to data analyses.

A. Estimating the tiger population

The methodology for estimating the tiger population size was described to us as follows:

- The tiger data obtained from the Phase I carnivore tracks surveys would be converted to presence/absences data at the beat level (~20 km² on average).
- The presence/absence data are modeled in a logistic regression with a number of covariates.
- These covariates include: transportation network (i.e., linear features such as roads and train tracks), forest cover, normalized difference vegetation index (NDVI), vegetation cover class, terrain model, hydrology (e.g., linear features for streams and rivers), and night light satellite data (to represent human disturbance).
- The independent variable from the logistic regression is equivalent to a probability of tiger occurrence in a given beat. The resulting probabilities will be partitioned into high, medium and low classes. We do not have any explicit information on how high, medium and low classes will be specified (e.g., such as through use of equal interval, quantile or quartile functions), though Project Tiger staff indicated that cut-off values would be area-specific.
- The map with high, medium and low classes will be used as a guide, to allocate resources for the intensive sampling in Phase III of the framework. We thought that stratified random sampling might be used to direct sampling efforts. However, upon asking for clarification, we were told that each strata will be 80-150 km^2, with a 4 km^2 square grid placed over top. Cameras would be placed to

maximize the probability of photographing a tiger in each grid cell. We did not receive clarification on how the 4-km^2 cells will be chosen for sampling in each strata.

- 25% of the presence data will be withheld for model validation. We did not receive information as to actual method that will be used, though it is typical to use receiver operating characteristic (ROC) curves for a resource selection probability function model.
- WII and Project Tiger also indicated that they might apply the following methods to the Phase I data: occupancy models of (23), ecological niche factor analysis, "Division Theoretic", and Bayesian approaches. We caution that use of these modeling approaches may be limited given the data type obtained in Phase I. Occupancy models require repeated surveys of the ***same*** transect line within a period of time in which occupancy is unlikely to change. Multiple surveys of the same transect line (search path) are not being conducted. Ecological niche factor analysis (presence only modeling) considers false absences, but cannot be used when explanatory variables are categorical (e.g., vegetation cover classes) or non-normally distributed (20). We have not heard of "Division Theoretic" approaches and assume that perhaps this may be Information-theoretic approaches (21). We recommend use of information theoretic model selection criteria, but this is merely an approach to specify the best model, and not a modeling approach on its own. "Bayesian approaches" covers a very broad range of new and emerging possible modeling approaches. With out further detail on how data might be used to specify priors or to build explanatory models, we are unable to comment on this application.

Key Point: We did not see a specification of statistical power to detect trends or projected confidence intervals on tiger population estimates.

Key Point: We observed that data collectors did not record tracks if the species was not clearly identifiable. This situation might arise where there were only partial tracks. This raises the issue of having false negatives, or beats recorded as "zeros", where no tiger was found but may still be presents. The approach described above does not deal with false negatives.

Recommendation: We recommend that WII scientists consider a use/availability design such as described in (14), rather than a presence/absence design. In this approach, tiger presence is coded as a one. The 'ones' are then considered against a random sample of all the sample units (or all sample units), or against a set of points representing 'availability' of resources. The available points, regardless of tiger presence, are then coded as 'zeros' and used in a logistic regression with the 'ones'. The intercept is dropped from the resulting algorithm because the sampling fraction cannot be estimated. This produces a relative probability, rather than an exact probability (or a resource selection function instead of a resource selection probability function). However, the relative probabilities can still be binned into high, medium, and low classes (most often through a quantile function). K-fold cross validation is used for model validation in this approach. Once densities have been determined using a mark-recapture framework in *selected areas as per Phase III, reference (15) describes an approach that can be used to extrapolate densities to the entire country from the resource selection functions.*

Key Point: An assumption of the proposed explanatory models is that, apart from issues related to density, the probability of finding tiger sign must be the same from sampling unit to sampling unit. That is, the probability of tiger sign occurrence should not be reflected in the search effort for tracks or other signs. There is flexibility in the study design for data collectors to search between 9 and 15 km of linear distance to detect tiger sign. This means that, all else being equal, there will be a higher probability of a tiger sign being found in sample units where more distance per area is searched.

Recommendation: We recommend using an area-corrected method of specifying transect line length for each sampling unit. In the 2006 modeling exercise, it may be valuable to consider using a ratio of the length of transects sampled to the area in the sampling unit as a covariate in the modeling process. This will help assess bias created by having variable search effort in sampling units.

B. A major suggestion for the Framework: Monitoring known tiger mortality

A substantive deficiency we noted in the **Framework for Monitoring Tiger Population Trends in India** is the absence of tiger mortality monitoring. While data appears to be available in forest guard records and records at higher administrative levels, we did not see evidence of an explicit methodology for analysis of this data or for incorporation of mortality data into the monitoring protocol. If habitat quality and prey densities are being monitored as a means to understand fluctuations in predator abundance, human-caused mortality probably plays a substantive role in tiger population dynamics. Populations of large carnivore can go and have gone extinct in habitats that have abundant food resources.

Human caused mortality should be monitored by tracking number of poaching incidents and number of human carnivore-human conflict incidents. Data should be spatially-explicit. These incident reports can become invaluable in the Framework. This information is critical for understanding the tiger population trajectory in the different landscapes and for providing targeted management recommendation to mitigate underlying problems with tiger population decline.

C. Estimating ungulate densities

WII and Project Tiger researchers indicated that pellet data will be used to develop indices of habitat occupancy. We are uncertain, but assume that the data may be converted to presence/absence data. Project Tiger indicated that pellet count data may provide alternate means of estimating ungulate abundance. The data may also be used as a check on animal encounter rate data. However, even in minimalist use of pellet count data, improper application of the methods may produce unreliable results. Our concerns are:

- We are uncertain as to how the number of pellets will be used rather than pellet group counts. In many instances, data collectors are not getting defecation rates because they are only getting total number of pellets.
- We did not determine how individuals dealt with clearing pellets off after surveying the area or aging disintegrating pellets. We did not have information on decay rates for pellets. Pellets may break down rapidly. If so, then differentiating between old-year and new-year pellets may be a trivial issue. Otherwise, this should be an important consideration for future surveys.
- Data collectors in Uttaranchal ran several practice sessions prior to conducting the actual survey. We are uncertain how disturbance of pellets during this exercise would bias the results.
- Plot size was chosen considering the ease of doing the work and chances of missing a pellet (i.e., reduced chance given 40-m^2 plot size); researchers did not conduct trials to determine at what plot size pellet group density reached an asymptote).
- No power analysis was done to determine how many plots were needed for analyses. This is necessary, even when data are being used only for trend detection.
- Transects have been placed non-randomly over the landscape, consequently, ungulate density (and vegetation data) will allow for examination of intra-year differences among beats, only for trends in ungulate density estimates from year to year.
- We are uncertain how ungulate group size has been incorporated into the *a priori* calculation of effective strip width for the distance sampling survey. Calculating the distance based on single animals alone would mean that the effective strip width is smaller than when considering groups of animals.

Key Point: Without incorporation of group size into calculations of effective strip width for the distance sampling exercise, ungulate density estimates may be bias low.

- Placement of transects may not be ideal for pellet counts. Placement of transects in Bihar was related to flatness of terrain because data collectors felt that it was important to not cross steep areas.
- Plantation forests are always in transition with rotational planting and harvesting, and hence, face different challenges in permanently marking transect lines and plots.

Key Point: During training, data collectors asked how to establish permanent transects in plantation forest, but did not receive a response from WII staff.

- Researchers selected the transect length for the distance sampling survey based on 1) “ease of walking” and 2) distance that a transect could be walked during a timeframe where animal behavioral patterns were relatively constant (i.e., early morning). However, transect length is usually determined as a product of the encounter rate of ungulates and the ratio of *b* to coefficient of variation, where *b* is a constant, usually held at three for planning purposes. We did not discuss with the implications of the selected transect length on the coefficient of variation with the researchers. However, researchers indicated that the coefficient of variation would be between 10 and 30%.

D. Other data analyses

Key Point: Vegetation data will be used to track the status of habitat and to map vegetation associations. Human disturbance data may be treated only as an explanatory variable for modeling animal densities, and as a variable used to monitor changes in human disturbance trends. While we are aware of what data will be used for, we have not seen explicit information on how vegetation or human disturbance data will be analyzed.

E. Observations of methods proposed for Phase III and Phase IV

i. Scale of inference

Prey densities are to be reported for a minimum area of 20 beats. The aggregation of the 20 beats will be based on similarity in vegetation types and meaningfulness of the boundaries to management. We assume that tiger densities will be reported commensurate with prey densities. Spatial attribute layers will be harmonized with the coarsest attribute layer (probably 1 km). Project Tiger staff indicated that the home range size for tigers would be considered in the data analysis, but tiger sign data is not spatially referenced and therefore cannot be readily transferred to analyses that transcend beat boundaries.

The tigers in India were commonly thought of as living in a single *population*. Indeed, the original goal of Project Tiger (1) was to ensure the maintenance of a viable *population* of the tiger in India. A cursory review of India land-cover and human activity/density maps shows that the India tiger *population* is actually several unconnected populations. Exactly how many populations into which it is divided is generally known but not with great precision. This is a subject of much debate in tiger conservation circles. The definition of these populations will be key considerations for WII and Project Tiger when reporting population estimates for tigers.

Key Point: Recognizing that few researchers consider the implication of boundary selection on the inference that can be drawn, we emphasize, particularly given arbitrary selection of the grain of the attribute data (i.e., because of convenience as opposed to ecological phenomenon), that meta-population dynamics of the species should be a key consideration in analysis and reporting of population status.

Advances in understanding ecological and life-history traits that make species, such as tigers, particularly sensitive to human impacts has demonstrated, through modeling and experimentation, that connectivity among populations as an essential component in long-term population viability. The larger the source population: the more robust and viable it becomes. The fewer and more tenuous the connections between source populations, the more vulnerable and less viable a species becomes in the long-term. In population persistence dynamics this is known as meta-population dynamics.

Key Point: Habitat connectivity and movement among populations are necessary for reducing the chance of species extinction. While acquiring better information on tiger densities, and modeling possible cause for fluctuations in tiger densities should be a primary activity for managing this species, understanding the meta-population dynamics and ecology of dispersal should be equally important.

Recommendation: There are several approaches for estimating connectivity probabilities for tiger populations. An explanatory model framework can be used to incorporate factors that influence tiger dispersal, including differential dispersal rates for tigers of various ages confounded by differential response to landscape attributes, tiger densities as it relates to land-cover types, reproductive and mortality rates, and human population densities or land-use patterns. We recommend the study of dispersal characteristics for tigers crossing various human-dominated landscape mosaics with their own characteristic tiger dispersal filter attributes be included as part of Phase IV. This is the least known component of tiger population dynamics. Formal studies have only been conducted in the Nepal Terai and in the Russian Far East but there are only a handful of antidotal observations from India to rely on. The technical details on how to estimate the probability of the connectivity between tiger populations should be made explicit, transparent, and peer reviewed.

ii. Supplementary data collection

The identification of individual tigers by pugmarks is a contentious issue among scientist who monitor tigers (5). The methodology (16) for identification of individual tigers using pugmark that is being applied in the Framework is an enhanced application of the methodology. However, the authors of that paper note: "An approach to incorporate the error probabilities of uncertain identification into the population estimation model as reported for genotype errors in mark-recapture studies (26) would need to be developed. (16:8)" The method is presented in the Framework as fully operational for medium to low density tiger areas, yet it has only been validated for use in high tiger density areas. Essential work remains to validate pugmark mark-recapture analysis design for tigers living at low (1-2 adults/100km^2) to medium densities (4-6 adults/100 km^2).

Recommendation: The pugmark mark-recapture approach be treated as experimental and work continue during Phase IV to see if the method can be validated for low to medium tiger density areas. In the interim camera trapping has been shown to be an effective methodology to establish density estimates even for tigers living at very low densities (24, 25).

The use of genetic markers from tiger scat is proposed as an emerging method in identifying individual tigers. Tiger scat material is being collected by WII with the intent to augment other methods in determining tiger distribution and abundance. No one has yet applied this methodology to determine tiger abundance within statistical confidence to a large landscape. Preliminary work has been done in the Russian Far East (17) to identify some individuals but not to estimate tiger density and in captive tigers in China (18). There is a stark lack of genetic variation in tigers that confounds this approach. As noted above, an approach to incorporate effort probabilities of uncertain identifications into population estimation model are yet to be established. While promising for the future, this methodology is not ready for actual field use as it is in other cat species. Further, while mitochondrial DNA may be used to identify individuals, actual markers to identify relationships between individuals will require identifying markers in tiger nuclear DNA. Identification of individual relationships is essential in establishing landscape connectivity. This work should be supported in Phase IV.

Distance sampling will be used to estimate ungulate densities in phase three. We did not receive clarification on whether the Phase one data will be used for this exercise, or if a second round of sampling would be conducted (apart from Phase I). We also did not have access to a student report on using distance sampling to estimate ungulate densities across India (22).

***TOR**: 5. Authenticate datasheets, apart from making observations, if any*

We reviewed datasheets for the carnivore surveys in Bihar. We were only able to review ‘practice’ datasheets for components of the protocol conducted in Uttaranchal. No datasheets for human disturbance were reviewed. With the exception of discrepancies noted above, all datasheets appeared to have been filled in correctly. In Bihar, we asked data collectors to fill in sheets in front of us and to conduct mock surveys. Data collectors there appeared to have little problem understanding how to fill in all datasheets, with the exception of the vegetation survey datasheets. Here, supervisors helped them fill in datasheets. We recognize that these sheets were the most complicated of all the datasheets, and that data collectors were often nervous with so many onlookers watching them. We also noted that while all data collectors did write down the percent cover of the canopy that was present, they stated the percent absence. We never saw the data on this written down incorrectly, but we note that the potential is there and that this should be a point emphasized in the manual.

Further Observations

We noted these further observations as ways to improve the Framework and its implementation.

A. Field guide

We reviewed the Field Guide and asked data collectors about there concerns with the document. Most data collectors indicated that the Field Guide was very useful. Diagrams were helpful for interpreting the instructions for conducting transects and other measurement. However, we noted the following issues:

- Some data collectors felt the Field Guide was too technically written for them. Indeed, in our view the language is highly technical for non-biologists.
- Some had issues with difference in translation of the Field Guide between the Hindi used in their region and the Hindi in the Guide; the English translation acted as a bridge between dialects.
- The data collectors all needed to go through the manual with supervisors to be able to interpret it.

- The depiction of the 1-m vegetation plot at the centre of the 15-m plot caused some confusion to data collectors. The manual indicates that the plot should be 5 m from the center of the 15-m plot, but the diagram is contradictory to this.
- Data collectors noted inconsistencies between use of imperial and metric system in manual. This caused some initial confusion.
- Some data collectors reporting that in the training sessions they were told to shorten transects to less than 2 km where there was not enough habitat. Data collectors noted that this was inconsistent with what the manual says and therefore were confused.
- Some data collectors felt that the Field Guide should have illustrations to help with identification and differentiation of ungulate pellets, specifically something to help scale the size of pellets. Data collectors also wanted to see actual pictures of pellets, not just drawings. Key written points on how to differentiate different types of pellets could also be included in the manual. We feel this section of the manual needs marked improvement because in testing staff on pellet recommendation we found there may be a notable, perhaps even significant, failure rate to correctly identify pellets.

Key Point: The Field Guide is a key resource in reducing error in data collection. The Guide could be improved to target error reduction in the weaker areas of data collection. The Guide is an important area to focus on for improvement of future iterations of the surveys.

B. Training

This is a key element of program success. To the benefit of the program, most data collectors have been in service for extended periods of time. However, long familiarity with where they were actually collecting data was quite short, compared to an assumed long familiarity by the Framework designers. We noted that:

- Most data collectors felt they were adequately prepared and felt that they had enough training.
- Data collectors had a minimum of two training session, and sometimes up to four training sessions. As expected, data collectors with more training were more comfortable with the fieldwork.
- Areas where there was recent staff turnover appeared weaker at collecting data than staff from areas where they had been serving for a longer period. This could be a cue for directing future training focus.
- Some data collectors expressed they would have felt more confident if they had been trained by running through examples of how to do the exercise in their own habitat type(s).
- Data collectors noted that it may be more useful to do the training together with people who are working in similar habitat types. For example, there are those who are working in plantations, those sampling thick forests, and those working in disturbed areas. Each habitat types present significantly different challenges.

Key Point: Areas that have few resources for conducting the exercise should receive a disproportionate amount of training and attention from WII and Project Tiger Directorate. Despite limited resources, these areas were taking the exercise very seriously and working hard to make the exercise happen anyway.

C. Resources

While there were differences in the availability of resources (equipment, labor, and training) among jurisdictions, we could not determine how this would affect the data quality. We note only the issues that seemed most prevalent and that we see may substantially affect data quality:

- All jurisdictions noted that there were not enough GPS units for the exercise. Supplemental GPS units that had been promised the Forest Department in Bihar were not available. As a consequence, the GPSing of transects took substantially longer than otherwise would be expected and staff were spread thinner dealing with this task rather than assisting forest guards with understanding the data collection procedures.
- There are no biologists with the necessary training in this form of quantitative sampling imbedded in the Forest Department structure and staff must rely heavily on the WII for resolution of problems with data collection. All staff felt that the WII was very accessible and that they could contact WII if they needed to. However, for many logistical issues, they have not done so.

D. Staff participation and feedback

We asked Forest Department staff about their understanding of the protocol. Forest Service staff had an excellent understanding of the overarching goals of the protocol. However, they did not have a strong understanding of why specific data were being collected. Some examples:

- Data collectors and their supervisors questioned the utility of collecting five major plant species, rather than three that would be necessary to place the plot in a recognizable habitat type.
- Data collectors did not understand why information on peafowl had to be collected. This lead to the sentiment that there was a lot of data to collect, reducing the time needed for collecting the centrally important data. Data collectors strongly suggested that the field methods be streamlined to allow them to focus on core data requirements.
- The data collection process seemed unnecessarily complex to some data collecting teams and their supervisors. To reduce the complexity of the data forms for their staff, Bihar re-did the data forms, using local names, and recoding human use information to categories between 1 and 5.
- Forest staff were also unclear about the timeline for implementation of the various phases of the protocol.

E. Staff attitude

- Forest staff at all levels were enthusiastic about having a structured way to monitor ecosystem changes that they can see for themselves. They liked that they can also monitor changes in prey and see how that relates to changes in predators.
- Data collectors reported that this method is easier than the previous method. Data collectors reported there is less pressure to find a pug mark, and they did not have to worry about identifying the gender or identity of the individual making the pug mark.
- Honesty in reporting was stressed to all staff and seems to have been taken quite seriously.

F. Communications

Internal communication at the ground level (e.g., between forest guards, foresters, and range officers) was exceptional. There was a high level of involvement at all three levels.

- Forest Department staff indicated they wanted feedback. Feedback should come in a way that is useful for the managers (so they improve things), and in a way that is interpretable and understandable for the forest guards.
- It is essential to the forest guards to make sure they see the results of their efforts. They are motivated by understanding what is going on with the data.
- More intra-reserve/forest division communication would assist in creating consistency with data collection among areas.

The Limitations of Our Review

We qualify our observations by noting that we were unable to observe all aspects of the implementation of this protocol.

- In our limited time we could review only a limited area and not the entire geographic scope of this project, especially areas that required the application of unique protocols, such as the Sundarbans and areas in the Northeast.
- We were only able to observe preparations for data collection, not actual data collection, in Uttaranchal, and therefore, were not able to validate any datasheets. We were able to validate data sheets in Valmiki, but only for the search path (carnivore survey) portion of the exercise.
- With the exception of seeing where some camera traps are to be located, we were not able to observe any elements of Phase III and IV of the protocol.
- We were not able to authenticate data entry or to review the data transfer from sampling unit level to the WII and Project Tiger Directorate.
- We were unable to view the final analysis of the presence/absence data because methodologies are still being worked out, so while we had a briefing on Phase II, we did not get to see the methods in full.
- We did not extensively review the collection of human disturbance data or how it how it would be incorporated into the final tiger estimation.

Thanks

We were honored to be asked to give our assessment of a ***Framework for Monitoring Tiger Population Trends in India***. We believe that the efficacy of conservation management of wild tigers rests on this new Framework and that the survival wild tiger rests on the efficacy of this conservation management.

We thank Kent Jingfors and Tejpal Singh at IUCN: World Conservation Union and Rajesh Gopal, Government of India, Project Tiger, for inviting us to participate.
We are grateful for the cooperation and hospitality extended by the Wildlife Institute of India. Dr. Y. Jhala made every effort to inform us about progress in developing the Framework and in arranging logistics.

Many Forest Department officers and personnel made our participation informative and enjoyable. It was a pleasure to make new friends and work with so many old friends again. We greatly appreciate the interviews and time granted to us by the Chief Wildlife Wardens of Uttaranchal and Bihar, S. Chandola and M.J. Mishra. The directors of Rijaji, Corbett, and Valmicki, G. S. Pande, Rajiv Bhartai, and Bharat Jyoti, made their forest resthouses available to us and provided graciously of their time. Samir Sinha, in Uttaranchal, and Surrinder Singh, Subramani Chandrasekar, Binod Prasad Sinta, and Bharat Jyoti, in Bihar, accompanied us, patiently explained and translated our persistent questions as we tried to ascertain how the instructions from the Framework designers were being interpreted by staff on the ground. We appreciate the honesty and the cooperation that we received from the tiger trackers, forest guards, beat officers, foresters, range officers, and district officers. We thank the resthouse staffs, drivers, forest guards, and police officers who ensured our safety and comfort during our assignment.

We are deep friends of India and we trust that our effort will contribute to sustaining India’s national animal - Wild Tigers - in the future.

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